PROCEEDINGS

United States and Canada

Northern Oil and Gas Research Forum

Current Status and Future Directions in the Beaufort Sea, North Slope and Mackenzie Delta

in Anchorage, Alaska

28-30 October 2008

CONFERENCE PARTNERS

The United States and Canada Northern Oil and Gas Research Forum 2008, Current Status and Future Directions for the Beaufort Sea, North Slope and Mackenzie Delta, held in Anchorage, Alaska 28 – 30 October 2008, was an accomplishment that demonstrated vision, commitment and cooperation of numerous individuals who represented a variety of organizations. Members of the conference executive committee, organizing committee and the organizations that supported their participation are listed below.

U.S. – CANADA NORTHERN OIL AND GAS RESEARCH FORUM

EXECUTIVE COMMITTEE

For the United States

Drue Pearce	Federal Coordinator, Office of the Federal Coordinator for Alaska Natural Gas Transportation Projects; Washington, D.C.
Mead Treadwell	Chairman, United States Arctic Research Commission; Anchorage, Alaska
Thomas Laughlin	Deputy Director, International Affairs Office, National Oceanic and Atmospheric Administration; Washington, D.C.
Julia Gourley	Senior Arctic Official for the United States, Bureau of Oceans, Environment, and Science, U.S. Department of State; Washington, D.C.
Hans Neidig	Special Assistant to the Secretary of the Interior for Alaska, U.S. Department of the Interior; Anchorage, Alaska
Captain Michael Inman	Chief of Response, United States Coast Guard 17th District, Department of Homeland Security; Juneau, Alaska

For Canada

Ruth McKechnie	Senior Advisor, Northern Oil and Gas Branch, Indian and Northern Affairs Canada; Ottawa, Ontario
Tom Hutchinson	Chairperson, Canadian Polar Commission; Ottawa, Ontario
Natalie Shea	Science and Technology Advisor, Energy Science and Technology Programs, Natural Resources Canada; Ottawa, Ontario
Ray Case	Director, Environment Division, Environment and Natural Resources, Government of the Northwest Territories; Yellowknife, Northwest Territories
Norm Snow	Executive Director, Inuvialuit Joint Secretariat; Inuvik, Northwest Territories
Hugh Bain	Senior Advisor, Habitat Science, Environment and Biodiversity Science Branch, Fisheries and Oceans Canada; Ottawa, Ontario

U.S. – CANADA NORTHERN OIL AND GAS RESEARCH FORUM

ORGANIZING COMMITTEE

For the United States

Dennis Thurston	Minerals Management Service, U.S. Department of the Interior
John Payne	North Slope Science Initiative and U.S. Bureau of Land Management
Michael Baffrey	U.S. Department of the Interior
Jennifer Thompson	Office of the Federal Coordinator, Alaska Natural Gas Transportation Projects
Dee Williams	Minerals Management Service, U.S. Department of the Interior
Ruthie Way	Minerals Management Service, U.S. Department of the Interior

For Canada

Ruth McKechnie	Northern Oil and Gas Branch, Indian and Northern Affairs Canada
Terry Baker	Northern Oil and Gas Branch, Indian and Northern Affairs, Canada
Natalie Shea	Energy S&T Programs, Natural Resources Canada
Fred Wrona	Aquatic Ecosystem Impacts Research Division, Environment Canada
Don Cobb	Northern Research Energy Development, Fisheries and Oceans Canada
Rob Dilabio	Geological Survey of Canada, Natural Resources Canada
Norm Snow	Inuvialuit Joint Secretariat, Canada
Paul Barnes	Canadian Association of Petroleum Producers

Forum Facilitation, Abstracts and Proceedings

Dave Kerr	Golder Associates, Calgary, Alberta
Bette Beswick	Golder Associates, Calgary, Alberta

U.S. – CANADA NORTHERN OIL AND GAS RESEARCH FORUM

SPONSORING ORGANIZATIONS

North Slope Science Initiative
ALASKA

ALASKA NATURAL GAS TRANSPORTATION PROJECTS
OFFICE OF THE FEDERAL COORDINATOR

Northwest Territories

Yukon
Energy, Mines and Resources

Inuvialuit Joint Secretariat

Indian and Northern Affairs Canada
Affaires indiennes et du Nord Canada

Environment Canada
Environnement Canada

Fisheries and Oceans Canada
Pêches et Océans Canada

Canadian Polar Commission
Commission canadienne des affairs polaires

Natural Resources Canada
Ressources naturelles Canada

Foreign Affairs and International Trade Canada
Affaires étrangères et Commerce international Canada

TABLE OF CONTENTS

This proceedings is a compilation of discussion, abstracts and presentations provided at the United States and Canada Northern Oil and Gas Research Forum, Current Status and Future Directions for the Beaufort Sea, North Slope and Mackenzie Delta. It is intended to be viewed electronically. Using the Bookmark navigation bar, click on the title of the section that you wish to view to link to the selected section

SECTION

LIST OF APPENDICES

1 INTRODUCTION

On October 28 to 30, 2008, the United States and Canada Northern Oil and Gas Research Forum, Current Status and Future Directions for the Beaufort Sea, North Slope and Mackenzie Delta was held in Anchorage, Alaska. The forum was attended by 306 participants.

The purpose of the research forum was to provide an opportunity for U.S. and Canadian scientists, industry, and regulators to share information about research programs and to discuss future directions for northern oil and gas development. The forum provided an important communication venue for regulators, industry and communities to become better informed about existing research, data gaps, and how information is used in decision-making. Future directions for research were identified as well as areas of common interest between the US and Canada.

The objectives of the forum were:

- to showcase current research programs, demonstrating how they have contributed to decision-making through environmental assessments and the regulatory process and highlighting the involvement of indigenous people in research programs;
- to identify how to move research findings into decision-making fora;
- to discuss future oil and gas research needs, including synergies and partnerships, for the Beaufort Sea, Mackenzie Delta and North Slope; and
- to identify research and development priorities and next steps to advance our understanding of the interaction between the oil and gas industry and the Arctic environment.

2 FORUM ORGANIZATION

2.1 OVERVIEW

The morning of the first day focused on setting the stage for the research forum. Participants to the forum were welcomed by Ms. Drue Pearce, Federal Coordinator of Alaska Natural Gas Transportation Projects, and Mr. Patrick Borbey, Assistant Deputy Minister of Indian and Northern Affairs. Their opening remarks were followed by Ms. Mead Treadwell, Chairman of the US Arctic Research Commission and Ms. Ruth McKechnie, Senior Advisor, Northern Oil and Gas Branch, Indian and Northern Affairs Canada who provided overviews of northern oil and gas activities in the US and Canada, respectively.

A joint US/Canada panel set the stage by providing a variety of perspectives on northern management research needs and priorities. Some insight into the ArticNet research program’s activities supported by the Canadian Research Icebreaker, the CCGS Amundsen was provided by luncheon speaker Dr. Martin Fortier, Executive Director of ArcticNet.

On the morning of the second day, industry representatives outlined research priorities from the perspective of industry in both the U.S. and Canada. This included an overview of current and future development scenarios, research issues and priority areas for future research.

Over the three days of the research forum, 39 presentations covered technical-engineering topics (including oil spill response), socio-cultural/socio-economic issues, biological resources, and physical sciences. An additional 25 posters were displayed covering a variety of research areas in the arctic region.

A wrap-up presentation summarized the forum highlights that had been identified by the forum facilitators including future research priorities. Conference participants were then invited to contribute their additional observations which were added to the wrap-up presentation and are summarized in the Research Priorities and Issues Section (section 3.11).

2.2 FORUM AGENDA

United States and Canada Northern Oil and Gas Research Forum: Current Status and Future Directions in the Beaufort Sea, North Slope and Mackenzie Delta

October 28 to 30, 2008
Marriott Hotel
820 W 7th Ave.
Anchorage, Alaska

Day 1 October 28, 2008

8:30 - 8:40 **Welcome**

8:40 - 9:05 **Opening Remarks**

USA – Drue Pearce
Federal Coordinator, Office of the Federal Coordinator
Alaska Natural Gas Transportation Projects; Washington, D.C.

Canada – Patrick Borbey,
Assistant Deputy Minister,
Northern Affairs Organization
Indian and Northern Affairs Canada; Ottawa, Ontario

9:05 - 9:15 **Purpose of the Forum (Facilitator)**

Setting the stage for the Forum
Objectives, agenda and results
Key questions for consideration throughout the workshop
Expectations for wrap up session

9:15 - 9:40 **Overview of USA Northern Oil and Gas Activities and Research Programs**

Mead Treadwell, Chairman of the U.S. Arctic Research Commission; Anchorage, Alaska

9:40 - 10:05 **Overview of Canadian Northern Oil and Gas Activities and Research Programs**

Ruth McKechnie, Senior Advisor, Northern Oil and Gas Branch, Indian and Northern Affairs Canada; Ottawa, Ontario
Natalie Shea, Science and Technology Advisor, Energy Science and Technology Programs, Natural Resources Canada; Ottawa, Ontario

10:05 – 10:20	Health Break
10:20 – 11:20	**Panel: Management Research Needs and Priorities**
	United States
	John Payne, Executive Director of the North Slope Science Initiative
	John Goll, Regional Director of Minerals Management Service
	Canada
	Robert Steedman, National Energy Board; Calgary, Alberta
	Norm Snow, Executive Director, Inuvialuit Joint Secretariat

Technical-Engineering

11:20 - 11:40	**Alaskan Beaufort and North Slope Solid Waste Disposal Under the UIC Program -** Thor Cutler, United States Environmental Protection Agency; Seattle, Washington
11:40 - 12:00	**Ice Engineering Issues for Beaufort Sea Development -** Garry Timco, National Research Council of Canada; Ottawa, Ontario
12:00 - 12:20	**Ice Road Construction and Recovery on Tundra Ecosystems, National Petroleum Reserve, Alaska (NPR-A) -** Scott Guyer, Bureau of Land Management, Alaska State Office; Anchorage, Alaska
12:20-12:30	**Questions on theme 1**
12:30 - 13:30	**Lunch Hosted by the Government of Canada** Speaker "**ArcticNet**" Dr. Martin Fortier, Executive Director
13:30 - 13:50	**Speculation on the Origin and Persistence of Thick Multi-Year Ice in the Arctic-** Humfrey Melling, Fisheries and Oceans Canada; Sidney, British Columbia
13:50- 14:10	**Creation of Leads and Ridges: What is the Ice Behavior?** Max Coon, NorthWest Research Associates, Inc.; Seattle, Washington
14:10- 14:30	**Materials R&D for Northern Pipelines – Integrity, Safety, and Environmental Protection in the North-** Winston Revie, CANMET Materials Technology Laboratory, Natural Resources Canada; Ottawa, Ontario

14:30 - 14:50	**Questions on theme 1**
14:50 - 15:10	**The Status of Current Technology for Oil Spill Cleanup in Ice -** Ian Buist, S.L. Ross Environmental Research Limited; Ottawa, Canada
15:10 - 15:30	Health Break
15:30 - 15:50	**Detection of Oil on and Under Ice: Phase III Evaluation of Airborne Radar System Capabilities in Selected Arctic Spill Scenarios** –John Bradford, Boise State University; Boise, Idaho
15:50 - 16:10	**The Oil Spill Recovery Institute: Present and Future Work in the Arctic -** W. Scott Pegau, Oil Spill Recovery Institute; Cordova, Alaska
16:10 – 16:30	**ERMA: A New High Resolution Environmental Data Display and Management System for Oil Spill Planning and Response -** Amy Merten, Co-Director, NOAA Coastal Response Research Center; Silver Spring, Maryland
16:30 - 16:50	**Oil Spill Preparedness, Response and Countermeasures Planning in the Arctic -** Steve Potter, S.L. Ross Environmental Research Limited; Ottawa, Ontario
16:50- 17:10	**Empirical Weathering Properties of Oil in Ice and Snow -** Ian Buist, S.L. Ross Environmental Research Limited; Ottawa, Ontario
17:10- 17:20	**Questions on theme 1**

Day 2 October 29, 2008

Industry Panel

8:00- 8:45	**USA Industry Research Priorities:**
	Highlights of current and future development scenarios, research issues and priority areas for future research
	Pete Slaiby, General Manager, Alaska, Shell Exploration & Production Company
	Geoffrey Haddad, Manager Alaska Exploration, ConocoPhillips Alaska, Inc.
	Marilyn Crockett, Director Alaska Oil and Gas Association

8:45 – 9:30	**Canada Industry Research Priorities:** Highlights of current and future development scenarios, research issues and priority areas for future research Gary Bunio, VP Operations and COO, MGM Energy, Calgary Bob Bleaney, Manager Commercial & Regulatory Affairs, ConocoPhillips Canada Paul Barnes, Manager - Atlantic Canada, Canadian Association of Petroleum Producers
9:30-9:50	Questions

Socio-cultural/ Socio-economic

9:50 - 10:10	**Variability in Cross Island (Arctic Alaska) Subsistence Whaling: An Examination of Natural and Anthropogenic Factors -** Michael Galganitis, Applied Sociocultural Research; Anchorage, Alaska
10:10 - 10:30	**Inuvialuit Community Perspective: Mackenzie Gas Project - Impacts, Planning and Mitigation** – Amanda Cliff, Inuvialuit Regional Corporation: Inuvik, Northwest Territories.
10:30 - 10:50	Health Break
10:50 - 11:10	**The Study of Ecosystem Services and Sharing Networks to Assess the Vulnerabilities of Communities to Oil and Gas Development and Climate Change in Arctic Alaska -** Gary Kofinas, Director, Resilience and Adaptation Program, School of Natural Resources and Argicultural Sciences, University of Alaska, Fairbanks; Fairbanks, Alaska
11:10 - 11:30	**The Environmental Stewardship Framework in the NWT -** David Livingstone, Director, Renewable Resources and Environment, Indian and Northern Affairs Canada; Yellowknife, Northwest Territories
11:30 - 11:50	**Caribou Harvest Monitoring in the National Petroleum Reserve-Alaska: Developing Effective Future Mitigation -** Stacie McIntosh, Bureau of Land Management, Arctic Field Office; Fairbanks, Alaska
11:50- 12:10	**Social and Economic Effects in Canada's Mackenzie Delta Region from the Return of Oil and Gas Activity 2000-2004 -** Thom Stubbs, Integrated Environments Limited; Calgary, Alberta

12:10- 12:30	**Questions on theme 2**
12:30 - 13:30	**Lunch Hosted by the University of Alaska Fairbanks Geographic Information Network of Alaska** Speaker "**Arctic observation systems, current and planned**" Aimee Devaris, U.S. National Weather Service, Alaska Region, Deputy Director; Anchorage, Alaska

Biological Sciences

13:30 – 13:50	**Assessing the Potential Effects of Near Shore Hydrocarbon Exploration on Ringed Seals in the Beaufort Sea Region 2003-2006 -** Lois Harwood, Fisheries and Oceans Canada; Yellowknife, Northwest Territories
13:50 - 14:10	**Populations and Sources of Recruitment in Polar Bears: Movement Ecology in the Beaufort Sea -**Andrew Derocher, Department of Biological Sciences, University of Alberta; Edmonton, Alberta
14:10 - 14:30	**Satellite Tracking of the Western Arctic Stock of Bowhead Whales -** Lori Quakenbush, Wildlife Biologist, Alaska Department of Fish and Game; Fairbanks, Alaska
14:30 - 14:50	**Bowhead Whale Feeding Variability in the Western Beaufort Sea - Feeding Observations and Oceanographic Measurements and Analyses -** Carin Ashjian, Woods Hole Oceanographic Institution; Woods Hole, Massachusetts
14:50 - 15:10	**Seasonal Distribution of Canadian Beaufort Beluga Whales -** Pierre Richard, Research Scientist, Marine Mammal Stock Assessment, Arctic Research Division, Fisheries and Oceans Canada; Winnipeg, Manitoba
15:10 - 15:30	**Questions on theme 3**
15:30 - 15:50	Health Break
15:50 - 16:10	**Bowheads and belugas in the Alaska Beaufort and Chukchi Seas: implications of oil and gas development and climate change -** Robert Suydam, Wildlife Biologist, North Slope Borough; Barrow, Alaska
16:10 - 16:30	**Fish Research in the Western Canadian Arctic in support of Hydrocarbon Development**. **-** Jim Reist, Arctic Fish Ecology/Assessment, Fisheries and Oceans Canada; Winnipeg, Manitoba

16.30 - 16:50	**Northern Marine Coastal and Ecosystem Studies, CCGS *Nahidik* Fishing Program -** Patricia Ramlal, Arctic Research Division, Fisheries and Oceans Canada; Winnipeg, Manitoba
16:50 – 17:10	**Questions on theme 3**

Day 3 October 30, 2008

Biological Sciences

8:00-8:20	**Timing and location of King Eiders staging in the Beaufort and Chukchi Seas. -** Abby Powell, Research Ecologist, U.S. Geological Survey; Fairbanks, Alaska
8:20-8:40	**Science-Based Decision Making: the Mackenzie Gas Project and Environmental Impacts on Birds -** Craig Machtans, Forest Bird Biologist, Western Arctic Unit, Environment Canada; Yellowknife, Northwest Territories
8:40-9:00	**Effects of Oil Field Infrastructure on Calf Growth and Survival in the Central Arctic Caribou Herd -** Steve Arthur, Wildlife Biologist, Alaska Department of Fish and Game; Fairbanks, Alaska
9:00 - 9:20	**Subsistence Mapping of Nuiqsut, Kaktovik and Barrow** Stephen R. Braund & Associates; Anchorage, Alaska
9:20-9:40	**Questions on theme 3**

Physical Sciences

9:40 - 10:00	**Seabed Geo-environmental Constraints to Offshore Hydrocarbon Development in Beaufort Sea -** Steve Blasco, Marine Environment Geoscience, Natural Resources Canada; Dartmouth, Nova Scotia
10:00 - 10:20	**Waves and Sediment Mobility in the Southeastern Beaufort Sea -** Steve Solomon, Marine Environment Geoscience, Natural Resources Canada; Dartmouth, Nova Scotia
10:20 - 10:40	**Automated Lagrangian Water Quality Assessment System (ALWAS) -** Robert Shuchman, Co-Director, Michigan Tech Research Institute, Michigan Technological University; Ann Arbor, Michigan
10:40 - 11:00	**Questions on theme 4**
11:00 - 11:20	Health Break

11:20 - 11:40	**Subsidence, Flooding, and Erosion Hazards in the Mackenzie-Beaufort Region -** Don Forbes, Marine Environmental Geoscience, Natural Resources Canada; Dartmouth, Nova Scotia
11:40 - 12:00	**Modern Erosion Rates and Loss of Coastal Features and Sites, Beaufort Sea Coast, Alaska** – Benjamin Zones, United States Geological Survey.
12:00 - 12:20	**Enhancement of Permafrost Monitoring in the Mackenzie Valley -** Sharon Smith, Permafrost Research Scientist, Natural Resources Canada; Ottawa, Ontario
12:20 – 12:40	**Questions on theme 4**
12:40 - 13:40	Lunch
13:40 - 14:00	**Characterization and Water Use of Alaskan North Slope Lakes -** Daniel White, Institute of Northern Engineering, University of Alaska Fairbanks and Michael Lilly, GW Scientific; Fairbanks, Alaska
14:00-14:20	**Hydrology of the Mackenzie Delta Region -** Philip Marsh, Land Use Impacts on Hydrology and Aquatic Ecosystems, Environment Canada; Saskatoon, Saskatchewan
14:20 - 14:40	**Wind and Wave Hindcasts for the Beaufort Sea -** Val Swail, Climate Data and Analysis, Environment Canada; Downsview, Ontario
14:40 - 15:00	**Regional Hydro-Climatology and Its Relationship to Northern Oil and Gas Development -** Barrie Bonsal, Climate Impacts on Hydrology and Aquatic Ecosystems, Environment Canada; Downsview, Ontario
15:00 - 15:20	**Questions on theme 4**
15:20- 17:00	Wrap Up Everyone (Facilitated)
17:00 – 17:15	Next Steps and Closing Remarks

3 CONFERENCE HIGHLIGHTS

3.1 OPENING REMARKS: DRUE PEARCE (U.S.A)

Drue Pearce, Federal Coordinator
Office of the Federal Coordinator for Alaska Natural Gas Transportation Projects
Opening Remarks: U.S. and Canada Northern Oil and Gas Research Forum
October 28, 2008
Anchorage, AK

It is my pleasure to welcome you all to the first United States and Canada Northern Oil and Gas Research Forum.

I'm Drue Pearce and I'm here to tell you why you are here.

Policy decisions are made every day that will affect the Beaufort Sea, the North Slope and the Mackenzie Delta for decades, even centuries.

We're here to learn about the research that's being done to inform the decision makers.

Many, if not most, policy makers are also politicians. And politicians learn – during long and often dull committee meetings – to ask questions. Unfortunately, sometimes they are just trying to appear smarter than the guy sitting next to them.

But most have a sincere intellectual curiosity that leads them to want as much information as they can possibly gather before they make a decision. The best of them don't, on the other hand, want to study every issue to death.

So your job in this modern world is to provide that information in a cogent fashion that informs the decisions of the day.

Key to the process or processes is framing the question. What do the decision makers need to know?

A few key quotes come to mind, such as

"You got to be careful if you don't know where you're going, because you might not get there." By Yogi Berra, and

"Research is the process of going up alleys to see if they are blind." --- By Marston Bates.

Now, I'm well aware that some of you probably don't hold policy makers in high esteem, assessing them as Yogi Berra did when he said, *"There are some people who, if they don't already know, you can't tell 'em."*

I'm here to tell you, though, that wise decision makers want to make informed decisions.

And your research results – if presented to the appropriate decision makers in a useful format - which synthesizes recommendations, conclusions and key issues in an unbiased manner - are some of the most useful tools that inform policy makers. Research results aren't the only tool that should be used in the decision making process but they are one of the most important components of information a policy maker should have.

Research can be sophisticated. But it doesn't have to be – some of the best knowledge comes from simply looking. I'm in a Yogi Berra mood since it's World Series time, and he also said, *"You can observe a lot by just watching."*

But sometimes we over think problems, here's an example:

Sherlock Holmes and Dr Watson were going camping. They pitched their tent under the stars and went to sleep. Sometime in the middle of the night Holmes woke Watson up and said: "Watson, look up at the stars, and tell me what you see."

Watson replied: "I see millions and millions of stars."

Holmes said: "and what do you deduce from that?"

Watson replied: "Well, if there are millions of stars, and if even a few of those have planets, it's quite likely there are some planets like earth out there. And if there are a few planets like earth out there, there might also be life."

And Holmes said: "Watson, you idiot, it means that somebody stole our tent."

Simple observation has resulted in major design changes on the North Slope. We learned in Prudhoe Bay that caribou don't want to cross ring roads. So, Kuparuk has a road system that looks from the air like the veins in a leaf – which allows the caribou to munch away to their hearts content without ever having to cross a road.

From simple observation to complicated scientific modeling, we are all engaged in answering the questions of our time.

I would like to extend my appreciation to all the people who worked so hard to pull together this Forum, in particular Dennis Thurston with the United States Department of the Interior's Minerals Management Service, Michael Baffrey with the United States Department of the Interior and Ruth McKechnie with Indian and Northern Affairs Canada.

The idea for a conference came, in time honored fashion, from a discussion over beer and wine after a long day of Arctic Council meetings in Narvik, Norway. Ruth was talking about ice scouring research that was being done in the Canadian Beaufort. That led to a discussion about the various research efforts on both sides of the border and the question of whether we were communicating effectively cross border.

Not a year later, here we are at the first of what I hope will be many forums.

As President Bush said, “We will act, learn and act again, adjusting our approaches as science advances and technology evolves.” The United States is committed to ensuring that our policies are informed by the best information science can provide.

This forum provides a great opportunity for the United States and Canada, countries that share not only a border but also a commitment to the responsible development of our resources, to bring together scientists, resource managers and industry to discuss what research is being conducted and how it can be used. But it’s not enough to simply catalog what you are doing; we want to build a cooperative effort in which the research that is being done is the research that policy makers need to make the decisions of the day.

The forum topics range across a number of important issues. We will focus on the heart of the North Slope indigenous culture: the Bowhead whales that migrate across our border, wherever it is, in the Beaufort Sea. We will look at work being done on ice behavior. We’ll hear about ice engineering issues and about infrastructure effects on caribou. As well as that ice scouring work I mentioned.

The information presented this week will be the cutting edge results that will inform decision makers and resource managers for the next few years.

Are we doing enough? Are we studying the right topics?

I can tell you that in my new position, Federal Coordinator for Alaska Natural Gas Transportation Projects, I’ve developed a to-do list that includes a number of new topics and old topics that need to be updated.

When I joined DOI under Gale Norton’s leadership, our mantra for decision making was Consultation, Communication, and Cooperation, all in the service of Conservation. While that mantra may no longer be in vogue, this forum brings all those C components together in an attempt to bring together the right people to begin a dialogue about what research is underway and how we can collectively and collaboratively engage in more.

Government funded or directed research must be tied to identified research needs, especially in these tough economic times. That’s why DOI led the charge to create the North Slope Science Initiative (NSSI). Dr. Bill Seitz, USGS, had the idea. He worked with Dr Rowan Gould, FWS and Henri Bisson, BLM, to refine the concept and it was a hit with the Secretary. The NSSI is comprised of the State and federal resource managers with Industry and local residents at the table. Together they decide what science is needed to make sound resource management decisions.

The Arctic is changing. The Northwest Passage is poised to become a major shipping thoroughfare and there are distinct changes ashore. Change presents both new opportunities and challenges for the Arctic. It’s imperative that we manage our response to those opportunities and challenges wisely.

The change has no borders and it’s important that the two nations – divided by a common language though we may be – attack the challenges collaboratively.

For the past year and a half, the U.S. Executive Branch has been reviewing its policies related to the Arctic region in a comprehensive manner. The last review was completed in 1994. The Department of State and the National Security Council are leading the process, which involves every federal agency with Arctic responsibilities. We are in the final stages of this review; a final product should be released soon. Because it's not final, I am not in a position to discuss its content and conclusions.

However, I can share some of the key issues that have been discussed.

Since 1994, much has changed in the Arctic, most notably the significant melting of Arctic sea ice. As a result, we anticipate increased human activity in shipping and energy development. We want to ensure that these activities are conducted in a way that minimizes any negative impacts on the Arctic environment.

The discussions focused on a number of topics, three of which are being discussed at this forum: international scientific cooperation, economic issues, and environmental protection and conservation.

In every meeting, without fail, people would ask what the relevant research results are and whether more research is being done.

From the Inupiat Elder who observes Bowhead whale or polar bear behavior to the decision makers in DC and Ottawa who ask "why", the common thread is curiosity and a need to understand our world. You men and women provide a critical link in the path to wise conservation and adaptive management.

It's not always pretty, as Albert Einstein observed in a Yogi moment of his own, saying, "*if we knew what it was we were doing, it would not be called research, would it?"*

But if you make your research relevant, package it into a useful format, which synthesizes recommendations, conclusions and key issues in an unbiased manner, I can assure you that your results attract attention and be used.

Thank you for being a part of this experiment in collaboration, which I hope leads to many future consultative, cooperative efforts between us. And if you run out of ideas, have I got a project or two for you!

Thank you and enjoy the forum.

3.2 OPENING REMARKS: PATRICK BORBEY (CANADA)

Patrick Borbey, Assistant Deputy Minister
Northern Affairs Organization
Indian Affairs and Northern Development Canada
Northern Oil & Gas Research Forum '08
Anchorage, Alaska
October 28, 2008

Let me start by thanking you, Drue, for your warm welcome and for making members of the Canadian delegation feel so at home in Alaska. I am sure I speak for everyone here when I say how much we are enjoying the tremendous hospitality of the City and people of Anchorage.

We are especially grateful to our American hosts for recognizing the importance of science to resource development, and for sponsoring this inaugural research forum. Whether we are policy makers, regulators, industry leaders or local residents, we all have a vested interest in capitalizing on each other's knowledge and expertise as we determine future directions for northern oil and gas development. Today's meeting comes at a pivotal time in this region's history. The Arctic is undergoing sweeping changes with consequences for Canada, the U.S., other circumpolar countries and the world as a whole.

On the one hand, the Arctic's enormous economic potential is being unleashed as the North's oil and gas reserves are unlocked. At a time when emerging economies require new energy sources and traditional energy producers' supplies are depleting, the Arctic's wealth of oil and gas has the potential to fuel decades of future global growth.

In Canada, we believe it is essential that Northerners – particularly Aboriginal people – benefit from these opportunities. Measures such as land claim settlements, consultations and direct involvement in resource development, such as the Aboriginal Pipeline Group, are enabling Northern communities to participate in development opportunities, decision-making processes and benefit from increased activity.

At the same time there is tremendous opportunity, there is also dramatic environmental change. Melting tundra and glaciers and shrinking ocean ice mean a shortened season for ice roads and the potential for new marine shipping channels opening across the circumpolar region.

The winds of change are also compromising the centuries-old way of life of Aboriginal people and affecting the Arctic's wildlife and fragile ecosystems. These impacts underscore the need for environmental management and adaptation strategies that help Northern residents adjust to a fast-changing world and ensure sensitive Arctic ecosystems are safeguarded for future generations.

Equally challenging, regulations designed in a bygone era can no longer keep pace with these rapid changes. It would be an understatement to say that oil and gas development in the North is expensive. Understandably, industry is hesitant to invest in these costly ventures without the certainty that the rules will be clear and fair to all parties involved. The business community wants to know what to expect from a regulatory perspective and be assured that timelines will be met. Otherwise, the investment becomes cost prohibitive.

Reconciling these diverse interests and demands is at the heart of sustainable development – and the reason why we need sound science. To respond effectively to the profound changes taking place in the Arctic, we must strengthen our ability to predict and prepare for them through groundbreaking research, the incorporation of traditional knowledge and the participation of Northerners and Aboriginal people in our research programs.

We also need to learn from each other's experiences and lessons learned wherever we can. And that is what this forum is all about. It's a chance to share research results and create synergies to ensure that science informs the decision-making processes for environmental assessments and regulatory processes. Ensuring effective mitigation measures are in place enables oil and gas activity to proceed in an environmentally responsible manner while simultaneously assuring local communities that the public interest is protected.

Given our shared geography and common economic and social goals, it is important that we take advantage of each other's experience and expertise. Certainly, Canada has much to learn from the U.S. experience as oil and gas exploration activity ramps up in the Canadian Beaufort. While there was a lot of activity in the area in the 1970's through to early 90's, only recently, since 2002, have we seen a renewed interest in offshore exploration. There have been record bids for exploration licenses in the Beaufort Sea in the last two years in the deeper oil rich zones, resulting in work commitments in excess of $1.2 billion.

Another area of interest in Canada's North is the proposed Mackenzie Gas Project,- a major pipeline infrastructure project to bring 6 trillion cubic feet of natural gas from the Mackenzie Delta to southern markets.

As potential infrastructure projects become a reality and exploration activity expands so, too, does the need to ensure that the baseline information is available, technical and engineering design issues based on sound science are being adequately addressed, and that the appropriate monitoring programs are in place and informed by traditional knowledge.

That's why science has played such a crucial role in oil and gas initiatives. Early on, a biophysical gaps analysis was conducted to identify the necessary research to be undertaken for both Mackenzie Gas development and induced oil and gas activity to respond to the environmental assessment and regulatory review. Since 2002, some $70 million has been spent on Northern oil and gas research to help decision makers make well-informed policy, regulatory and investment choices.

Over the last three years, under the leadership of the United States and Norway, Canada has been very involved in the Arctic Council`s Arctic Monitoring and Assessment Programme. The programme recently completed an exhaustive scientific study of oil and gas activities in the Arctic. A summary of the scientific results can be found in the Overview report – Arctic Oil and Gas (2007).

This Arctic Council initiative offers an assessment of the environmental, social, economic and human health impacts of current oil and gas activities in the Arctic and their probable impacts in the future. These assessments help us to focus on what research and monitoring should be undertaken for oil and gas activity. In fact, it was through this very process of collaboration that today's forum was initiated. Cooperation such as this is essential and must be the underpinning for future science efforts in the North.

Canada is eager to share its research and knowledge on these issues with industry and regulators both here in Canada and the U.S. Indeed, our goal is to ensure that our country becomes a global leader in Arctic science.

To advance this goal, we are planning to establish an Arctic Research Station. In planning the station, we have borrowed best practices from our international partners. We have visited facilities from pole to pole – from the Barrow Arctic Research Station and Toolik Station here in Alaska to the Rothera Station in the Antarctic.

The year-round, large-scale polar research facility will put Canada on the cutting edge of environmental science and resource development, such as oil and gas. Our goal is to establish a staging and research facility that will attract the best researchers from around the globe who can collaborate on joint projects and build on the legacy of the International Polar Year research efforts.

Canada's commitment to science is further reflected in its accelerated research investments under the International Polar Year. At $150 million, Canada's contribution to this global initiative is the largest of any of the 60 participating nations. Almost all of the funds – $100 million – are being spent on 43 science and research projects employing 1200 Canadian and 130 foreign scientists from 20 countries.

Much of the research will be of benefit to regulators and industry involved in oil and gas development, such as those studying sea ice and oceans, hydrology and the carbon cycle. Also of interest are projects examining the effects of climate change and potential adaptation strategies. For example, there is a project looking at the impacts of climate change on permafrost across northern Canada. Permafrost is of vital interest to industry since its presence dramatically affects infrastructure such as buildings, roads and local services.

Research also has a major contribution to make in informing sound regulatory decisions. Canada is taking action to encourage future exploration and development by improving Northern regulatory systems. Our Northern Regulatory Reform Initiative has a two-fold approach, focussing on both operational-level improvements to areas of federal responsibility and on fundamental changes in legislation to ensure that the systems meet the highest standards of effectiveness, predictability and timelines. This will increase certainty for industry while ensuring that our environmental goals are met through sustainable development.

So, clearly, there are multiple benefits from sharing research at a forum such as this one. Recognizing this, both our countries hope to foster greater connections and understanding among everyone with a stake in Arctic oil and gas.

I am optimistic that this week's meeting will be just the beginning of a longer-term research relationship. Canada would be very interested in hosting a future follow-up forum, so we can continue to identify emerging research priorities that we should pursue together and build on this collaborative first effort.

In light of the challenges and opportunities I`ve outlined, there has perhaps never been a time when this work was more needed. Nor, as this forum underscores, has there been a better chance to make the right decisions today – based on sound science – that will benefit northern communities, our economies and countries for years to come. I encourage everyone here to fully seize the tremendous potential this forum offers and look forward to learning the results of your deliberations.

Thank you.

3.3 RESEARCH PROGRAM OVERVIEW

To set the stage for the research forum, representatives of the government agencies which coordinated funding and research for northern environments provided overviews of their agencies' programs.

Mr. Mead Treadwell, Chair of the U.S. Arctic Research Commission, described oil and gas resources in northern Alaska within the context of the circumpolar environment. The Arctic U.S. Research Program of approximately $400 million per year is spread across at least 15 federal agencies in cooperation with over a dozen nations, using infrastructure worth billions of dollars. Highlight issues include maritime boundary discussions, global climate change, and changes in moving product to market, especially tanker traffic enabled by longer Arctic shipping seasons.

Ms. Ruth McKechnie, Senior Advisor to the Northern Oil and Gas Branch, Indian and Northern Affairs Canada (INAC) outlined the hydrocarbon potential of northern Canada and the Beaufort Sea. The Federal Northern Oil and Gas Science Research Initiative funds research projects in a number of federal government departments, is leveraged with a number of other programs, and provides linkages with academia. The research is in support of the environmental assessment and regulatory requirements for the Mackenzie Gas Project and induced oil and gas activity. Initiatives that promote international cooperation include the Arctic Council, International Polar Year, High Arctic Research Station, and ArcticNet. The Environmental Studies Research Fund (ESRF) finances environmental and social studies related to exploration, development, and production activities on frontier lands and is funded by levies on frontier oil and gas licences.

Ms. Natalie Shea, Science and Technology Advisor for Energy Science and Technology Programs for Natural Resources Canada outlined the Program of Energy Research and Development (PERD), which has an annual budget of approximately $56 million and supports energy research and development programs across 13 federal science-based departments and agencies. PERD's northern-related programs include research and development to support northern regulatory processes pipelines, marine transportation and safety, offshore environmental factors, remediation, and gas hydrates.

3.4 PANEL ON MANAGEMENT RESEARCH NEEDS AND PRIORITIES

A joint United States and Canada panel provided insight into current management research needs and priorities.

Dr. John Payne, Executive Director North Slope Science Initiative, presented an overview of previous and current research in Alaska's arctic. Both broad categories of research, such as sea ice conditions and socio-economic change, were identified along with examples of more specific research needs such as permafrost measurement techniques and caribou demographic data analysis. The need for greater communication and dissemination of information was highlighted, together with a need for greater collaboration among researchers and managers.

Dr. John Goll, the Alaska Regional Director U.S. Minerals Management Service (MMS) described the work of the MMS, which manages the U.S. outer continental shelf. The MMS supports research programs, including the Technical Assessment and Research Program, which encompasses engineering and oil spill response studies, and the Environmental Studies Program. The Environmental Studies Program is guided by three broad research themes: monitoring marine environments, fate and effects research, and social and economic impacts.

Dr. Robert Steedman, from Canada's National Energy Board, provided a regulators perspective on Beaufort Sea research priorities. These included spill cleanup readiness, facility evacuation in mixed ice conditions, same- season relief well capability, offshore waste treatment guidelines and drilling on the shelf slope. This was complemented by an overview of the Biophysical Research Requirements (Data Gaps) for Beaufort Sea Hydrocarbon Development report (2008) commissioned by Environmental Studies Research Funds (ESRF) Management Board.

Mr. Norm Snow, Joint Secretariat, Inuvialuit Settlement Region, Northwest Territories, Canada described Western Arctic Management research needs and priorities. These encompass species-specific research on priority harvested species such as marine mammals and fish as well as research needs towards management of oil and gas activities, including oil spill response and waste management. The need to include climate change considerations in research was also highlighted, along with an integrated data management system.

3.5 PANEL ON OIL AND GAS INDUSTRY RESEARCH PRIORITIES

A joint United States and Canada industry panel presented information on current industry activity, challenges and research in the Arctic.

Mr. Pete Slaiby, General Manager, Shell Exploration and Projection, Alaska presented an overview of Shell's Arctic experience, current and future activities and research and technical challenges. He identified critical research needs and opportunities for synergies between industry partners, regulators and the scientific community. Among the challenges presented for responsible and successful development, safety, reliability and cost effectiveness were highlighted, along with continued efforts to reduce the operational footprint while maximizing benefits and minimizing impacts.

Mr. Geoffrey Haddad, Vice- President, Exploration and Land, ConocoPhillips, Alaska discussed current exploration and development in the NPR-A and Chukchi Sea and associated research focus areas in both the onshore and offshore. Key Alaska research areas for the onshore focused on minimizing environmental impacts for example, through extended reach drilling and small footprint developments. Offshore research areas included site- specific drilling solutions, acquisition of baseline information, ice- hardened structures and seabed interactions with development infrastructure.

Ms. Marilyn Crockett, Executive Director Alaska Oil and Gas Association, discussed industry activities and research needs in the arctic. This included a “Tool Box” for Oil and Gas Development in sensitive areas to address research needs such as baseline studies, technological advances in seismic, drilling and access to remote sites. Population data on ESA listed species and underwater sound impacts were examples of research needs presented. Research challenges were identified in the areas of coordination/collaboration, prioritization, government funding and publication, peer review of study results.

Mr. Gary Bunio, Vice- President Operations, MGM Energy Corporation provided an overview of MGM’s drilling programs in 2008-09, along with ongoing research programs in Canada’s arctic. He explored the theme of research in the context of a research model that should address our “understanding”, “invention”, “innovation” and “implementation of findings” as applied to the arctic oil and gas industry. Key items identified for Northern Energy Development in the context of research needs included timelines, infrastructure, labour and the regulatory framework.

Mr. Bob Blainey, Manager- Commercial and Regulatory Affairs, ConocoPhillips, Canada provided an overview of oil and gas resource potential in the Canadian arctic. Key onshore challenges were identified as tundra/permafrost preservation, narrow weather windows, logistics and transportation, infrastructure and sensitive environments. Key offshore challenges include ice structure/seabed interaction, sensitive marine environments and safety. Regional research priorities were identified in the areas of navigation/transportation, ice environment, cost reduction, and support for the Canadian Beaufort Regional Environmental Assessment Initiative.

Mr. Paul Barnes, with the Canadian Association of Petroleum Producers (CAPP) presented an overview of CAPP’s role in the Canadian Oil and Gas industry. This was followed by a review of northern Canada’s petroleum industry activity, challenges of operating in northern Canada and the use of research and development to address these challenges. Research drivers were identified in the areas of resource recovery, regulatory streamlining, project level assessment, physical and biological baseline data and stakeholders expectations regarding environmental and social performance. CAPP acknowledges the collaboration that is taking place between industry and government research and development funders in the north and see continued opportunities to advance sustainable northern communities, support individual and community economic self sufficiency, and to develop associated infrastructure.

3.6 TECHNICAL-ENGINEERING

Most presentations in the technical-engineering session focused on the predominant engineering challenge of the oil and gas industry in Arctic environments – ice, both on sea and on land.

Sea ice was the topic of three of the presentations. Dr. Garry Timco provided an overview of the research conducted by the Natural Research Council's Canadian Hydraulics Centre which addresses ice engineering challenges faced in the Beaufort Sea. Dr. Humphrey Melling (Fisheries and Oceans Canada) spoke about the PERD-supported long-term pack-ice monitoring program, and resulting observations about multi-year ice floes. Dr. Max Coon outlined progress in developing a model to predict sea ice behaviour in the creation and evolution of leads and ridges.

On land, Mr. Scott Guyer presented the results of the Bureau of Land Management's investigations into the effects and recovery of tundra ecosystems following ice road construction, and Dr.Winston Revie of Natural Resources Canada's CANMET Materials Technology Laboratory spoke about research and development focused on reliability issues faced by northern pipelines operators.

The status of the Underground Injection Control program used to manage solid waste in the Alaskan oilfields was described by Mr. Thor Cutler of the U.S. Environmental Protection Agency (EPA), who also spoke about the future for carbon dioxide geosequestration under the EPA's proposed new Class VI rule.

3.7 OIL SPILLS

Comments and questions from forum participants on the issue of oil spills indicated that it is a topic of particular concern for northern residents and environmental organizations. Industry representatives commented that understanding the behaviour of oil spills and knowing how to deal with them was important, but that implementing practices that prevented them in the first place was the priority.

The presentations dealt with a variety of issues related to oil spills. Dr. John Bradford discussed the results of an MMS-sponsored research program on how airborne radar systems can be used to detect oil under ice. Mr. Ian Buist discussed the results of laboratory testing on weathering properties of oil in ice and snow. Technologies and preparedness to deal with spills after they occurred were addressed in presentations by Dr. Scott Pegau (Oil Spill Recovery Institute), Mr. Steve Potter and Mr. Ian Buist (SL Ross Environmental Research Ltd.), and Dr. Amy Merten (Coastal Response Research Center, National Oceanic Atmospheric Administration).

3.8 SOCIO-CULTURAL, SOCIO-ECONOMIC

Topics related to issues affecting human communities were the focus of the session on socio-cultural and socio-economic research. Four presentations presented results of research of socio-cultural and socio-economic conditions in areas affected by oil and gas development in northern environments. Two of them – Mr. Michael Galginaitis' (Applied Sociocultural Research) presentation on subsistence whaling, and Ms. Stacie McIntosh's (Bureau of Land

Management) presentation on caribou harvest monitoring – discussed community resource use. Dr. Gary Kofinas (University of Alaska Fairbanks) described two in-progress research projects examining the resilience and vulnerabilities of communities in northern Alaska to oil and gas development and climate change. Mr. Thomas Stubbs (Integrated Environments) described the social and economic effects of the renewal of oil and gas activity to Canada's Mackenzie Delta Region in 2000 – 2004.

Two presentations described processes that provide context for socio-cultural and socio-economic programs. Ms. Amanda Cliff (Inuvialuit Regional Corporation) described planning processes related to obtaining funds from the $500 million Mackenzie Gas Project (Social) Impact Fund, and Mr. David Livingstone (Department of Indian Affairs and Northern Development) described the environmental stewardship framework, which establishes the context for responsible economic development in the Northwest Territories.

3.9 BIOLOGICAL SCIENCES

Biological sciences were the primary focus of twelve presentations. Mr. Stephen Braund's (Stephen R. Braund & Associates) presentation on subsistence mapping of Nuiqsut, Kaktovik, and Barrow linked the topics of subsistence use of wildlife with biological research topics. This was illustrated through the results of interviews with community members and maps produced by data collected in a GIS.

Research on marine mammals was a strong focus of the biological sciences sessions. Ms. Lois Harwood (Department of Fisheries and Oceans) presented results of an investigation into the effects of near- shore hydrocarbon exploration on ringed seals. Dr. Andrew Derocher (University of Alberta) described the preliminary findings of a 5-year research program, initiated in 2007, to examine polar bear movement in the southern Beaufort Sea population. Bowhead whales were the topic of two presentations: Dr. Carin Ashjian (Woods Hole Oceanographic Institution) spoke about bowhead whale feeding behaviour, and Ms. Lori Quakenbush (Alaska Department of Fish and Game) spoke about bowhead whale movement. Mr. Pierre Richard (Fisheries and Oceans Canada) presented the results of satellite tracking of beluga whales in the Beaufort Sea. Mr. Robert Suydam (North Slope Borough) described observations of bowhead and beluga whale responses to oil and gas development in the Alaskan Beaufort and Chukchi seas, compounded by the influences of subsistence hunting and climate change.

Dr. James Reist (Fisheries and Oceans Canada) provided an overview of fish research in the western Canadian Arctic, and Dr. Patricia Ramlal described the multidisciplinary research program based from the Canadian Coast Guard Ship *Nahidik.*

Dr. Stephen Arthur (Alaska Department of Fish and Game) presented the surprising findings that when intensive industrial development caused a shift in the location used by calving of the Central Arctic caribou herd to an area of reduced habitat quality, the population of the herd increased.

Dr. Abby Powell's (University of Alaska) presentation on king eiders showed the movement patterns of king eider ducks revealed through satellite tracking. Mr. Craig Machtans' (Canadian Wildlife Service, Environment Canada) presentation was also about birds, with a focus on the special demands placed on research when it is to be used to support regulatory processes and decisions.

3.10 PHYSICAL SCIENCES

The last topic to be addressed at the research forum was physical sciences. Two presentations of research from the Geological Survey of Canada highlighted the dynamic nature of the Beaufort Sea. Steve Blasco's presentation on seabed geoenvironmental issues, including ice scour and seabed permafrost, highlighted a number of constraints to hydrocarbon development. Mr. Steve Solomon's presentation described research into hydrodynamics and sediment movement in the nearshore environment of the Mackenzie Delta region of the Beaufort Sea.

Dr. Donald Forbes (Natural Resources Canada) spoke about the on-shore Mackenzie Delta, and how subsidence of the delta affects flooding and erosion. He also presented the results of research on the hydrology of the Mackenzie Delta Region (Marsh et.al). Results from the Geological Survey of Canada's permafrost monitoring network were described by Dr. Sharon Smith.

Two papers described research in freshwater environments. Mr. Robert Shuchman (Michigan Tech Research Institute) described how water quality data can be collected using the Automated Lagrangian Water Quality Assessment System (ALWAS). Mr. Michael Lilly presented results of investigations into effects of water withdrawal for oil and gas development from lakes on the Alaska North Slope.

The final two presentations of the conference addressed an issue underlying much of the discussion of the preceding presentations – climate. Ms. Val Swail's (Environment Canada) presentation described the use of historical data of wind and wave conditions in the Beaufort Sea to create models that can be used to predict extreme events. Dr. Barrie Bonsal's presentation discussed climate change, and how projected changes to hydro-climatology raise a number of research issues with respect to future oil and gas exploration and development in the Mackenzie Basin/Beaufort Sea.

3.11 RESEARCH PRIORITIES AND ISSUES

Research needs and priorities was the subject of three panel discussions, representing the "consumers" of research: oil and gas resource managers, U.S. industry, and Canadian industry. Each forum participant identified different research priorities and issues because each holds different perspectives, has different issues that require resolution, and must respond to different core missions or directions. Nevertheless, some common themes were identified, along with common research priorities. Highlights of these are presented below.

3.11.1 Infrastructure

Many forum participants identified the need for more robust infrastructure and logistical support for research programs and industrial activity. Providing safe, reliable and cost-effective support facilities is a challenge. The value of support facilities was demonstrated by the varied research programs supported by the CCGS *Nahidik* and the ArcticNet initiatives supported by the CCGS

Amundsen. Access to ice-strengthened vessels for marine research was identified as a priority in both the US and Canada.

3.11.2 Sea Ice

The physical properties of sea ice, how it affects design and engineering of facilities, changes in ice cover related to climate change and its influence on the marine environment were identified as continuing priorities for research. While predictive modeling of ice behaviour is improving, there remains the need for more research using remote sensing and on the physical properties of sea ice. Effects of ice scour, movement and behaviour of multi-year ice, characteristics and probability of extreme ice features, were some of the items identified as requiring further research attention.

3.11.3 Long-term Studies

Natural systems are dynamic; observations made at a single point in time have limited usefulness compared to long- term observations. Knowing long-term trends and natural variability in populations like polar bear and caribou provides clues to how oil and gas development may contribute to other factors that drive population changes. Similarly, being able to analyze physical data such as meteorological data provides a better understanding of extreme events and trends, as well as provides clues to long- term climate change.

Long-term studies were also felt to be important in our understanding of cumulative effects in the Arctic, providing data sets and information that can be used as benchmarks to help us understand changes in biophysical conditions over time.

3.11.4 Information Use Across Boundaries

The range of presentations and discussions from a variety of perspectives illustrated how the usefulness of information can be enhanced by making a transition across boundaries of time, scale, jurisdiction, and application.

Time

The technology used to collect data and interpret information that formed the basis of many of the forum presentations would have been considered fantastical during the Arctic oil and gas development initiatives in the early 1980's. Being able to monitor the daily (hourly!) circumpolar movements of an Eider duck or beluga whale, by using satellite imagery and to detect the depth of scour of ice movements on the floor of the Beaufort Sea by using multibeam technology are examples of technological transitions that have significantly changed the ability to understand the natural environment.

It was acknowledged that advances in technology should continue to be supported as new information is provide which in turn strengthens knowledge based decision making. Nevertheless, on a number of occasions through the course of the forum, reference was made to the importance of capturing the knowledge and experience of people who were involved in earlier northern industrial initiatives. Bringing together the knowledge gained from different time periods, including intergenerational knowledge provided by Traditional Knowledge, allows for a baseline to be established, enabling monitoring of long-term trends and an increased understanding of the interaction of oil and gas development in northern environments.

Forum participants also frequently observed that oil and gas industrial practices have evolved significantly. Most notable from an environmental impact perspective is the reduction in the size of the footprint of industrial sites, which reduces the area of impact as well as the level of activity required to construct and operate the facility.

Scale

A number of forum presentations exposed the challenge of applying research results collected at one scale to resolving problems at a different scale. For example, understanding the physical properties of oil weathering in laboratory tests is only the beginning of understanding how it will behave in the field conditions experienced in the Beaufort Sea. Similarly, computer models of the behaviour of ice movement require significant testing against real conditions before they can provide reliable predictions of the real world environment.

Jurisdiction and Collaboration

Much of the research presented at the forum demonstrated interagency cooperation and collaboration among multiple government agencies, industry, academia and non-government organizations. A number of studies demonstrated that researchers' focus is on developing an understanding of the natural environment regardless of the jurisdiction in which it occurs. Pointed examples of how the natural environment boundaries have little relationship to political boundaries was demonstrated in satellite tracking of wildlife – from krill to bowhead whale, and from ducks to polar bear. Research collaboration across jurisdictions is beneficial for all stakeholders and should be encouraged.

Application

Proponents of oil and gas development and the managers of the resource emphasized the importance of the transition from data collection to the application of that data in ways that solve problems. Decisions are rarely made in a "science bubble", and decisions must often be made even though information is not complete or perfect. Decision makers emphasized the importance of receiving information in a form that is relevant and useful to them.

3.11.5 Collaboration and Communication

Many of the presentations highlighted the collaborative nature of the research programs, with funding and cooperation shared among a number of agencies, and including participation of academia, industry, and government organizations. Many also demonstrated widespread availability of their work, through mechanisms such as websites that provided access to data as it was collected. Nevertheless, a number of participants identified the need for better collaboration and communication, particularly with respect to the compatibility of data and methods of data acquisition.

The complexity of factors that affect social systems requires additional collaboration to bring together information to better understand factors such as climate change, economic effects of development, and external social influences on communities. Furthermore, clarity is required about appropriate and meaningful indicators of social conditions. In addition, it was identified that better sharing of information among communities would enhance their ability to be resilient in the face of these changes.

3.11.6 When Things Go Wrong

The Beaufort Sea, North Slope and Mackenzie Delta are harsh and isolated. This presents special challenges for working in these areas, particularly when things go wrong.

Oil Spill Cleanup

The focus of dealing with oil spills in Arctic marine environments is on prevention for example through engineering design, use of innovative technologies and reduced industrial footprint. Nevertheless, the consequences of an oil spill and the ability to clean it up, particularly in remote areas or in ice-infested water, were issues of particular concern to many forum participants. The assessment of risk and acceptable levels of risk is also an area that needs more attention.

Although the increasing ability to detect oil on and under ice was demonstrated (see Bradford's presentation), the current technology to detect oil spills in mixed ice environments, illustrated by images of people in small boats tipping over ice pans with poles to see if oil was present, suggests that some aspects of detection remain rudimentary.

The current best-practice method of cleaning up oil on ice by burning (see Buist's abstract), is still viewed as a valid practice. After a winter oil spill, burning is used for spill cleanup during spring breakup. Cleanup in mixed ice environments was identified as particularly problematic. Issues related to spill cleanup readiness, such as available materials and resources, ability to deal with spills in mixed ice environments, and disposal of recovered oily wastes are also research priorities.

Emergency Response

Inclement weather conditions and long distances from well-equipped and adequately-staffed emergency response centres are a few of the factors that present challenges to conducting research or working in these remote northern locations. Facility evacuation in mixed ice conditions from platforms and ships was identified as an area requiring further attention.

Same-Season Relief Well Capability

Research into the benefits, alternatives and risks associated with same-season relief wells, and implementation of regulatory policies on same-season relief wells were identified as priority issues.

Communication and Information Sharing

The need to share information and research results with regulators and industry was a common theme when discussing oil spill prevention, response and further research priorities. In particular, the sharing of best practices/best available technology and lessons learned was seen as a way to advance our understanding of the issues and to improve access to available data.

3.11.7 Emerging Issues and Challenges

The forum provided an opportunity to identify a number of emerging issues, trends and challenges that the oil and gas industry will face in the future. The theme of "Change" emerged as a key driver for research in the arctic, either as a result of climate change and the need to look at adaptive research across, physical, biological and socio-economic fields, or change in the context of technological advances in both industry tools and practices and in the ability to access increasingly more remote resources and to bring them to market.

Climate change, ocean shipping, technological advances in oil spill prevention, response and monitoring, cumulative effects and gas hydrates were identified as issues that are likely to gain increased importance for future research programs in the Arctic.

Climate Change

The need to address climate change as an underlying consideration in research programs was mentioned by many forum participants. Forecasting models were felt to be important, particularly with respect to broad scale studies on Arctic shelf conditions. Questions about potential climate change effects on the natural environment including permafrost integrity, sea ice conditions, implications for traditional cultural practices (e.g., subsistence harvesting), and increased shipping traffic were raised frequently. Similarly, the need to look at adaptive management research was felt to have increasing relevancy with respect to exploration and production.

Ocean Shipping

An extended ice-free season will allow for increased shipping. The direct effects of increased shipping including shipping noise and waste management, as well as its potential to contribute to cumulative effects, are issues that require consideration. This was felt to be particularly important in regards to a potentially ice- free northwest passage.

Oil Spill Prevention, Response and Monitoring

Although oil spills have been a concern since exploration and production first took place in the arctic region, research and development continues to make advancements in the areas of spill prevention, response and monitoring. Data Management systems, linked to real-time environmental conditions (wave, wind and sea-ice) are expected to advance in the future, improving our ability to predict hazardous conditions for exploration, production and shipping activities. In addition, technological advances in drilling production and shipping are expected to increase, further reducing the potential for spills. Similarly, our ability to track and monitor spills, both on and under the ice, in all four seasons is expected to advance through a variety of remote sensing and site-specific technologies.

Cumulative Effects

As industrial development, shipping traffic and other uses of the arctic region increases, the cumulative effects and management of these activities is expected to become an issue both within and across U.S. and Canada's jurisdictions. This has implications for various regional land use management initiatives and the development of effective means to monitor and manage a range of activities in remote environments. Issues of arctic sovereignty, security, environmental protection and provision of socio-economic opportunities for aboriginal peoples of the North are likely to overlap as oil and gas activity expands in the region.

Gas Hydrates

Gas hydrates in the arctic were identified as a possible future source of energy, albeit with a longer time frame for development than oil and gas resources. Information about geo-environmental properties of gas hydrates, regulation and information about safety of gas hydrate development and production was identified as an emerging issue in the Arctic requiring additional research.

4 CONCLUSION

Participants at the Northern Oil and Gas Research Forum concluded that such events provide important opportunities to share the results of research across the US and Canada's arctic regions. Collaborative research programs that extend across U.S. and Canada borders have been undertaken in the past and are continuing to provide insight into a range of key issues facing the oil and gas industry in the arctic.

Technological advances in exploration and development activities continue to reduce the footprint that the industry has on the environment; however there remain many issues to address with regards to environmental and socio-economic effects management, including oil spill prevention, response and monitoring. Applied research must continue to answer questions on key issues to improve decision making and our knowledge of the interaction between the industry and the arctic environment.

.

5 ABSTRACTS AND PRESENTATIONS

5.1 PANELS

5.1.1 Arctic Resource Exploration: A Knowledge based industry U.S. Arctic research commission, *Mead Treadwell*

Arctic Resource Exploration: a knowledge based industry

Mead Treadwell, Chair
U.S. Arctic Research Commission

U.S. and Canada Northern Oil and Gas Research Forum: Current Status and Future Directions in the Beaufort Sea, North Slope and Mackenzie Delta

Anchorage, Alaska -- October 28, 2008

United States and Canada

Northern Oil and Gas Research Forum '08

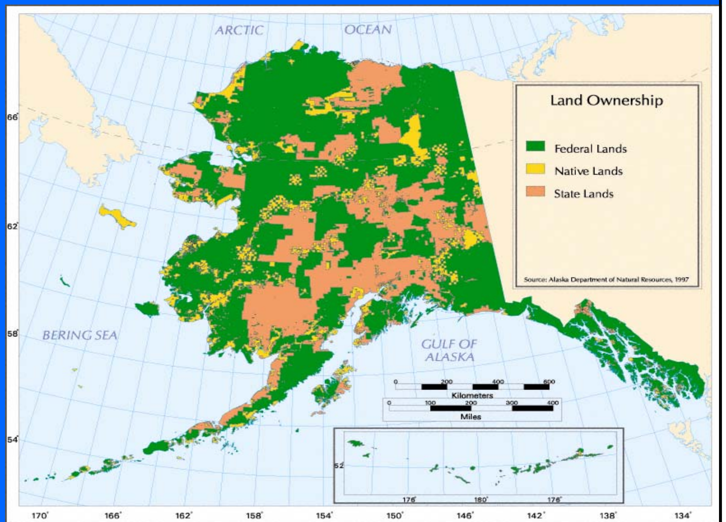
Current Status and Future Directions for the Beaufort Sea, North Slope and Mackenzie Delta

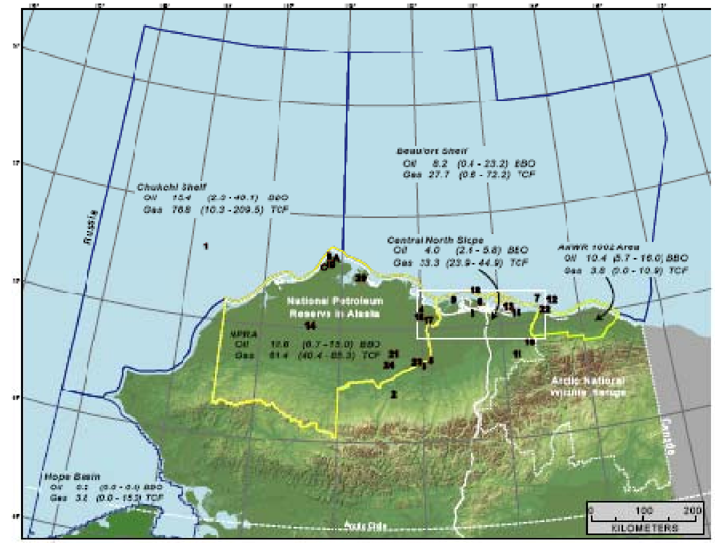
in Anchorage, Alaska
October 28 to 30, 2008

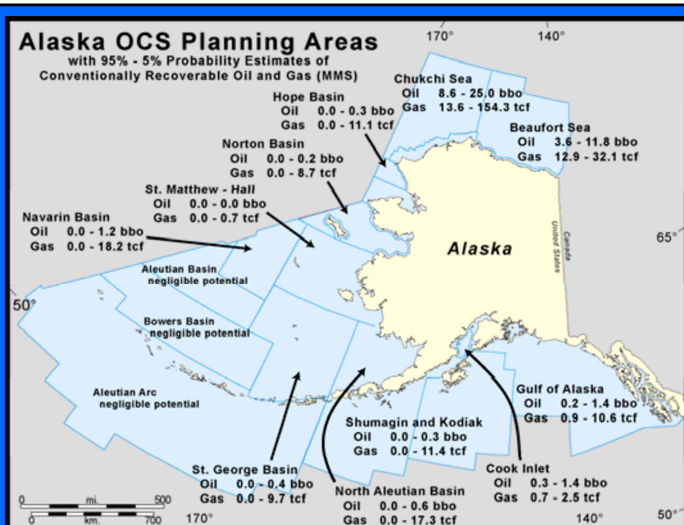
Check from U.S. to Purchase Alaska from Russia

August 1, 1868

Alaska Common wealth: location, people, critters, culture, beauty, land, oil, gas, minerals, timber, fresh water . .

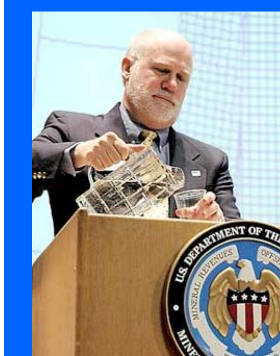






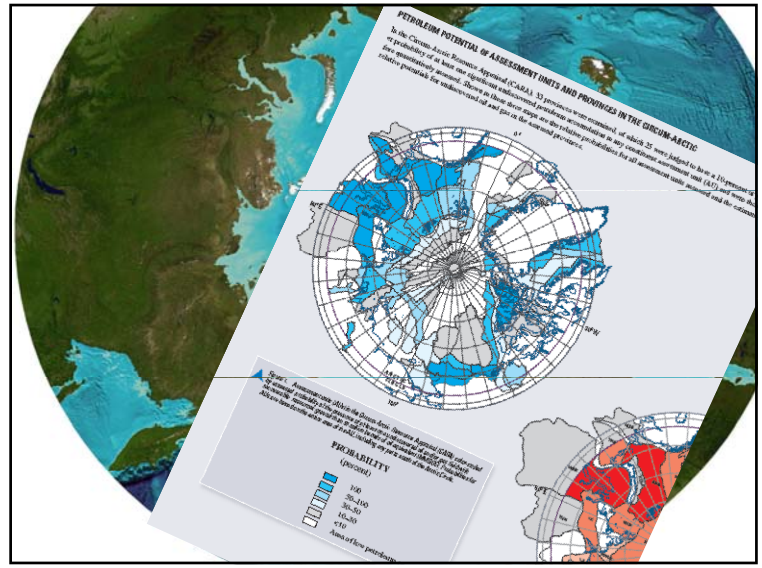
Record $2.7 billion bid for Alaska oil and gas leases

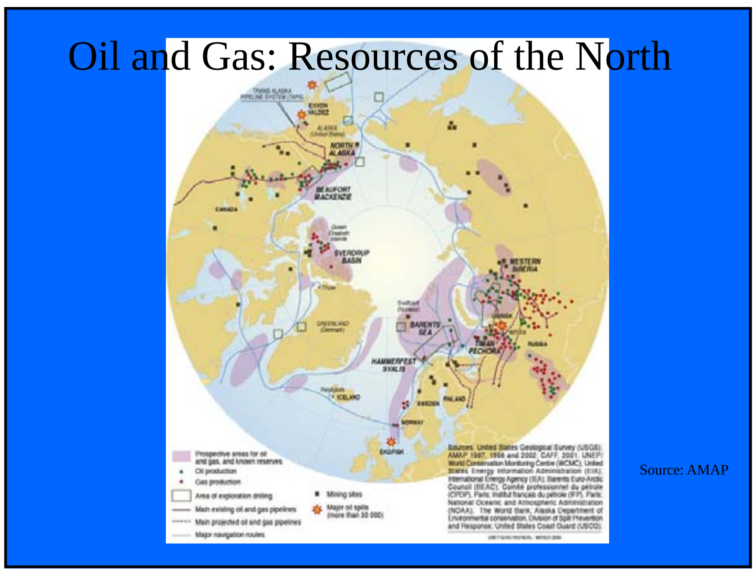
RON ENGSTROM / Anchorage Daily News



Minerals Management Service's Alaska Regional Director John Goll pours a glass of water before reading the 667 lease sale bids for the Chukchi Sea that totaled $2.66 billion, the largest lease sale in Alaska's history. Photo/Rob Stapleton/AJOC


Arctic Energy
INSTITUTE OF THE NORTH
UNITED STATES ARCTIC RESEARCH COMMISSION
THE ARCTIC ENERGY SUMMIT
ARCTIC ENERGY Themes
RURAL
EXTRACTIVE
SUSTAINABILITY




Oil and Gas: Resources of the North
Source: AMAP


UNITED STATES ARCTIC RESEARCH COMMISSION
Two points:
1. The world needs energy; the Arctic has it
2. Knowledge begets success
1. in finding and efficiently producing the resource; moving it to market
2. Indentifying and protecting values we hold dear: opportunity, clean air, water, wild land, climate, biodiversity & traditional culture,

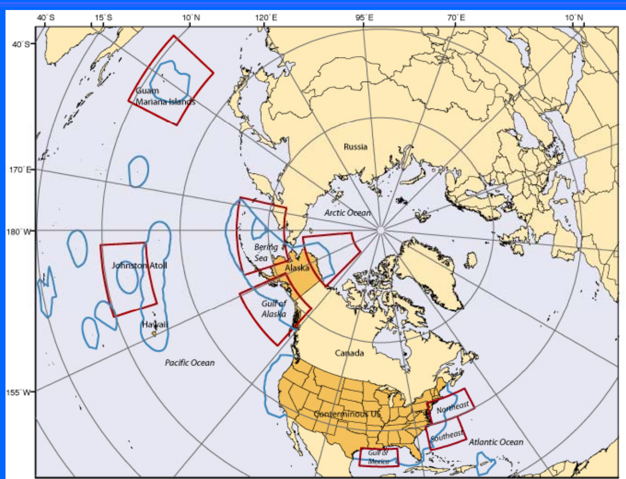
Arctic Research in the US

- The U.S. Arctic Research Program is approximately $400 million per year…across at least 15 federal agencies…cooperating with over a dozen nations …using research infrastructure worth billions…and building America's competitive position

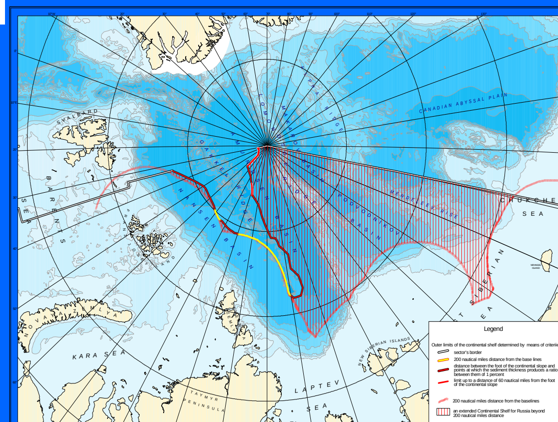
Context:

Changing the Arctic Map

Where Is Our ECS?



New Arctic Territory?



Source: Russian Federation claim

How Much Are the Resources Worth?

At least $1 trillion in resources

Hydrocarbons (Oil & Gas)
- Estimated 10 Billion Barrels
- 750,000 square kilometers where sediment thickness exceeds 1 km

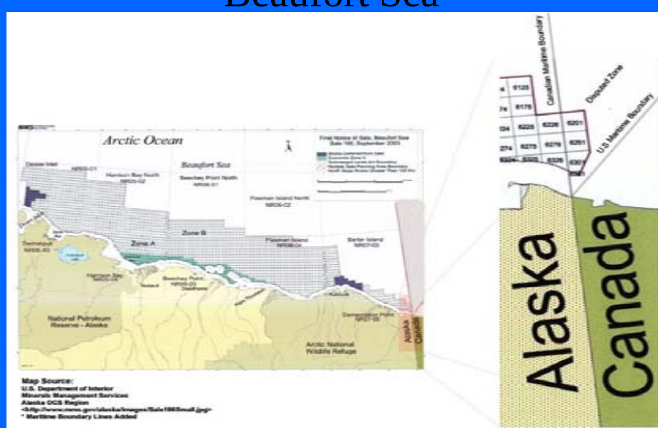
Manganese Nodules and Crusts
- Highest concentration of manganese nodules and at the highest average grades
- Manganese: 182 million tons
- Copper: 9 million tons
- Nickel: 12 million tons
- Cobalt: 5,000 tons

Jack #2 Well in the Gulf of Mexico
Drilled in record 7,000 feet of water
AP Photo/Devon Energy Corporation

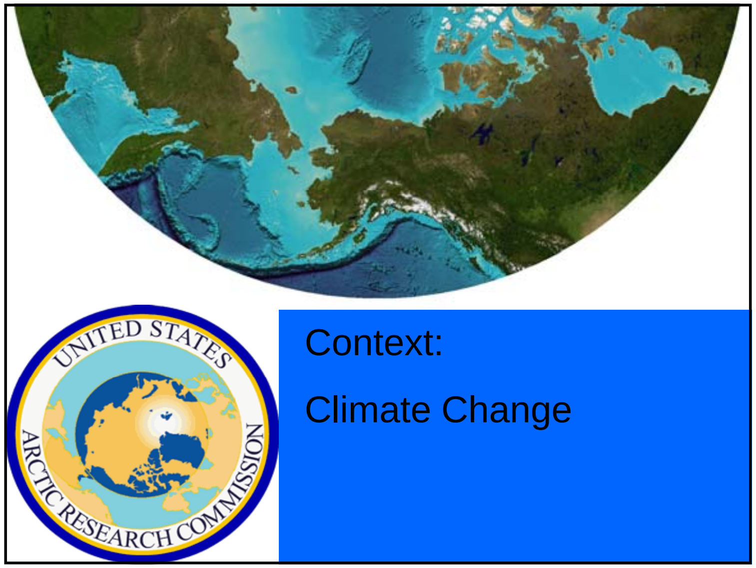
Reference: *Global Non-Living Resources on the Extended Continental Shelf: Prospects at the Year 2000.*
Values based on June 2000 prices.

Beaufort Sea Canada-US Border

Maritime Boundary Issues: Beaufort Sea

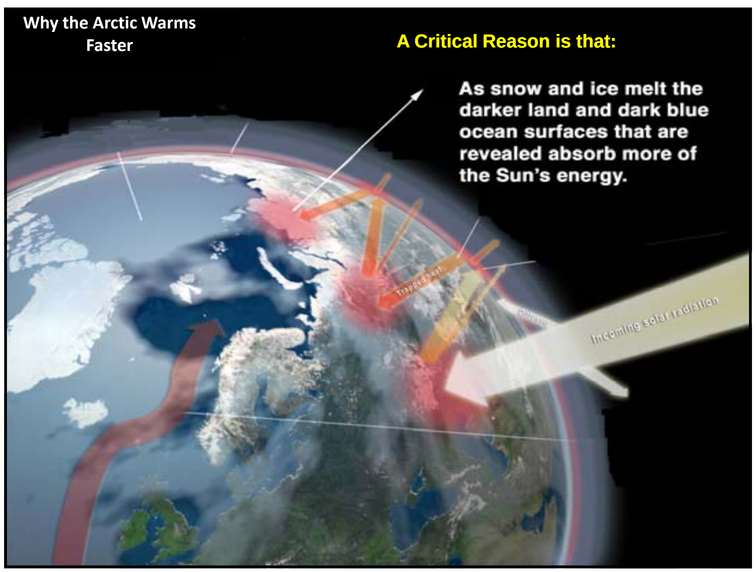


Source: US Dept of Interior

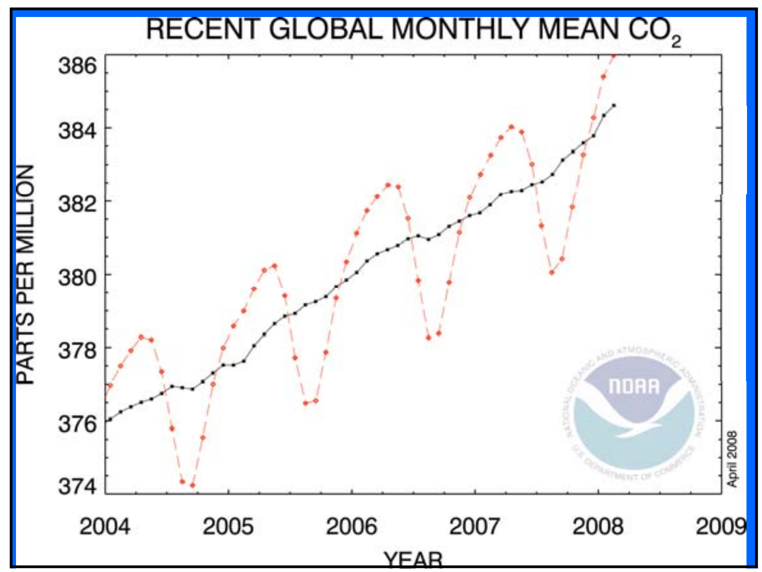


UNITED STATES ARCTIC RESEARCH COMMISSION
Context:
Climate Change

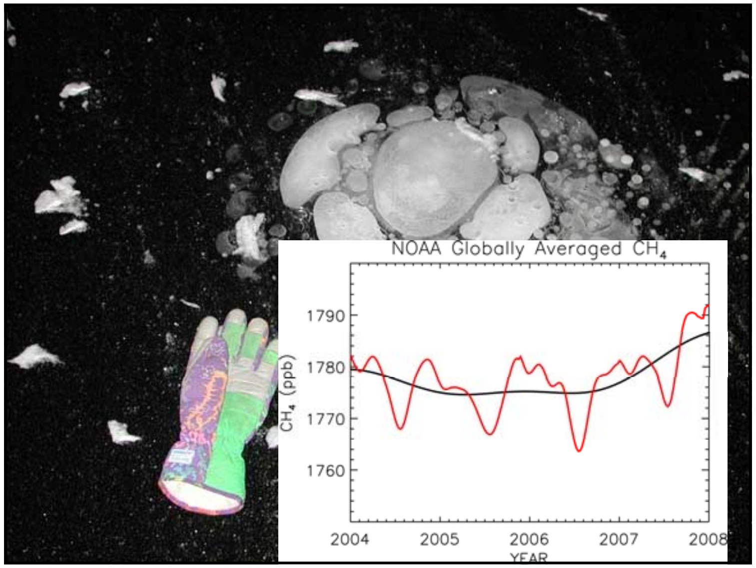
Changes across many sectors of Arctic
Plants & Vegetation
Ocean & Climate
Snow & Ice
Fish, Sea Birds & Marine Mammals
Forest & Grassland
Freshwater, Lakes & Rivers
Permafrost & Tundra
Indigenous Culture
Wildlife & Waterfowl
Sea Ice & Icebergs
Human Health
Land Use & Agriculture



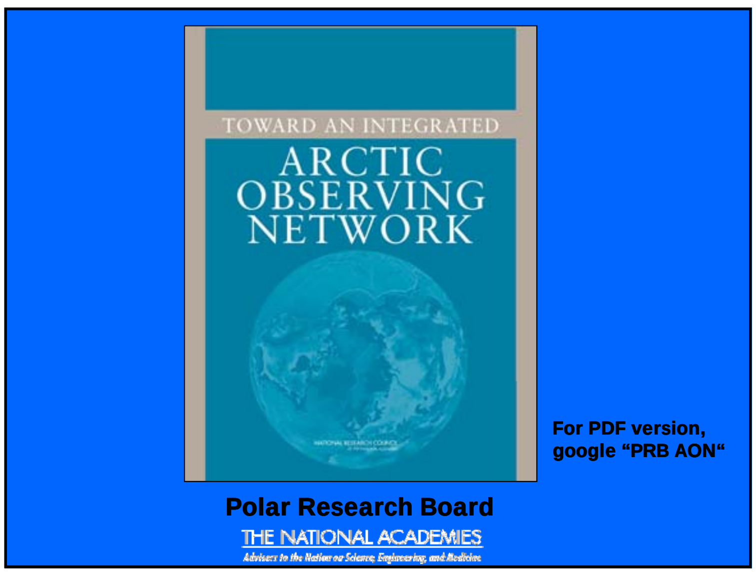
Why the Arctic Warms Faster
A Critical Reason is that:
As snow and ice melt the darker land and dark blue ocean surfaces that are revealed absorb more of the Sun's energy.
Incoming solar radiation

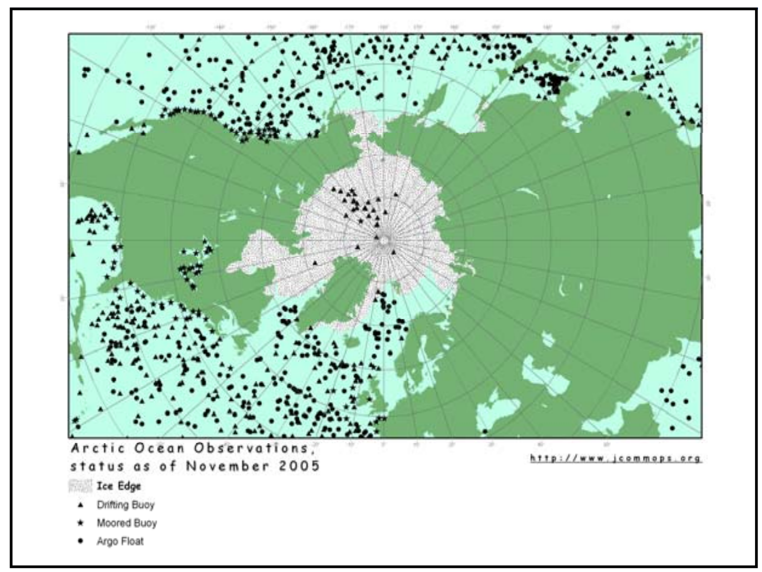


RECENT GLOBAL MONTHLY MEAN CO_2
PARTS PER MILLION
386
384
382
380
378
376
374
2004
2005
2006
2007
2008
2009
YEAR
April 2008
NOAA


NOAA Globally Averaged CH_4
CH_4 (ppb)
1790
1780
1770
1760
2004
2005
2006
2007
2008
YEAR


Permafrost degradation - NPRA, Alaska


TOWARD AN INTEGRATED
ARCTIC
OBSERVING
NETWORK
For PDF version, google "PRB AON"
Polar Research Board
THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine


Arctic Ocean Observations,
status as of November 2005
http://www.jcommops.org
Ice Edge
Drifting Buoy
Moored Buoy
Argo Float

Context:

Moving energy to market

Figure 1. Alaska Oil and Gas Pipelines

Source: Adapted from CRS Report RL31278, *Arctic National Wildlife Refuge*, Figure 6, based on Energy Department maps.

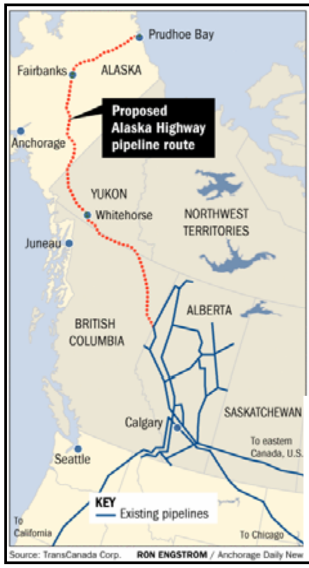
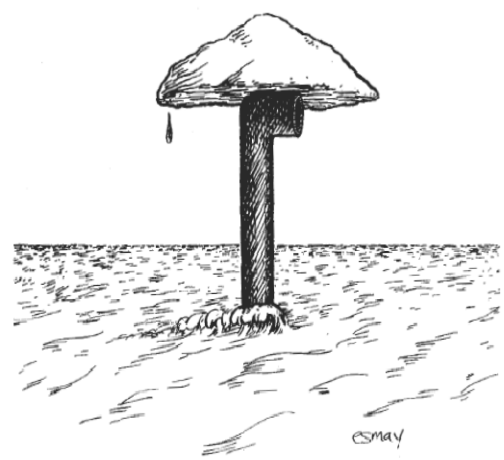


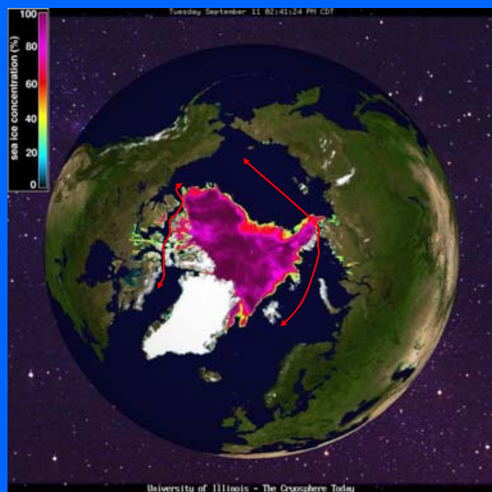
Table 1. Selected Dates from Alaska Natural Gas Development

1968	Prudhoe Bay oil and gas discovered
1971	United States begins export of LNG to Japan from south central Alaska (Cook Inlet)
1976	Alaska Natural Gas Transportation Act (ANGTA) passed, P.L. 94-586
1977	Presidential Decision and FPC Report to Congress on ANGTS
1977	FERC (successor to FPC) issues conditional certificate for pipeline
1978	TAPS oil pipeline into service (ANS natural gas re-injected)
1979	Office of Federal Inspector (OFI) established
1981	"Western leg" of Alaska gas pipeline (Pacific Gas Transmission) pre-build into service
1982	"Eastern leg" (Northern Border Pipeline) pre-build into service
1983	Maritime Administration study of alternatives to pipeline released
1992	OFI eliminated
1997	United States becomes net importer of LNG for the first time
2001	Alaska Natural Gas Interagency Task Force established (State Dept., Dept. of Interior (including MMS and BLM), Dept. of Transportation, Dept. of Energy (including FERC))
2004	Alaska Natural Gas Pipeline Act passed, Division C, P.L. 108-324
2006	New governor announces Alaska Gasline Inducement Act (AGIA) initiative
2007	Five proposals submitted for AGIA consideration
2008	Governor determines one AGIA proposal meets AGIA criteria
2008	Conoco Phillips and BP announce the Denali Project as an alternative to an AGIA project
2008 (August)	Alaska legislature approves governor's AGIA recommendation and it becomes law



Last Trip Under the Polar Ice Cap

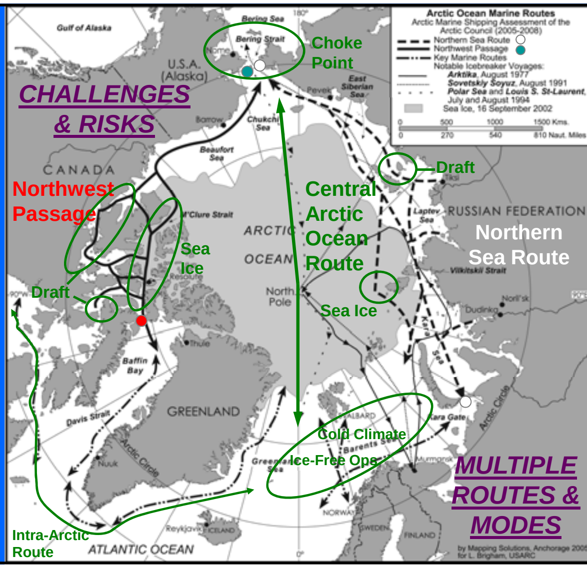
11 September 2007



Source: Samsung Heavy Industries

"Demand for ice-class tankers has been steadily rising as oil exports from Russia's Arctic regions become ever more attractive. The ordering pace…in the tanker industry…(reached) some $4.5 billion in (2004) alone."

--American Bureau of Shipping, *Surveyor*, Summer 2005

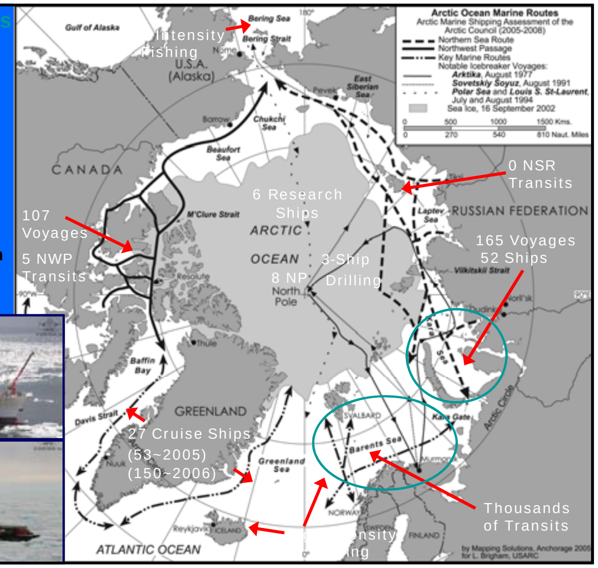


How Many Ships in the Arctic?

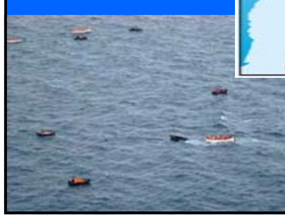
Snapshot of Summer 2004 Traffic

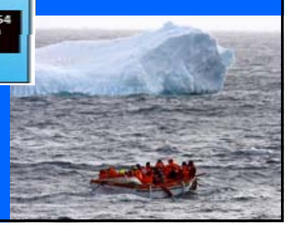
Modes of Arctic Marine Transport

- Destinational / Regional
- Trans-Arctic
- Trans-Arctic with Transshipment
- Intra-Arctic



"Stricken cruise ship off Antarctica evacuated" MSNBC-11/23/07





Having a safe, secure and reliable Arctic shipping regime is vital to the proper development of Arctic resources, especially now given the extent of Arctic ice retreat we witnessed this past summer…We can have such a regime only through cooperation, not competition, among Arctic nations. Denial of passage through international waterways, even though they may be territorial waters, and burdensome transit requirements will not benefit any nation in the long run."

-- Assistant Secretary of State Daniel S. Sullivan, 10/15/2007

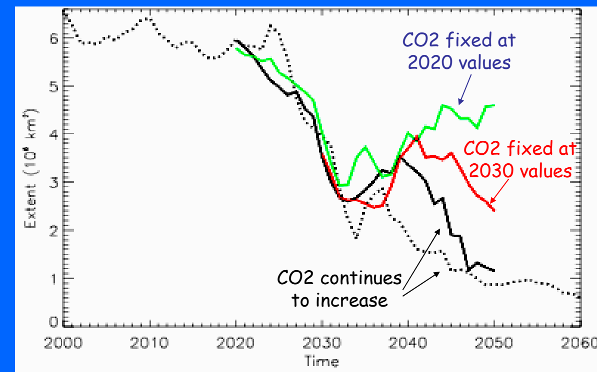

Icebreaker Design for Greater Efficiency
Future Convoy Requirements?
ARCTIC EXPRESS
Icebreaking (Double Acting) Container Ship
Norilskiy Nickel in the Kara Sea
March 2006
Aker Arctic


Great Lakes St. Lawrence Seaway
Ports
Canadian Locks
United States Locks
Locks
1 St. Lambert
2 Cote Ste. Catherine
3 Lower Beauharnois
4 Upper Beauharnois
5 Snell
6 Eisenhower
7 Iroquois
8 Welland Canal (8 locks)
Thunder Bay
Duluth/Superior
Lake Superior
Lake Michigan
Lake Huron
Lake Ontario
Lake Erie
St. Lawrence
Green Bay
Milwaukee
Chicago
Burns Harbour
Detroit
Toledo
Cleveland
Erie
Buffalo
Hamilton
Toronto
Oshawa
Oswego
Ogdensburg
Prescott
Valleyfield
Montreal
Trois-Rivieres
Becancour
Quebec


Arctic shuttle container link from Alaska US to Europe
AARC K - 63
Aker Arctic
aker yards.
Mach 2006
M. Arpiainen
R. Kiili


UNITED STATES ARCTIC RESEARCH COMMISSION
Context:
Mitigation Science,
Applied Science,
Basic Science

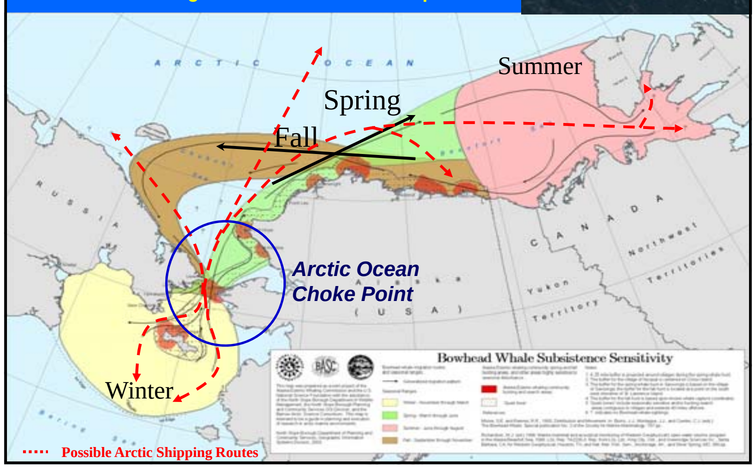
Have we passed a point of no return?



Preliminary model results suggest
- that sea ice can recover if CO_2 levels fixed/decline
- that a seasonally ice-free Arctic might be avoidable.
- May depend on when/for what ice state this occurs.

'Wild Card' Issue 1 ~ Multiple Ocean Use Management & Enforcement

Bowhead Whale Migrations & Arctic Marine Operations

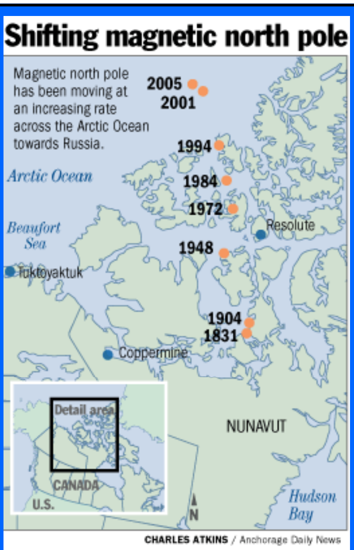


- Federally supported oil in ice research continues, in international programs, supported by several agencies

Permafrost degradation - NPRA, Alaska

USARC ECUMENICAL BELIEF

- The United States must maintain its global maritime capability—as a government AND as a Nation
- If the U.S. does not exercise its visible maritime presence in the Arctic Ocean—we cede it to whomever wants it!



U.S. Arctic Research Commission

Report on Goals & Objectives 2007

IARPC meeting
April 27, 2007

To the Explorers of the International Polar Year, Godspeed!

http://www.ipy.org www.arctic.gov
www.us-ipy.org
www.us-ipy.gov

www.arctic.gov

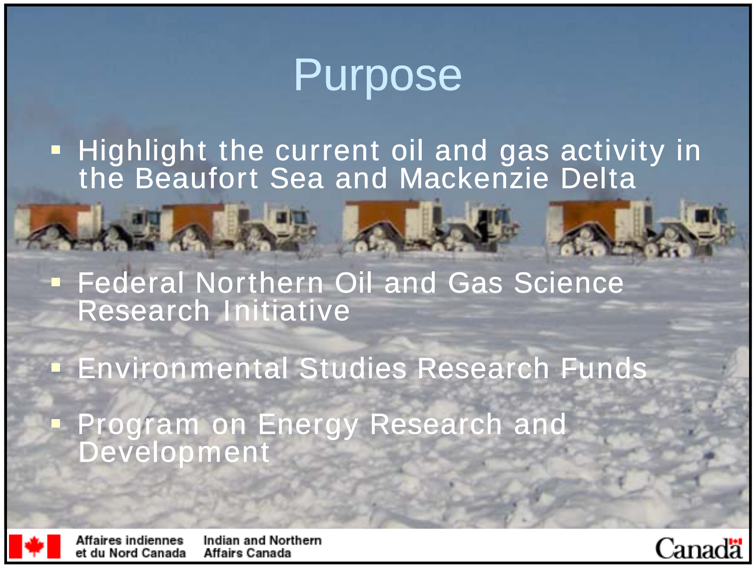
meadwell@alaska.net

www.institutenorth.org

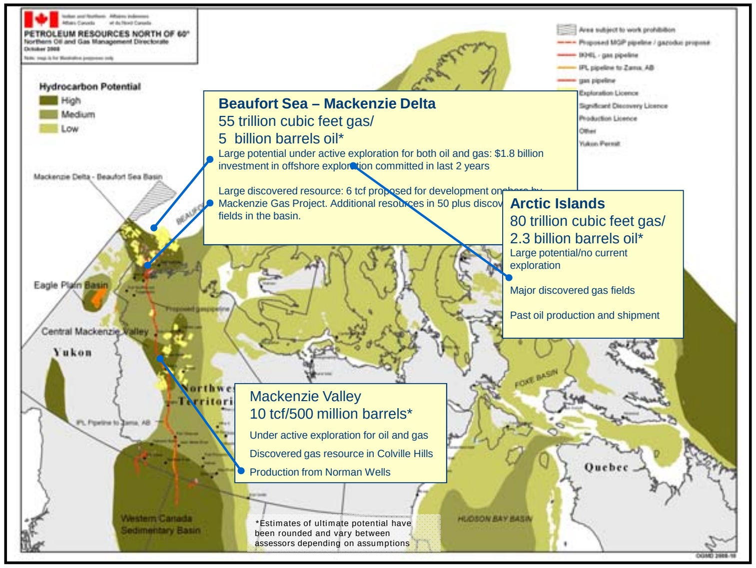
5.1.2 Overview of Canadian Northern Oil and Gas Activities and Research Programs, Indian and Northern Affairs Canada,

Ruth McKechnie

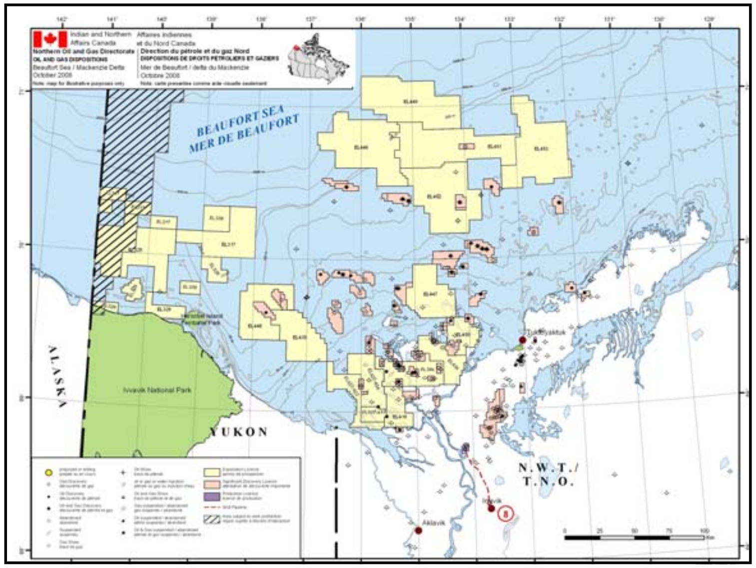
Overview of Canadian Northern Oil and Gas Activities and Research Programs
United States and Canada
Northern Oil and Gas Research Forum
Ruth McKechnie
Northern Oil and Gas Branch
Indian and Northern Affairs Canada
October 28, 2008
Affaires indiennes et du Nord Canada
Indian and Northern Affairs Canada
Canada



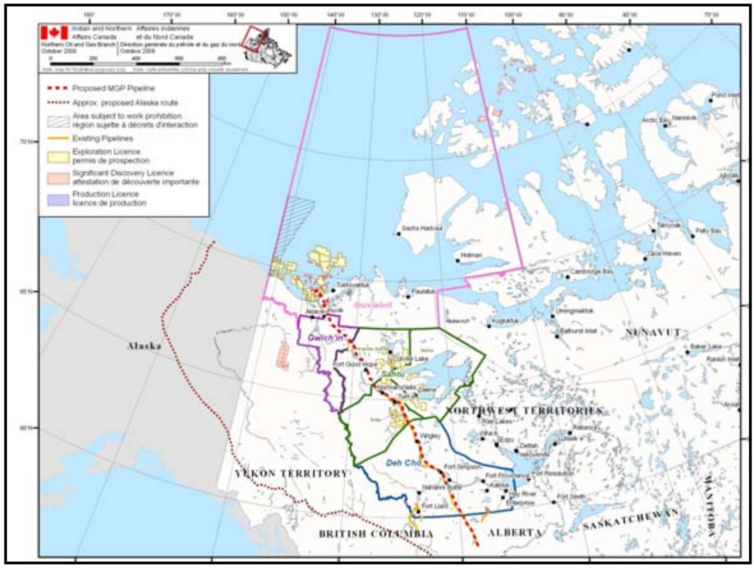
Purpose
▪ Highlight the current oil and gas activity in the Beaufort Sea and Mackenzie Delta
▪ Federal Northern Oil and Gas Science Research Initiative
▪ Environmental Studies Research Funds
▪ Program on Energy Research and Development
Affaires indiennes et du Nord Canada
Indian and Northern Affairs Canada
Canada



PETROLEUM RESOURCES NORTH OF 60°
Hydrocarbon Potential
High
Medium
Low
Beaufort Sea – Mackenzie Delta
55 trillion cubic feet gas/
5 billion barrels oil*
Large potential under active exploration for both oil and gas: $1.8 billion investment in offshore exploration committed in last 2 years
Large discovered resource: 6 tcf proposed for development onshore by Mackenzie Gas Project. Additional resources in 50 plus discovered fields in the basin.
Arctic Islands
80 trillion cubic feet gas/
2.3 billion barrels oil*
Large potential/no current exploration
Major discovered gas fields
Past oil production and shipment
Mackenzie Valley
10 tcf/500 million barrels*
Under active exploration for oil and gas
Discovered gas resource in Colville Hills
Production from Norman Wells
Eagle Plain Basin
Central Mackenzie Valley
Yukon
Quebec
Western Canada Sedimentary Basin
*Estimates of ultimate potential have been rounded and vary between assessors depending on assumptions



BEAUFORT SEA
MER DE BEAUFORT
ALASKA
YUKON
N.W.T./
T.N.O.
Ivvavik National Park



Federal Northern Oil and Gas Science Research Initiative

- Started in 2001
- **Drivers:**
  - Mackenzie Gas Project Proposal
  - Oil and gas exploration and development
- **Need for science**:
  - Enables federal, territorial government, northern boards and agencies to respond to the environmental assessment and regulatory processes
  - Informed decisions, effective mitigation measures , essential baseline information and basis for long-term monitoring

Northern Oil and Gas Science Research Initiative

- 2002-2009 $70 million in research funds
- Identified Biophysical Information Gaps
- Funded research projects in:
- Environment Canada,
- Fisheries and Oceans Canada,
- Indian and Northern Affairs Canada
- Natural Resources Canada
- Leveraged other programs, linkages with Academia and potential linkages with U.S. efforts

Federal Northern Oil and Gas Science Research Initiative

Environment Canada

- **Kendall Island Bird Sanctuary -** baseline info on migratory birds, habitat and impacts monitoring
- **Shorebird Surveys** in Mackenzie Delta
- **Forest Birds and Waterfowl Surveys**
- **Marine Bird Program**
- **Northern Water Quality Monitoring**

Environment Canada Research Continued

- **Hydrology Program**
  - Extreme events/ice jams, assess climatic data, flow rates, lake drainage, hydrological & atmospheric modeling, channel migration, sedimentation in outer delta, flooding of habitat etc.
- **Water Flow Monitoring Program**
  - hydrometric stations to monitor water levels and flow
- **Polar Bear Surveys**

Fisheries and Oceans

- Mackenzie Gas Project Rivers and Lakes Studies
- Sensitive Fish Species Study
- Water Drawdown Study
- Seismic Survey Study
- Fish Habitat Modeling
- Sediment Studies

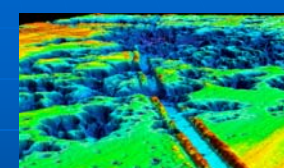
Fisheries and Oceans Research

- **Beluga Monitoring**
- **Ringed and Bearded Seals Study**
- **Update Navigational Charts**

Fisheries & Oceans and Natural Resources Canada

- **Northern Coastal Marine Program aboard the Nahidik**
  - seabed mapping, data on ice scours, artificial islands, seabed disturbance, navigation hazards, physical and biological sampling to understand ecosystems and unique habitats

Natural Resources Canada Research



- Beaufort Sea Geoscience
- Permafrost Monitoring
- Surficial Mapping
- Seismic Hazards Assessment and Earthquake potential
- Telluric Current Hazard Evaluation
- Geotechnical Evaluation of Slope Failures and Movement Mechanisms
- Regional Terrain Hazards Evaluation and Landslide Mapping
- Geospatial Database Coverage
- Materials Reliability
- Coastal and Near Shore Conditions
- Geoscience studies and Petroleum Potential

Indian and Northern Affairs Canada

- Pipeline Stream Crossings Study
- Terrain and Permafrost Conditions in the Mackenzie Delta
- Aerial Photography of the Mackenzie Valley and the Delta and Development of a Digital Elevation Model for the Delta
- Cumulative Effects Assessment and Database
- Regional Geoscience and Petroleum Potential-Peel Plateau and Plain
- Protected Areas Strategy – non renewable resource assessments
- Community and Regional Science Projects
- Science Coordination

International Cooperation

- Arctic Council
  - Arctic Monitoring and Assessment Program- Oil and Gas Assessment
  - Protection of the Marine Environment- Shipping Assessment, Offshore Oil and Gas Guidelines
  - Emergency Prevention, Preparedness and Response
  - Conservation of Arctic Flora and Fauna
  - Sustainable Development
- International Polar Year
- High Arctic Research Station
- ArcticNet

Environmental Studies Research Funds

To finance environmental and social studies pertaining to the manner in which, and the terms and conditions under which, exploration, development and production activities on frontier lands . . . should be conducted."

Canada Petroleum Resources Act, s. 76 (2)

- Funded by levies on frontier land oil & gas licenses
- Focus on environmental & social impacts of oil & gas exploration & development on Canada's Frontier Lands
- Science funding to support policy, regulation and technology
- Directed by a multi-stakeholder Management Board- chaired by the National Energy Board

Current ESRF Northern Research Projects

- Biophysical Research Requirements for Beaufort Sea Hydrocarbon Development
- Study of seismic effects on fish in shallow water
- Assessment of Impacts and Recovery of Seismic Lines
- Assessment of Drilling Waste Disposal Options in Inuvialuit Settlement Region
- Bosworth Creek Monitoring study
- Cumulative effects: Valued components and thresholds for oil and gas –implementation strategy
- Considerations in Developing Best Practices

ESRF Northern Research Priority Areas for 2009

- Oil and gas effects on Northerners' use of land and water
- Cumulative effects assessment
- Seismic issues
  - a) onshore, habitat effects
  - b) offshore, whales
- Topics from Beaufort Sea research gaps analysis
- Oil spill fate and effects, cleanup and monitoring – Beaufort Sea and Mackenzie Delta

New 2009 Projects

- Oil Spill –literature review
- Tuktoyatuk Harbour Study
- Whale survey detection technique
- Workshop on Sound effects on Whales
- Water Quality Monitoring Bosworth Creek

ESRF website: http://www.esrfunds.org/

Looking Ahead

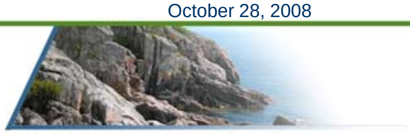
- Oil and gas research is essential and needs to adapt to emerging development scenarios
- Do not reinvent the wheel, build on past research results and learn from international projects
- Collaboration and partnerships are necessary- Community, National and International levels
- Communication of scientific results is fundamental for decision-making
- Information management and data sharing continue to be challenges; new decision support tools for rights issuance, incorporate Traditional knowledge

5.1.3 R & D Programs at the Office of Energy R & D, Natural Resources Canada,

Natalie Shea

Overview of Northern Oil and Gas R&D Programs at the Office of Energy R&D

Natalie Shea
Natural Resources Canada
October 28, 2008



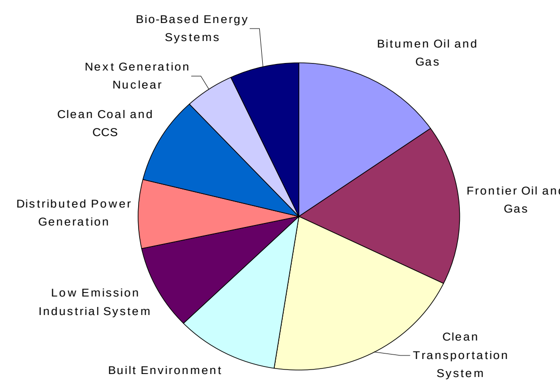
Outline

- Program of Energy R&D
- Northern Related Programs
- US/Canada Linkages

The Program of Energy Research and Development (PERD)

- Horizontal R&D program that supports Energy R&D across 13 Federal Science-Based Departments and Agencies.
- PERD's portfolio of activities responds to the three pillars of Sustainable Development: Economic growth, Environmental protection, and Secure (and reliable) supplies.
- Annual budget of approx. $56 million

Energy R&D Funding – PERD 08-09



Frontier Oil and Gas

Objectives:

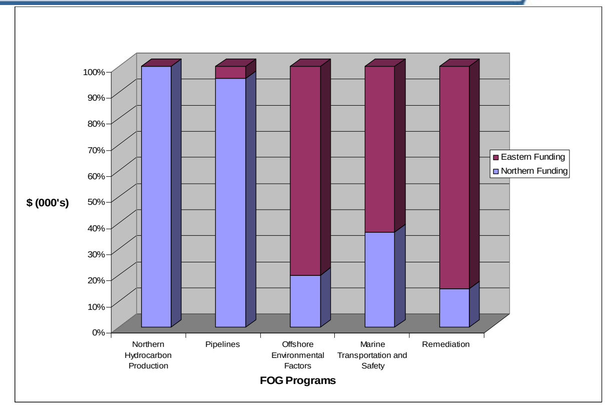
To develop new knowledge and advance technologies in aid of regulatory development, codes and standards and public good to ensure safety and security of energy supply in Canada.

Program Areas:

- Northern regulatory
- Marine transportation
- Offshore environment
- Pipeline
- Remediation

Focus: East Coast and Northern Region (excluding the West Coast)

Percentage PERD Investment in Frontier Research- $8M



Northern-Related Programs

Northern Regulatory: R&D to support regulatory processes & to minimize environmental and safety risks for northern oil and gas development (Includes: Biophysical Environment, Environmental Impacts, and Ice Engineering and Design)

Pipelines: To supply high-priority, federally relevant S&T information on the regulation and maintenance of aging pipelines and the regulation and construction of new pipelines to help federal decision-makers fulfill their regulatory responsibilities and to reduce environmental impacts.

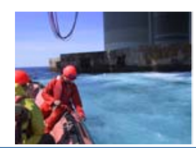
Annual PERD Northern Open Forum (end of February in Calgary, Alberta)

Northern-Related Programs

Marine Transportation and Safety: Carry out R&D in aid of regulatory requirements for the safe and efficient transportation of oil and gas by tankers, and personnel safety standards in offshore operations.

Offshore Environmental Factors: To determine offshore environmental factors for regulatory, design, safety, and economic purposes

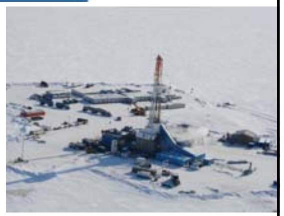
Remediation: Regulatory requirements for drilling and production wastes, assessment of cumulative effects, and remediation of accidental discharges and spills.



Northern-Related Programs

Proposed New PERD Gas Hydrates Program

- **Assessment of resource characteristics**
- **Understanding production requirements**
- **Safety and environmental issues associated with production**
- **National network of gas hydrate researchers and stakeholders**



US/Canada Linkages

- Growing interest in creating cross-border research collaborations with the US
- Collaboration between Canada and the US can play a key role in more efficiently identifying and overcoming the major R&D obstacles to be faced in the North.
- Researchers have created important linkages over the years with the US (government and universities).
- Continued joint workshops will help strengthen these linkages and collaborative efforts.

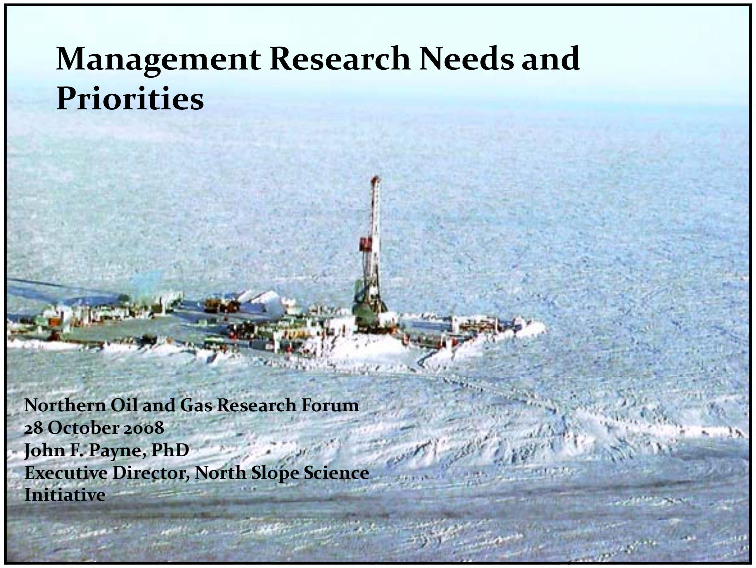
Contact Information

Natalie Shea
NShea@NRCan.gc.ca
(613) 944-5130

OERD Website: http://www2.nrcan.gc.ca/es/oerd/

5.1.4 Management Research Needs and Priorities, Northern Slope Science Initiatives,

John Payne



Management Research Needs and Priorities

Northern Oil and Gas Research Forum
28 October 2008
John F. Payne, PhD
Executive Director, North Slope Science Initiative

Presentation Content

- Review of Previous and Current Research
- Need for Coordination of Research Activities
- A "One Stop Shop" Approach to Information Sharing
- Defining Information Needs
- International Coordination and Cooperation
- Measuring Success

What's Going On in Alaska's Arctic?

2007- some 565 individual projects
Duplication may reduce down to 400

2007 – Estimated all projects total between $30 - $40 million investment

2007-2009 – Addition of IPY, generating much information that may be applicable to oil and gas operations in the Arctic

Each agency or academic program has their core missions or directions

Some information needs are "site specific," others are broad area such as regional or landscape

The Information Needs
Broad Categories

- Permafrost
- Costal/Riverine Erosion
- Sea Ice Degradation and Oceanographic Condition
- Hydrology
- Arctic Contaminants
- Socio-Economic Change
- Species of Interest
- Increasing Marine Activity
- Meteorological
- Salt Water Intrusion
- Vegetation Change
- Changing Fire Regime

Examples of More Specific Needs Permafrost

- How and where is permafrost being measured?
- Are current measurement techniques sufficiently precise?
- How do we deal with potential infrastructure instability?
- Limited understanding of distribution of permafrost
- Thermal models useful, but, baseline monitoring is critical
- Information needs to be "centralized"

Species of Interest Caribou

- Can we differentiate impacts from anthropogenic activities vs natural cycles?
- What is the effect of changes in caribou numbers and distribution on subsistence harvest?
- Need better demographic data
- Better evaluation of caribou food production and habitat
- Climatological data (temperature, snow cover, persistence, icing events)

Need for Greater Communication and Dissemination of Information

A Need for Greater Collaboration

- Look at the agenda for this forum – varied studies and research
- Comparable data collection
- Speak in like language that is understood by both scientists and decision makers
- Strong application component to research

Measuring Success

- Increased networking among scientists and managers
- Insuring the collection of information that is used to help make decisions
- Be willing to “adapt” as our knowledge base increases
- Working across knowledge discipline boundaries to integrate and better understand the information we are gathering

Thank You

5.1.5 Panel on US Management Research Needs and Priorities, 11th MMS ITM/ U.S. Canada Oil and Gas Research Forum, *John Goll*, MMS Alaska Regional Director

Good morning, my name is John Goll, the Alaska Regional Director for the US Minerals Management Service here in Anchorage.

We are very pleased to have helped pull together this forum with our Canadian counterparts. It was very fortuitous timing, because we were already planning to hold what we call our Information Transfer Meeting – a gathering we hold every other year in which we bring researchers we fund to give us an update on their results.

We have been able to meld the Forum and our ITM, and have a number of our Beaufort Sea researchers presenting at this meeting, and others next door at our ITM. I will go into that more in a few minutes.

For our Canadian counterparts, a few words on who we are and our Program. MMS is an agency of the US government that manages the US outer continental shelf – the area from 3 miles out to 200 miles (5 km out to over 320 km) or so in the ocean. In Alaska that translates into 1 billion acres (or 405 million hectares) of seabed.

Within our staff we have geologists, geophysicists, marine biologists, oceanographers, meteorologists, archaeologists, economists, social scientists, other environmental scientists, petroleum, civil, mechanical engineers, and many others.

We estimate the amount of oil and gas that may be present offshore, we go through an evaluation process to lease areas to companies for oil and gas, we review, monitor, and inspect industry plans to explore, develop, and produce from these waters, and we perform our own environmental impact analyses. Our agency also collects the royalties and fees we charge companies for the opportunity to explore and hopefully one day produce.

In addition to oil and gas, we also manage other mineral development, such as gold, or sand and gravel, and now have new responsibilities for alternative energy offshore, such as wind, waves, currents, and solar. So our program goes through all phases of searching for resources, through production.

Currently we have about 4.1 million acres (1.66 million hectares) leased in the BF and Chukchi Seas.

After nearly 30 years of leasing in the federal waters of the Beaufort Sea, presently our only production is from Northstar west of Prudhoe Bay, which production we share with the State of Alaska. The State has offshore production from the Endicott Island, and a few coastal sites. Early this year, we approved the development plan for the Liberty Prospect that will be developed by ultra extended reach drilling from the existing Endicott site east of Prudhoe Bay. Only 30 wells have been drilled in the federal offshore in the Beaufort Sea, so for a petroleum province, the area is minimally explored.

Another facet of our agency is our robust research programs – our Technical Assessment and Research Program – which includes engineering and oil spill response studies -- and our Environmental Studies Program. Over the next few days you will see presentations from both within this forum, including a number performed by Canadian researchers. As I mentioned, we are holding our ITM for our Environmental Studies Program in conjunction with this forum. Let me make some remarks about that, as it will give you an overview of the issues we are considering.

MMS directs environmental studies to understand:

What are the expected changes in the human, marine, and coastal environment from offshore industrial activity?

We use the information to evaluate the effects industry activities might have, and through that process, to develop mitigation – by using our existing rules, rules of other agencies, such as EPA, or FWS, or NMFS, and for use in Endangered Species consultations. Industry uses our data, but also collects information to support their permit requests.

Currently the Alaska Region has focus on upcoming developments, proposed lease sales, and exploration activities in the Beaufort, Chukchi, and Bering Seas, which our ITM will cover.

The ESP is guided by three broad research themes

- Monitoring marine environments
- Fate and effects research, which includes physical oceanography, meteorology, and sea ice, and discharges into the water and oil spills; and
- Social and economic impacts

I will walk you through our programmatic agenda as we share study results over the next 3 days:

I. Monitoring Marine Environments

One of the most significant issues we face is protection of endangered species, especially the bowhead whale in arctic waters and the North Pacific Right Whale in the Bering; MMS dedicates many resources to conduct aerial surveys of marine mammals to monitor changes in distribution and relative abundance over long-term horizons; [first three talks in our ITM share results of these studies]

Data from these studies help us and NMFS to review, monitor, and coordinate industrial activities to protect the whales, and other marine mammals, and related Alaska native subsistence hunts under the MMPA and ESA.

We obtain information on many protected species, so we also feature interim study results on walrus, seals, polar bears, birds, and fish. {a number of our researchers will make presentations on polar bears and whales tomorrow afternoon here at the Forum.]

Day 3 offers a review of 7 years of research monitoring (ANIMIDA) around the Northstar and Liberty areas in the Beaufort Sea.

II. Fate and Effects Research

Potential discharges into the water are another topic we study – be it routine discharges or oil spills. Of course, our regulatory strategy is focused first on prevention of a spill through strong regulations, engineering research, use of redundant prevention systems, training, and inspection of industry activities; and our offshore record has been extremely good.

But MMS also devotes many resources to research oceanographic conditions to facilitate our ability to understand, predict, and manage for discharges and spills

[day 2 offers recent results from this group of studies, and carries over to day 3 when two complementary approaches to oil spill occurrence estimators will be presented; plus studies on Detection of Oil on and Under Ice and on dispersants.

III. Understanding Social and Economic Impacts

A third area of study is the relationship between offshore activities and the human dimension and the need to address changes on coastal communities. MMS studies changes in demography, subsistence hunting activities, including harvest and community distribution, and economic benefits and detriments (such as wealth stratification) of oil and gas development

[Three presentations of current MMS social research projects will occur as FORUM speakers on the mornings of day 2 and day 3]

Closing: We hope you enjoy the 32 MMS presentations that are on the agendas for the Forum and our ITM. All information is available on our website for past and current research.

See:

http://www.mms.gov/alaska/ess/itm/ITMINDEX.htm

http://www.mms.gov/tarprojectcategories/arcticoilspillresponseresearch.htm

http://www.mms.gov/tarprojectcategories/ice.htm

http://www.mms.gov/alaska/fo/osrrRpt.htm

5.1.6 Northern Oil and Gas Management Research Needs and Priorities, National Energy Board, *Robert Steedman*

Northern Oil & Gas Management Research Needs and Priorities

Robert Steedman
National Energy Board, Calgary, Alberta, Canada

Northern Oil & Gas Research Forum
Anchorage Alaska, 28-30 October, 2008

Beaufort Sea Research Priorities

1. Regulator's perspective
   - Thanks to Dr. Bharat Dixit, COGOA CCO
2. Science funder's perspective
   - Thanks to KAVIK-AXYS Inc.

A Regulator's Perspective on Beaufort Sea Research Priorities

1. Spill cleanup readiness
2. Facility evacuation in mixed ice
3. Same season relief well capability
4. *Offshore Waste Treatment Guidelines*
5. Drilling on the shelf slope

Spill cleanup readiness

Gaps related to:

- suite of tools for containment & clean-up
- scope (e.g. self-sufficient for season)
- open water: booms?
- mixed ice: burning?
- disposal / storage of recovered oily waste

Facility evacuation in mixed ice

- from ships
- from platforms
- getting survival craft to safety in 3/10 – 9/10 ice, fog

Same-season relief well capability

- update on benefits, alternatives & risks

Offshore Waste Treatment Guidelines

- collaborative, multi-agency updating & revision process underway
- Canada-Newfoundland & Labrador Offshore Petroleum Board leading

Drilling on the Shelf slope

- geotechnical risks associated with unstable sediments
- appropriate baseline information
- gas hydrates as a stability factor

A Science Perspective on Beaufort Sea Research Priorities

- “Data Gaps” study commissioned by Environmental Studies Research Funds (ESRF) Management Board
- Contract to KAVIK-AXYS Inc., Inuvik, in association with FMA Heritage Resources Consultants Inc.

A Science Perspective on Beaufort Sea Research Priorities

1. Marine life
   - plankton, benthos, macrophytes
   - fish, mammals, birds
2. Archaeology & palaeontology
3. Traditional land use
4. Accidents and malfunctions

Overview of Project

- “*Biophysical Research Requirements (Data Gaps) for Beaufort Sea Hydrocarbon Development*”
- Support regulatory review & mitigation of offshore exploration & development
- Support environmental assessments

Plankton, Benthos, Macrophytes and Marine and Anadromous Fish

- Baseline surveys of deepwater plankton, benthos & fish
- Identification of key areas for macroalgae (e.g., kelp) and macro-invertebrates (e.g., crabs, squid)
- Fish habitat use (overwintering, spawning, migration) in major habitat types
  - brackish/Mackenzie plume, inshore pelagic, inshore benthic, offshore pelagic, offshore benthic

National Energy Board / Office national de l'énergie

Marine Mammals

- Prediction of bowhead whale feeding concentration areas (oceanographic conditions & copepod blooms)
- Detecting bowhead and beluga whales in low visibility (night, fog, high seas) during offshore seismic surveys
- Effects of multiple offshore seismic programs on marine mammals and fish

Canada

National Energy Board / Office national de l'énergie

Marine Mammals cont'd

- Philopatry of ringed seals (i.e., annual re-use of the same area by the same seals each year)
- Vibroseis effects on polar bear denning
  - response of denning bears to equipment and human disturbances
  - underwater/under ice sound propagation of noise
- Effects of climate change on polar bear distributions and potential for increased bear-human conflicts

Canada

National Energy Board / Office national de l'énergie

Marine and Nearshore Avifauna

- Update on offshore bird distributions
- Focus on specific groups such as eiders, loons, etc.

Canada

National Energy Board / Office national de l'énergie

Archaeology and Palaeontology

- Assessment of coastal archaeological and palaeontological resources
- Areas of high risk due to slumping and erosion, potential industrial activities.
  - support development of an archaeological atlas
  - identification of shipwreck sites
    - use historical literature on shipwrecks to identify potential sites.
    - need guidelines on identification of artifacts

Canada

Traditional Land Use

- Identify important remote coastal camps & harvesting sites
- Update harvest studies & share with industry

Canada

Accidents and Malfunctions

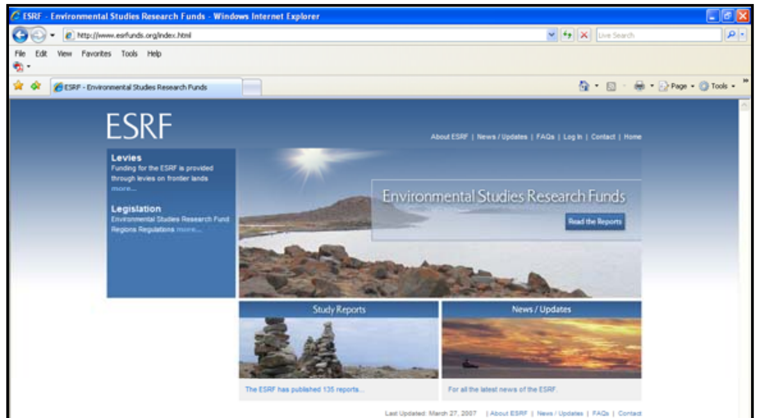
- Dispersion modeling
  - update & verify Beaufort oil spill dispersion models
  - update oceanographic data to support models
  - update methods to contain and collect spilled hydrocarbons in Arctic conditions

Canada

Accidents and Malfunctions cont'd.

- Update Oil Spill Sensitivity Atlas
  - current biophysical & cultural conditions
  - current infrastructure & response measures
- Fate and effect of released hydrocarbons
  - emphasize contaminant cycling
  - ice & open-water situations
  - behaviour of oil under ice

Canada



ESRF website: http://www.esrfunds.org/

- feedback always welcome!

5.1.7 Western Arctic Management Research Needs and Priorities, Joint Secretariat – Inuvialuit Settlement Region, *Norm Snow*

Western Arctic Management Research Needs and Priorities

An Inuvialuit Perspective

Norman B. Snow
Joint Secretariat – Inuvialuit Settlement Region
Inuvik, Northwest Territories Canada

US and Canada
Northern Oil and Gas Research Forum
Anchorage, Alaska 28-30 October, 2008

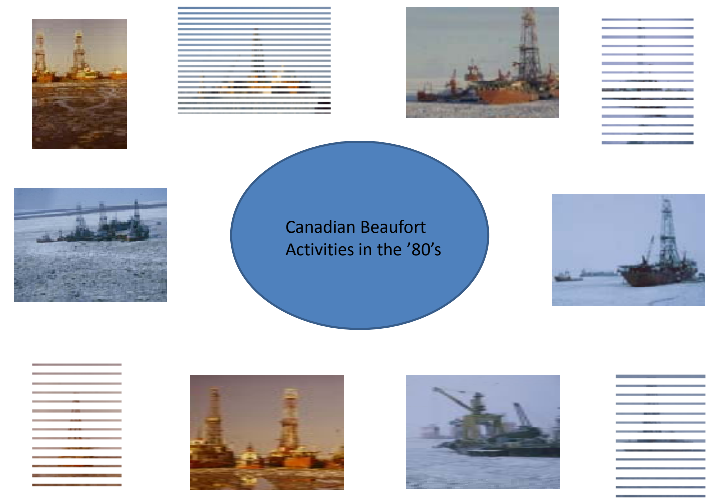
The Inuvialuit Final Agreement (I.F.A.)

- First negotiated Comprehensive Land Claim wholly within the Arctic.
- Signed in 1984.
- Has enabled land ownership and harvesting rights on Crown lands within the Settlement Region.
- Has enabled the development of an integrated wildlife and habitat co-management system.

Two Principles of the IFA are:

- To enable Inuvialuit to be equal and meaningful participants in the Northern and national economy and society.
- To protect and preserve the Arctic wildlife, environment and biological productivity.

These encompass the involvement of the Inuvialuit in the development and implementation of Wildlife and Environment Research



Recent Programs Directly or Indirectly Involving and Relevant to the Inuvialuit

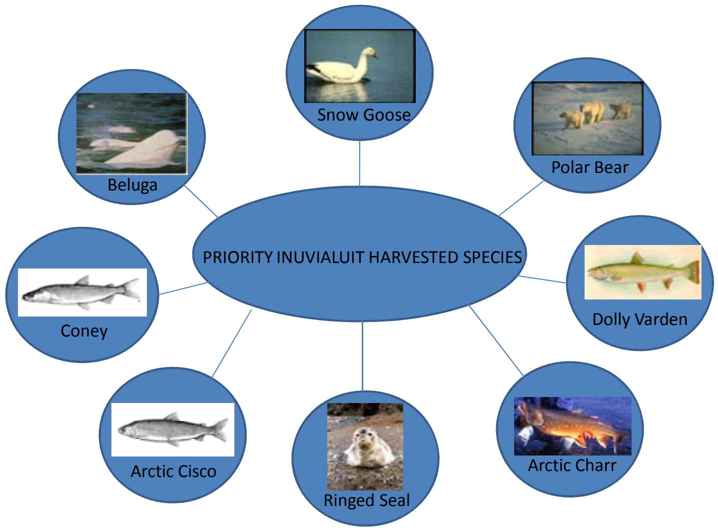
Research

- CASES
- Arctic Net
- IPY-CFL Project
- "NAHIDIK" Cruises

EA and Regulatory Management

- BSStRPA
- BREA

Since 1986 most of the species-specific research has been directed towards those species which are harvested for subsistence purposes by the Inuvialuit.



The FJMC has initiated, coordinated, or conducted research on fish and marine mammals within the Settlement Region as well as some ecosystem and fisheries studies.

These include:

- Condition, distribution, abundance and biology of Ringed Seals, Beluga and Bowhead Whales, Arctic Charr, Dolly Varden, Lake Trout and Coregonids.
- Contaminants (esp. Hg) in animals and their habitats.
- Harvest studies
- Food-web studies
- Acoustic monitoring
- Beluga entrapments
- Seal and Beluga parasites.

Inuvialuit Priorities Emerging from BSStRPA

- The need to improve EA and Regulatory processes and to harmonise adjacent or overlapping process.
- The need for a regional waste-management strategy.
- The need for clarity and consistency in the implementation of the “Same Season Relief Well” policy.
- The regulation of fuel-use from unattended overwintered barges in the Mackenzie Delta and Beaufort Sea.
- Optimising benefits and mitigating Environmental Social and Cultural impacts.

Inuvialuit Priorities Emerging from BSStRPA Continued

- More towards a zero-discharge of harmful substances policy target.
- Make better efforts to incorporate TK into project design and decision making.
- Develop a research plan for future Oil and Gas activities.
- Improve collaboration and coordination to allow for an ecosystem-based approach to management activities.
- Need to strengthen and maintain the existing research infrastructure in the Settlement Region, and to develop new facilities as required.

  This would include education as well as training in biological and Socio economic disciplines.
  - Oil spill response preparedness.

Overall there is a need to :

- Include Climate-Change considerations in all research, management and operational procedures, to the extent possible.
- Develop an integrated data-management system or modify existing ones.
- Consider the effects of increased shipping as a result of climate change in CEA of Oil and Gas activities, to the extent possible.

Since the Oil and Gas Industry moved into the Region in the ‘60s, the primary environmental concern of the Inuvialuit has been the effect of a major oil-spill in the Beaufort Sea, contaminating the shoreline. This is still the primary concern today. It is felt that there is a priority need to:

- Review and refine existing oil spill trajectory models.
- Review and assess the usefulness of historical and extant oceanographic and meteorological input parameters to such models – including the current and projected ice-regime.
- Acquire new air-sea-ice data as required.
- Continue Research and Development for mechanical counter measurements and *in situ* procedures – especially with respect to oil in broken ice.


I thought he would never end.

5.1.8 University-led Arctic Research Programs in Canada, ArcticNet,

Martin Fortier

ArcticNet
ᐅᑭᐅᖅᑕᖅᑐᒥᒃ ᑐᑭᓯᓂᐊᖅᑲᑎᒌᑦ

University-led Arctic Research Programs in Canada

Dr. Martin Fortier
Executive Director, ArcticNet

United States and Canada Northern Oil and Gas Research Forum '08
Anchorage, Alaska
October 2008

Canada | Université Laval

ArcticNet
ᐅᑭᐅᖅᑕᖅᑐᒥᒃ ᑐᑭᓯᓂᐊᖅᑲᑎᒌᑦ

- Short history
- ArcticNet
  - Structure
  - Research program
  - Focus on research with relevance to Oil & Gas
- IPY

Since 2002, our University-led Arctic Research Consortium has received investments of over 120 million dollars by the Government of Canada, in of support Canadian-led, international efforts to study the changing Canadian Arctic

1. Canadian Research icebreaker *Amundsen* (CFI-DFO/CG): 30 million (2003-)
2. Canadian Arctic Shelf Exchange Study (NSERC): 10.6 million (2002-2007)
3. ArcticNet (NCE): 25.7 million for 7 years (2004-2011), potential for 14 years (2004-2018)
4. Scientific Equipment for *Amundsen* (CFI, Gvt of Quebec, Gvt of Manitoba): 10.9 million (2006-)
5. International Polar Year (30-50 million): (2007-2009)

CCGS AMUNDSEN
CANADIAN RESEARCH ICEBREAKER
www.amundsen.quebec-ocean.ulaval.ca

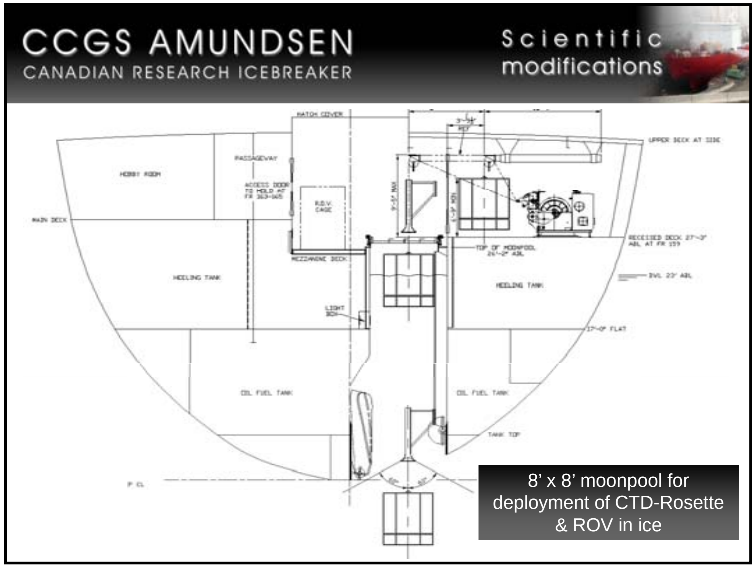
The CCGS *Amundsen*: a Canadian research icebreaker for international collaboration in the study of the changing Arctic

Canada Foundation for Innovation / Fondation canadienne pour l'innovation | Pêches et Océans Canada / Fisheries and Oceans Canada | Garde côtière / Coast Guard | Université Laval | Canada

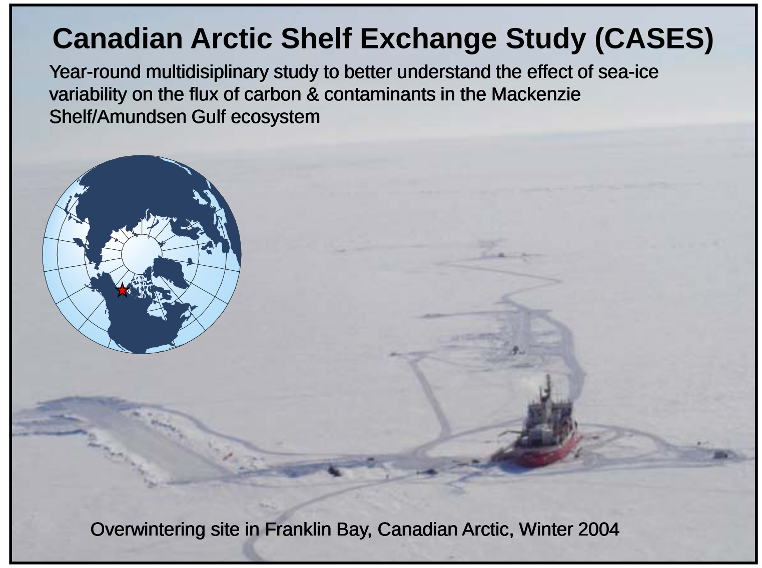

8 Ton Deck cranes
733 Zodiac
Lab containers
MVP300
60hp Winch
AFT labs
CTD-Rosette deployment
area, A-frame, 40 hp winch
CCGS AMUNDSEN
CANADIAN RESEARCH ICEBREAKER
10 ton A-frame &
500hp winch
Barge
Helodeck
Halftrack
Moonpool, acoustic well &
EM300 sounder
Paleo/benthos labs

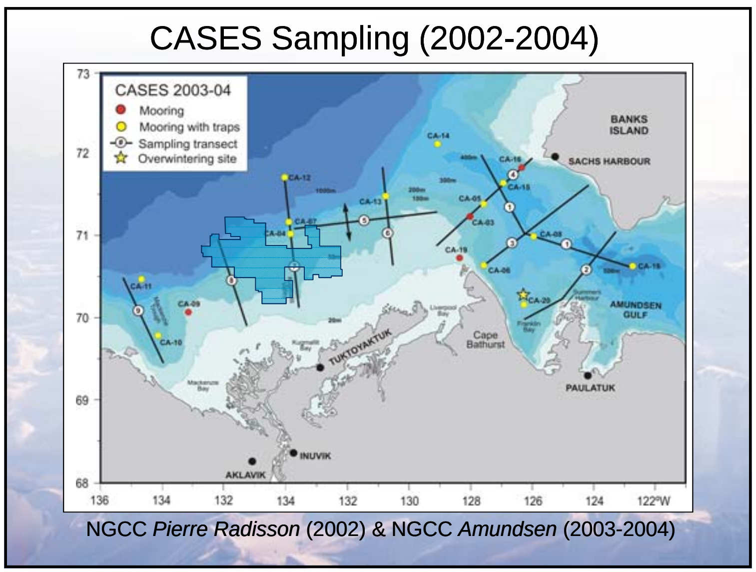

CCGS AMUNDSEN
CANADIAN RESEARCH ICEBREAKER
Scientific
modifications
12 Interior laboratories (cold rooms)


CCGS AMUNDSEN
CANADIAN RESEARCH ICEBREAKER
Scientific
modifications
8' x 8' moonpool for
deployment of CTD-Rosette
& ROV in ice


CCGS AMUNDSEN
CANADIAN RESEARCH ICEBREAKER
Scientific
modifications
8' x 8' moonpool for
deployment of CTD-Rosette
& ROV in ice


CCGS AMUNDSEN
CANADIAN RESEARCH ICEBREAKER
Scientific modifications
8' x 8' moonpool for deployment of CTD-Rosette & ROV in ice


Canadian Arctic Shelf Exchange Study (CASES)
Year-round multidisiplinary study to better understand the effect of sea-ice variability on the flux of carbon & contaminants in the Mackenzie Shelf/Amundsen Gulf ecosystem
Overwintering site in Franklin Bay, Canadian Arctic, Winter 2004


CASES Sampling (2002-2004)
CASES 2003-04
Mooring
Mooring with traps
Sampling transect
Overwintering site
BANKS ISLAND
SACHS HARBOUR
AMUNDSEN GULF
TUKTOYAKTUK
Cape Bathurst
PAULATUK
INUVIK
AKLAVIK
NGCC *Pierre Radisson* (2002) & NGCC *Amundsen* (2003-2004)


CASES 2003-2004 OVERWINTERING EXPEDITION
www.cases.quebec-ocean.ulaval.ca
• ONE-YEAR EXPEDITION
• 29 000 PERSON-DAYS AT SEA
• > 200 SCIENTISTS FROM 8 COUNTRIES
• ENORMOUS AMOUNT OF DATA
• Two dedicated Special issues of scientific journals (In press)
• Journal of Marine Systems
• Journal of Geophysical Research-Oceans
•A dedicated compendium of results book (In press)
LARGEST EXPEDITION YET EVER LAUNCHED TO STUDY THE CHANGING ARCTIC MARINE ECOSYSTEM

ArcticNet
ᐅᑭᐅᖅᑕᖅᑐᒥᒃ ᑐᑭᓯᓂᐊᖅᑏᑦ

- •TRANSFORMATION OF THE ENVIRONMENT OF INUIT
- • COAST AND PERMAFROST DEGRADATION
- •FRESHWATER AND FOOD SUPPLIES
- •SOVEREIGNTY AND SECURITY
- •ECONOMIC OPPORTUNITIES
- •EMERGING DISEASES
- •GLOBALISATION

ArcticNet
ᐅᑭᐅᖅᑕᖅᑐᒥᒃ ᑐᑭᓯᓂᐊᖅᑏᑦ

One of 18 Networks of Centres of Excellence (NCE) jointly funded by the 3 Research Councils of Canada.

Hosted at Université Laval, Quebec City

Canada

UNIVERSITÉ LAVAL

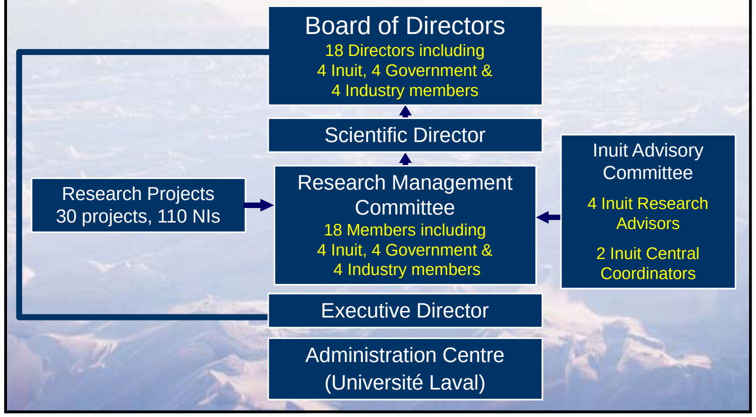
ArcticNet
ᐅᑭᐅᖅᑕᖅᑐᒥᒃ ᑐᑭᓯᓂᐊᖅᑏᑦ

General objectives of ArcticNet:

- **To build synergy among existing Centres of Excellence in the natural, human health and social arctic sciences.**
- **To involve Northerners, government and industry in the steering of the Network and scientific process through bilateral exchange of knowledge, training and technology.**
- To increase and update the observational basis needed to address ecosystem-level questions raised by climate change and globalization in the Arctic.
- To provide academic researchers and their national and international collaborators with stable access to the coastal Canadian Arctic.
- To consolidate national and international collaborations in the study of the Canadian Arctic.
- To contribute to the training of the next generation of experts, from north and south, needed to study, model and ensure the stewardship of the changing Canadian Arctic.
- **To help translate our growing understanding of the changing Arctic into impact assessments, national policies and adaptation strategies.**

ArcticNet
ᐅᑭᐅᖅᑕᖅᑐᒥᒃ ᑐᑭᓯᓂᐊᖅᑏᑦ

- Management involving the user sector



Board of Directors

- **Aatami, Pita** — **President, Makivik Corporation**
- Boucher, Bernie (Chair) — President , JF Boucher Consulting Ltd
- Bégin, Yves — Director, INRS-Eau, Terre et Environnement
- **Bishop, Glen S.** — **Vice-President, Canadian Arctic, ConocoPhillips Canada**
- Bourget, Edwin — Vice-President Research, Université Laval
- Corell, Robert — Director, Global Change Program, The H. John Heinz III Center fo Science, Economics and the Environment
- Corey, Mark — ADM, Earth Sciences Sector, NRCan
- **Eetoolook, James** — **1st Vice-president, Nunavut Tunngavik Incorporated**
- Fortier, Louis — Scientific Director, ArcticNet, Université Laval
- Fortier, Martin — Executive Director, ArcticNet, Université Laval
- Gray, Brian — ADM, Environment Canada, Science and Technology
- Keselman, Joanne C. — Vice-President Research, University of Manitoba
- **Loberg, Carmen** — **President and CEO, NorTerra Inc.**
- **Thomas, David** — **President, The AXYS group Ltd.**
- Watson-Wright, Wendy — ADM, Science, Fisheries and Oceans Canada
- **Simon, Mary (Co-chair)** — **President, Inuit Tapiriit Kanatami**
- **Smith, Duane** — **President, Inuit Circumpolar Council-Canada**
- **Wojczynski, Ed** — **Division Manager, Power Planning & Development, Manitoba Hydro**
- Woods, Shelagh Jane — Director General , Primary Health Care and Public Health Directorate of the First Nations and Inuit Health Branch, Health Canada

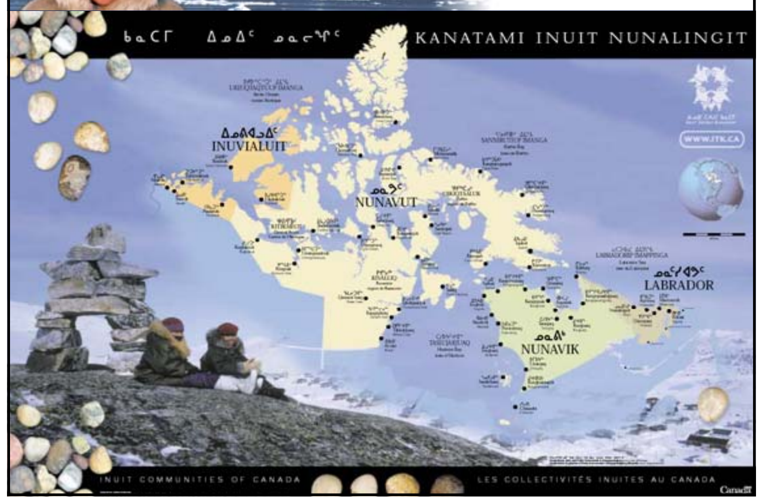
ArcticNet
ᐅᑭᐅᖅᑕᖅᑐᒥᒃ ᑐᑭᓯᓂᐊᖅᑏᑦ

ArcticNet in Numbers

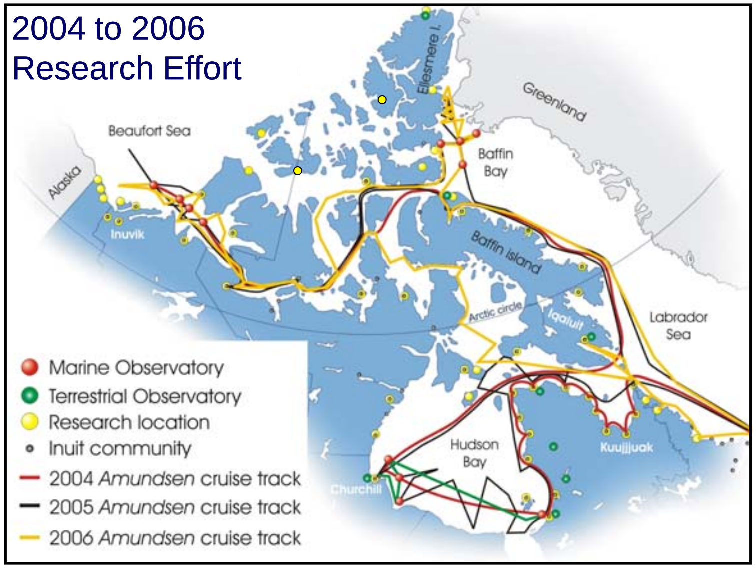
- Funded for 7 years (2004-2011). Possibility of renewal for another 7 years (2011-2018)
- $CDN 6.4 Million from NCE per year (85% research & infrastructure,10% networking, 5% administration)
- Over $CDN 11 Million cash & in-kind contributions from partners per year
- 28 research projects covering the entire Coastal Canadian Arctic from Labrador to the Yukon
- Over 110 researchers from 28 universities and 8 Federal departments in Canada.
- Over 250 graduate students and post-docs and 120 research associates and technicians
- Over 100 partner organizations from 15 countries

Research Program

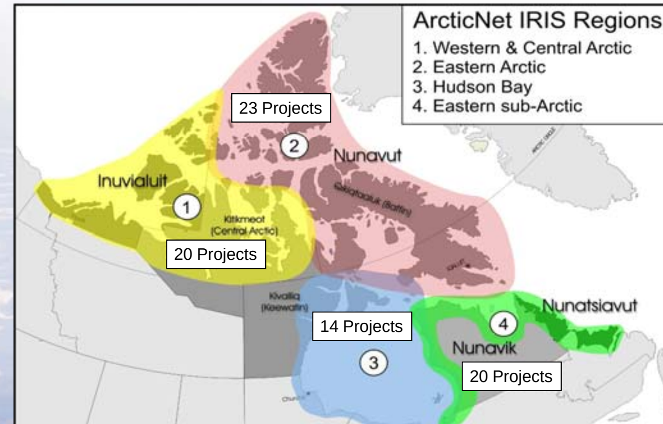
ArcticNet
ᐅᑭᐅᖅᑕᖅᑐᒥᒃ ᑐᑭᓯᓂᐊᖅᑏᑦ



2004 to 2006 Research Effort



Integrated Regional Impact Studies



The IRIS regions are defined by eco-climate, socio-cultural, political and economic considerations. The formulation of impact and adaptation assessments and recommendations will take into account political jurisdictions.

ArcticNet ᐅᑭᐅᖅᑕᖅᑐᒥᒃ ᑐᑭᓯᓇᓱᒃᑎᑦ

Phase II Research Program (2008-2011)

- 28 research projects in natural, human health and social sciences covering the entire Canadian Coastal Arctic

Building on the strengths of Phase I with a balance of renewed projects and new projects

- to provide access to the Arctic
- to train HQP with additional emphasis on Northerners
- to consolidate international collaborations
- **to further engage industry**
- to implement the Integrated Regional Impact Study framework
- **to formulate Regional Impact Assessments for the Canadian coastal Arctic**
- to present to and discuss the Regional Impact Assessments with stakeholders

ArcticNet ᐅᑭᐅᖅᑕᖅᑐᒥᒃ ᑐᑭᓯᓇᓱᒃᑎᑦ

Phase II Research Program (2008-2011)

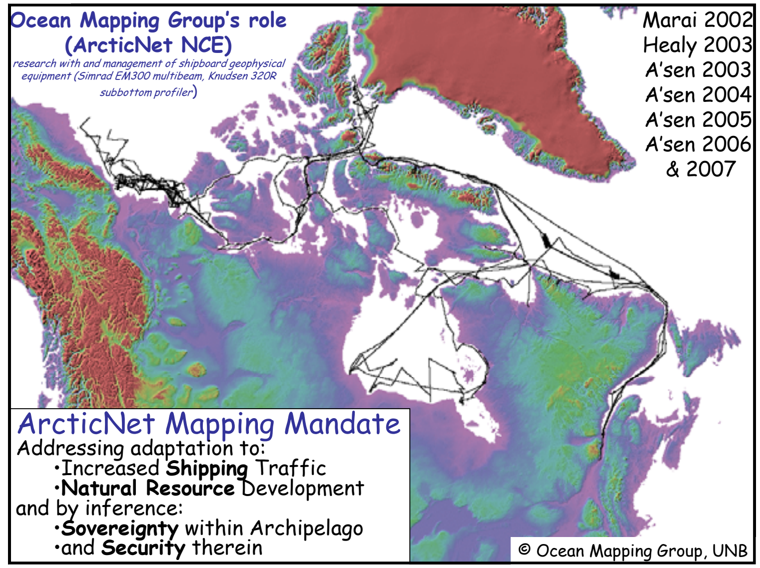
About half of funded projects have direct relevance to environmental and technical needs of Oil & Gas industry

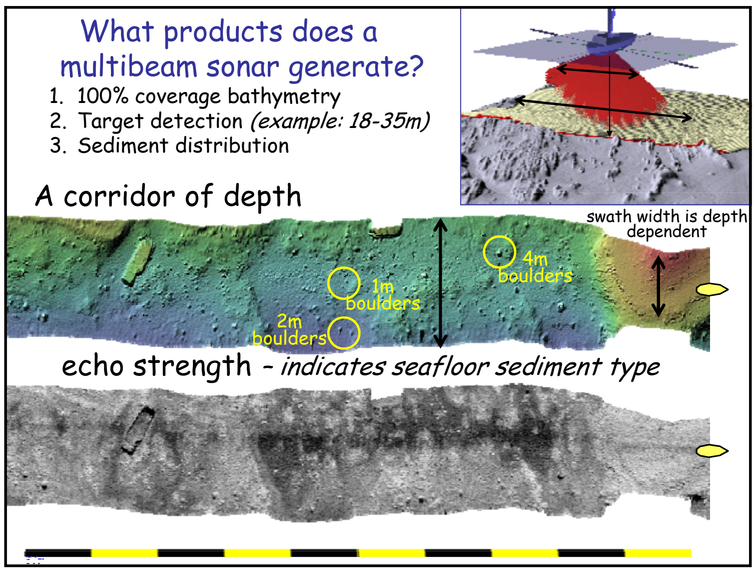
1. **Impacts of Global Warming on Arctic Marine Mammals (Ferguson)**
2. **Effects of Climate Change on Carbon and Contaminant Cycling in the Arctic Coastal and Marine Ecosystems (Stern, Macdonald & Wang)**
3. **The law and politics of Canadian jurisdiction over Arctic Ocean seabed (Byers)**
4. **Development of an Ocean Modelling Capacity for the Canadian Arctic Archipelago (Myers)**
5. **Effects of Climate Change on Carbon Exchange Dynamics in Arctic Coastal and Marine Ecosystems (Papakyriakou)**

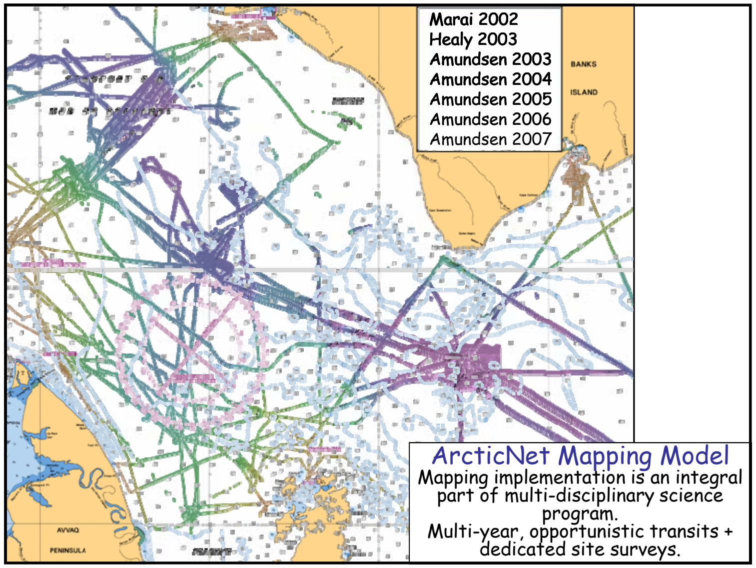
ArcticNet

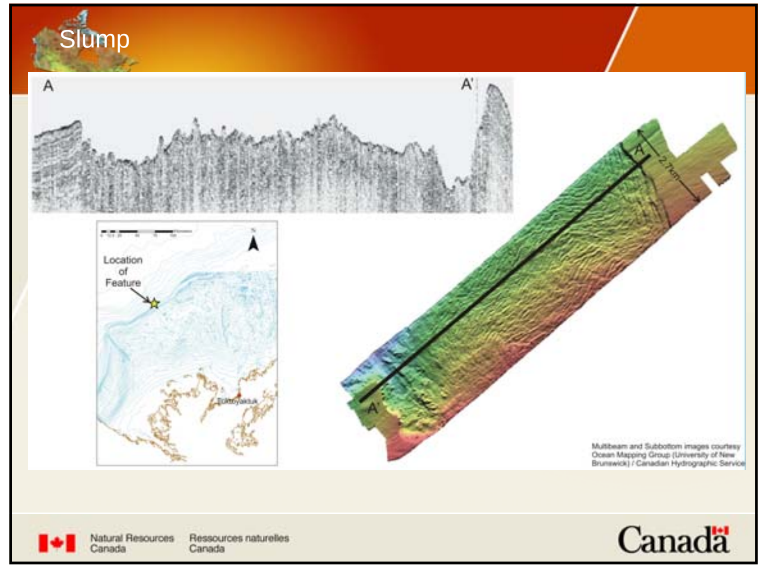
Phase II Research Program (2008-2011)

6. **Adaptation in a Changing Arctic: Ecosystem Services, Communities and Policy (Smit)**
7. **The Role of Sea Ice in ArcticNet Integrated Regional Impact Studies (Barber)**
8. **The Canadian Arctic seabed: navigation and resource mapping for community and regional impact studies (Hughes-Clarke)**
9. **Long-term observatories in Canadian Arctic waters (Gratton)**
10. **Monitoring the impact of climate change on Arctic benthos (Archambault)**
11. **Marine biological hotspots: ecosystem services and susceptibility to climate change (Tremblay)**



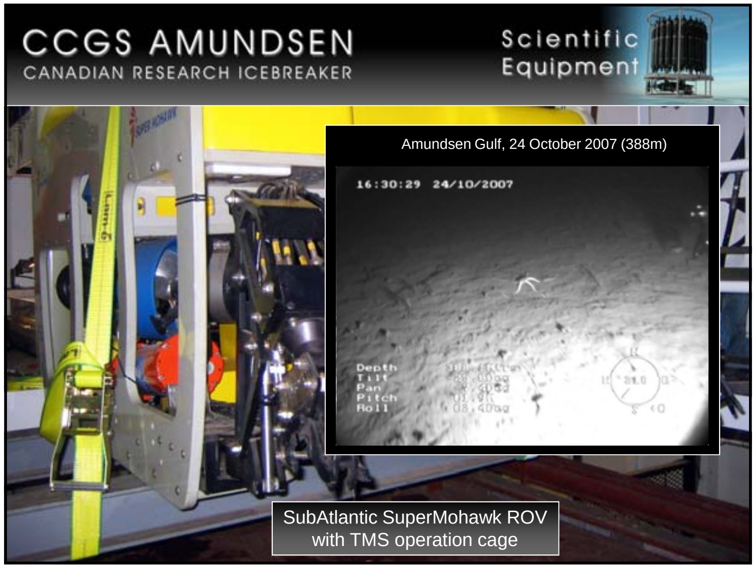


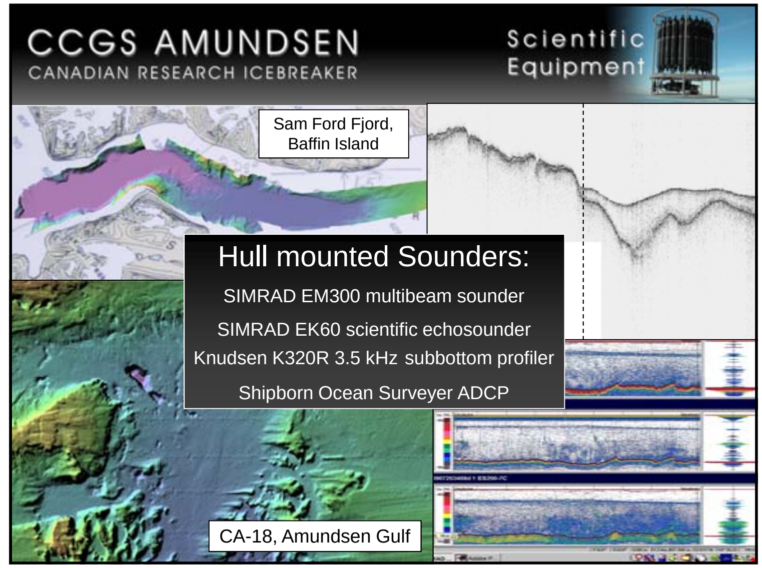

Marai 2002
Healy 2003
Amundsen 2003
Amundsen 2004
Amundsen 2005
Amundsen 2006
Amundsen 2007
BANKS
ISLAND
AVVAQ
PENINSULA
ArcticNet Mapping Model
Mapping implementation is an integral part of multi-disciplinary science program.
Multi-year, opportunistic transits + dedicated site surveys.

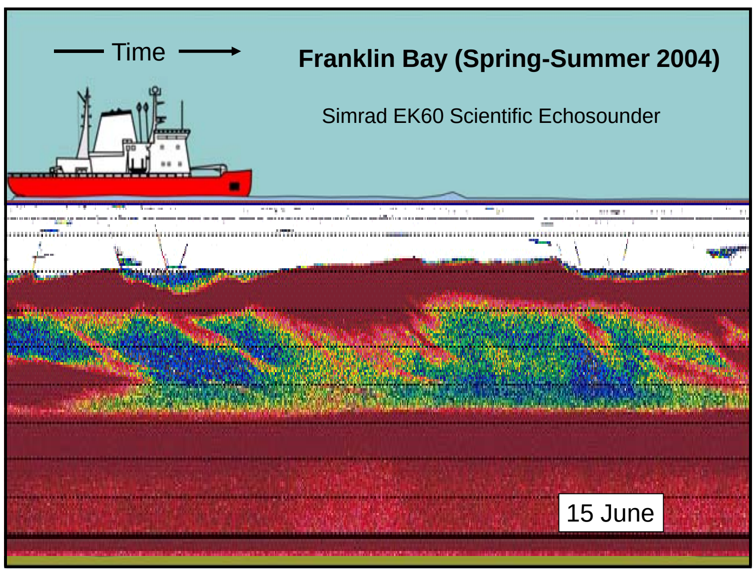

Slump
A
A'
Location of Feature
Multibeam and Subbottom images courtesy Ocean Mapping Group (University of New Brunswick) / Canadian Hydrographic Service
Natural Resources Canada
Ressources naturelles Canada
Canada

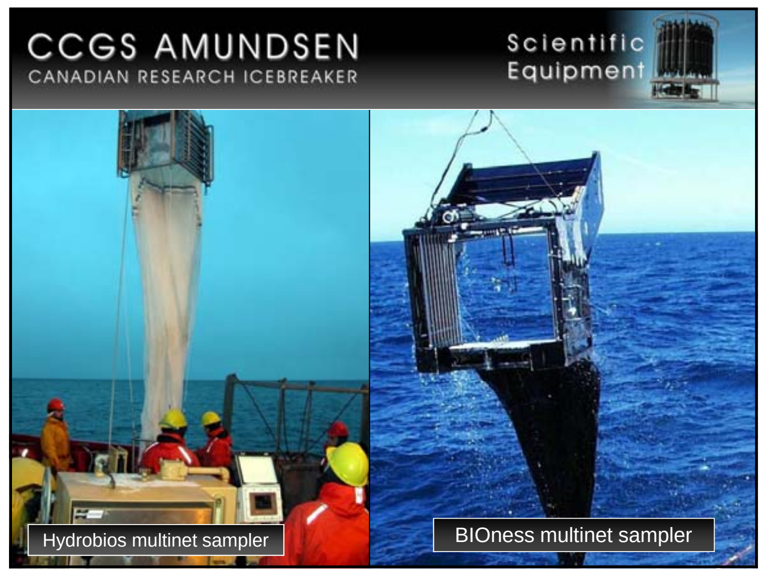

CCGS AMUNDSEN
CANADIAN RESEARCH ICEBREAKER
Scientific Equipment
Corers:
2 Boxcorers
Minicorer from moonpool
15m Piston corer

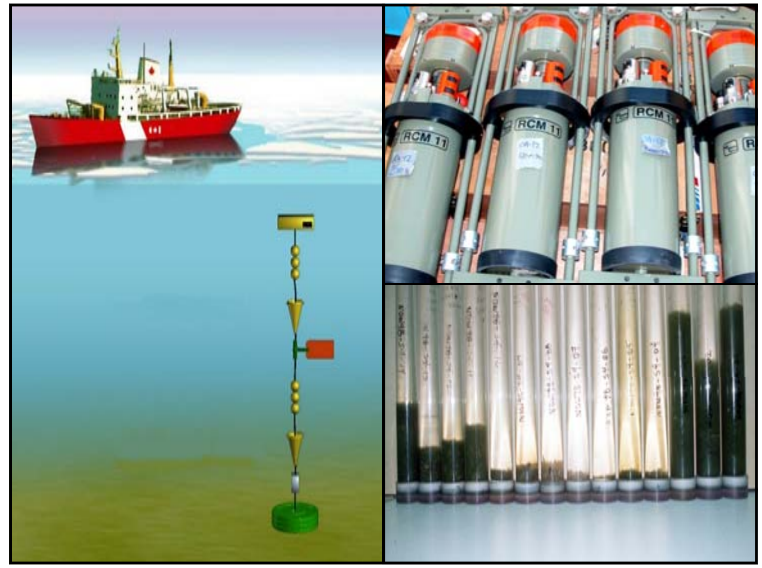

CCGS AMUNDSEN
CANADIAN RESEARCH ICEBREAKER
Scientific Equipment
SubAtlantic SuperMohawk ROV
with TMS operation cage
TMS Operation

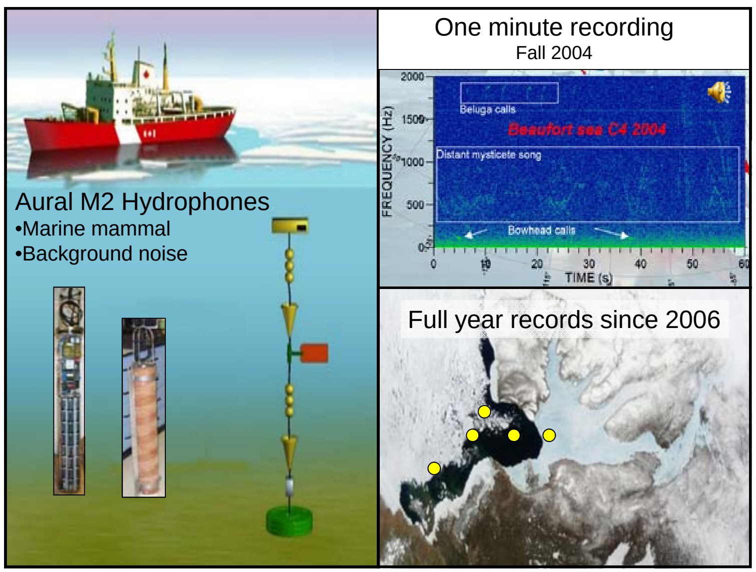

CCGS AMUNDSEN
CANADIAN RESEARCH ICEBREAKER
Scientific Equipment
Amundsen Gulf, 24 October 2007 (388m)
16:30:29 24/10/2007
SubAtlantic SuperMohawk ROV
with TMS operation cage

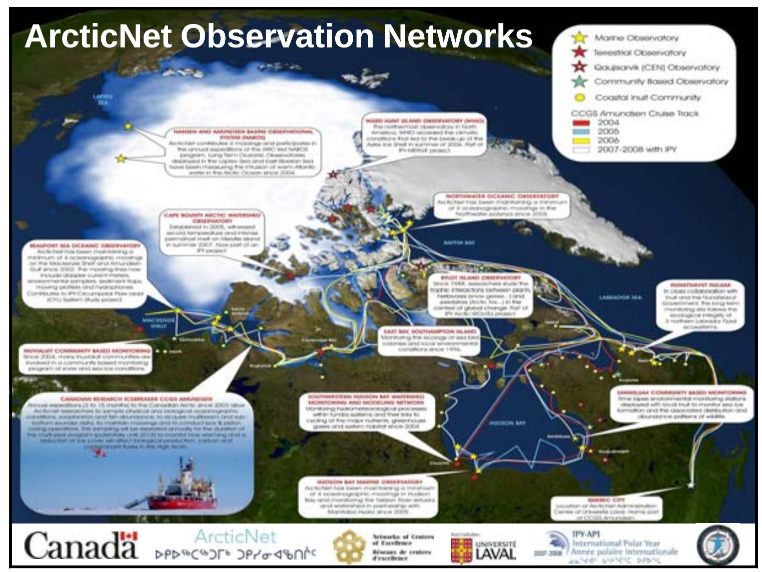

CCGS AMUNDSEN
CANADIAN RESEARCH ICEBREAKER
Scientific Equipment
Sam Ford Fjord, Baffin Island
Hull mounted Sounders:
SIMRAD EM300 multibeam sounder
SIMRAD EK60 scientific echosounder
Knudsen K320R 3.5 kHz subbottom profiler
Shipborn Ocean Surveyer ADCP
CA-18, Amundsen Gulf


Time
Franklin Bay (Spring-Summer 2004)
Simrad EK60 Scientific Echosounder
15 June


CCGS AMUNDSEN
CANADIAN RESEARCH ICEBREAKER
Scientific Equipment
Hydrobios multinet sampler
BIOness multinet sampler


RCM 11
RCM 11
RCM 11


Aural M2 Hydrophones
•Marine mammal
•Background noise
One minute recording
Fall 2004
Beluga calls
Beaufort sea C4 2004
Distant mysticete song
Bowhead calls
FREQUENCY (Hz)
TIME (s)
2000
1500
1000
500
0
0
10
20
30
40
50
60
Full year records since 2006


ArcticNet Observation Networks
Marine Observatory
Terrestrial Observatory
Qaujisarvik (CEN) Observatory
Community Based Observatory
Coastal Inuit Community
CCGS Amundsen Cruise Track
2004
2005
2006
2007-2008 with IPY
Canada
ArcticNet
UNIVERSITÉ LAVAL

IPY·API
International Polar Year
Année polaire internationale
2007·2008

Canadian Commitment of $156 million

44 IPY Federal Program Projects:

- 11 led by ArcticNet NIs
- 30 involve ArcticNet collaborators

- 11 NSERC-IPY Projects:
  - 6 led by ArcticNet NIs

IPY·API
International Polar Year
Année polaire internationale
2007·2008

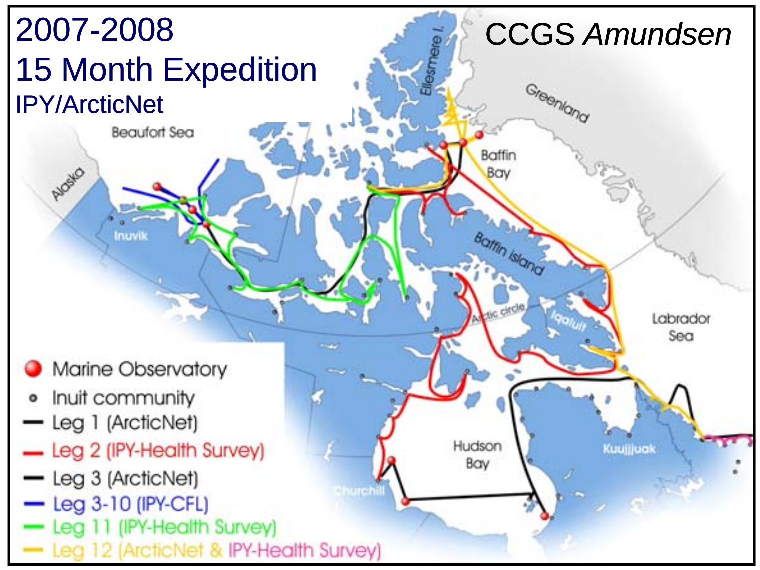
Two largest IPY projects

- Inuit Health Survey
- Circumpolar Flaw Lead System (CFL) Study

Conducted from the CCGS *Amundsen*

2007-2008
15 Month Expedition
IPY/ArcticNet

CCGS *Amundsen*

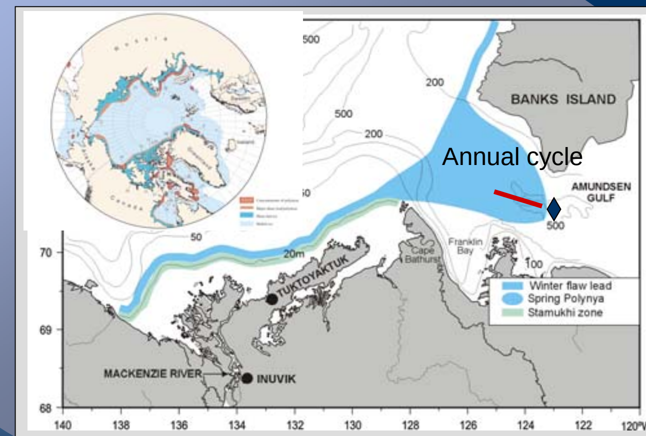


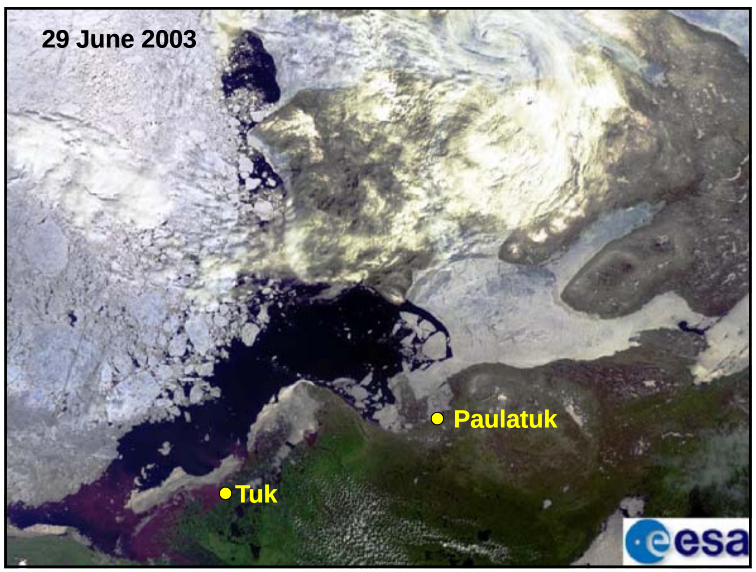
The Circumpolar Flaw Lead (CFL) system study

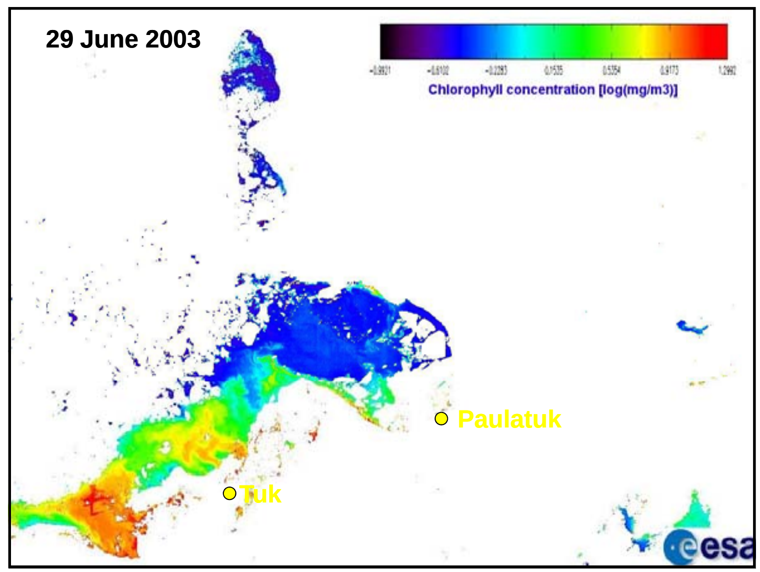
Prof. David Barber, University of Manitoba, Science Leader
Prof. Gary Stern, University of Manitoba & DFO, Co-leader

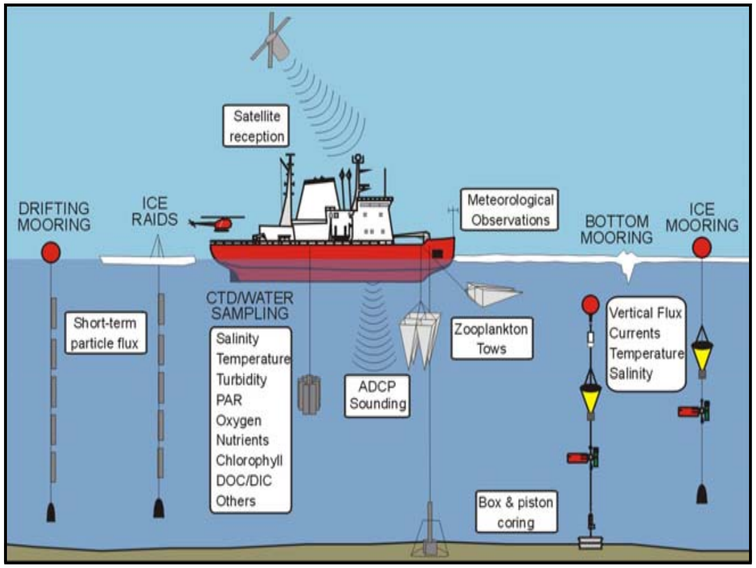
- Full physical-biological study of the ocean-sea ice-atmosphere interface in the Banks Island Flaw lead
- Connected to international studies examining related Arctic ocean ecosystem studies through the PAN-AME cluster of IPY

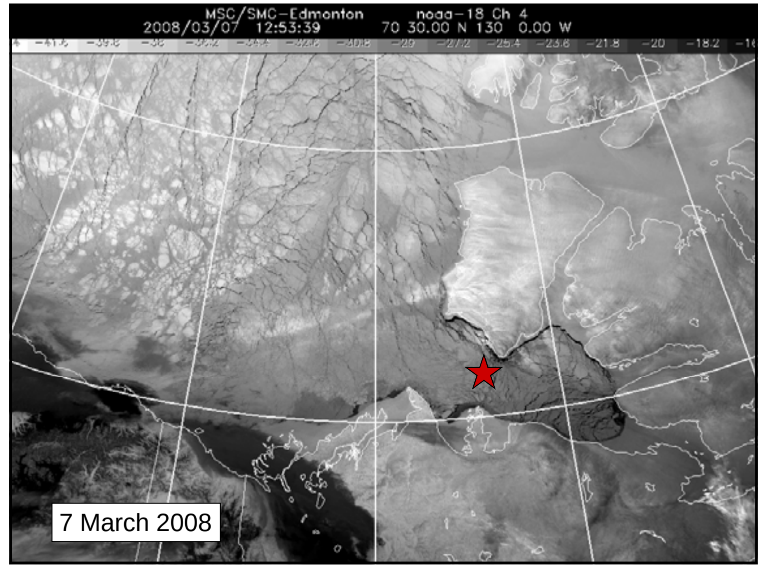
System study of the CFL

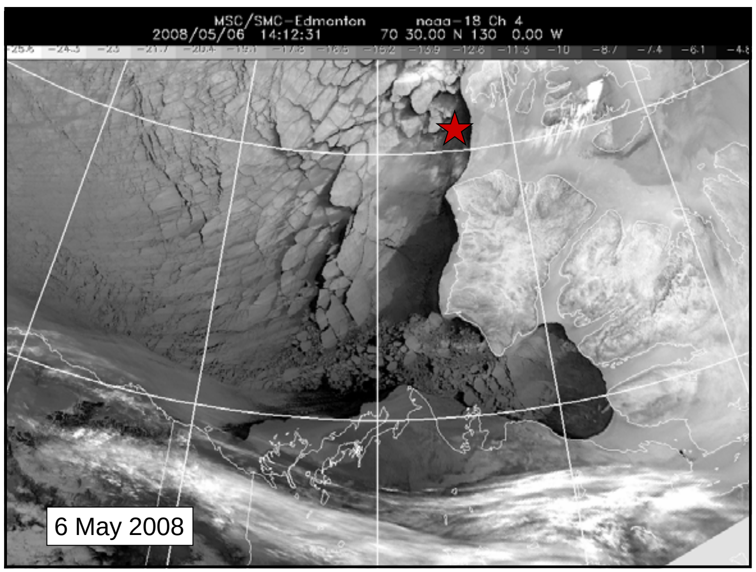










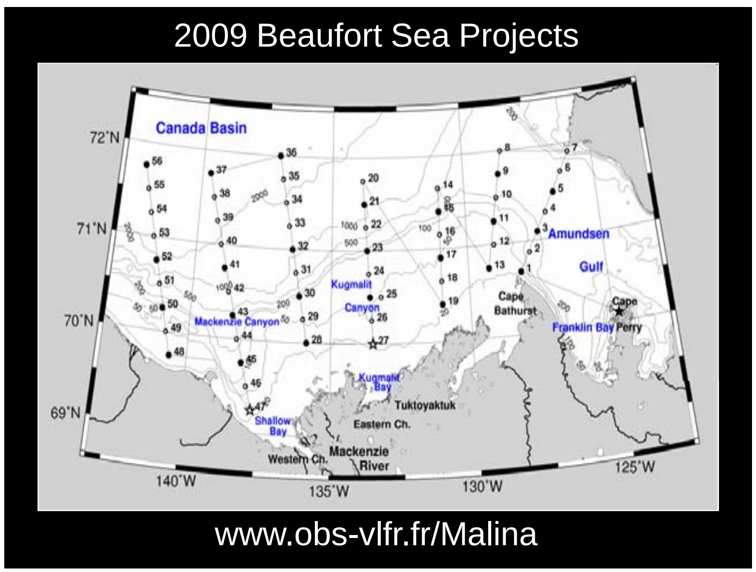


CFL research teams

1) Physical oceanography (Gratton)
2) Ocean-sea ice-atmosphere processes (Barber)
3) Light, nutrients and primary productivity (Gosselin)
4) Pelagic and benthic foodwebs (L. Fortier)
5) Marine mammals and sea birds (Ferguson)
6) Gas fluxes (Miller/Papakyriakou)
7) Carbon fluxes (Tremblay)
8) Contaminants (Stern)
9) Physical - biological modelling (Hanesiak)
10) Engaging Communities (Smith/Meakin)


www.ipy-cfl.ca
CIRCUMPOLAR FLAW LEAD SYSTEM STUDY
CFL
INTERNATIONAL POLAR YEAR 2007-2008
First results workshop in Winnipeg, May 2009


2009 Beaufort Sea Projects
Malina
Malina
Sun goddess of Inuit
www.obs-vlfr.fr/Malina


2009 Beaufort Sea Projects
Canada Basin
72°N
71°N
70°N
69°N
Amundsen
Gulf
Cape Perry
Franklin Bay
Cape Bathurst
Kugmallit Canyon
Mackenzie Canyon
Kugmallit Bay
Shallow Bay
Tuktoyaktuk
Eastern Ch.
Western Ch.
Mackenzie River
140°W
135°W
130°W
125°W
www.obs-vlfr.fr/Malina


Polar Data Catalogue
Incorporating IPY Master Directories
Menu
Completed Form Sample
Input Assistance
Keywords Library
Word Template
Report Error
Search
Sign In
Sign In
E-mail
Password
Sign In
Forgot Password
New user?
Register
Help
Email ArcticNet Data Manager
Terms of Use Agreement
Data Policy
Privacy Policy
Contact Us
This database has been developed through partnership between
ArcticNet
AND
CCIN.CA
www.polardata.ca

ArcticNet

In conclusion

- The long term nature and structure of ArcticNet offers tremendous challenges/opportunities
- Opportunity to :
  - break barriers between research sectors
  - work in real and meaningfull partnership with Northerners in the full research process
  - **work in partnership with stakeholders and industry**
  - start long term monitoring (14 years)
  - consolidate international Arctic collaborations
  - help maintain an IPY legacy
  - contribute to adaptation policies

www.arcticnet.ulaval.ca

5.1.9 Oil and Gas Exploration and Development in the Arctic, Shell Exploration and Production,

Pete Slaiby

Shell Exploration & Production

United States and Canada Northern Oil and Gas Research Forum: Current Status and Future Directions in the Beaufort Sea, North Slope, and Mackenzie Delta
October 28-30, 2008

Oil and Gas Exploration and Development in the Arctic

Peter Slaiby, Alaska General Manager

Shell Exploration & Production

Disclaimer statement

Shell Exploration & Production

Outline

- Shell's Arctic Experience
- Shell Alaska Current and Future Activities
- Research and Technical Challenges
- Critical Research and Opportunities for Synergies

Shell Exploration & Production

The Arctic – A Diverse and Challenging Operating Environment

- Ice cover
- Seasonal windows/darkn ess
- Remoteness
- Extreme temperatures
- Permafrost
- Environmental sensitivity
- Subsistence

Shell's Half Century in Alaska

- 20 years sustained R&D
- 1st royalty payer to Alaska 1965
- 2 producing fields in Cook Inlet
- 10+ seasons of marine seismic
- 9 exploration discoveries
- 5 Beaufort Sea gravel islands

Tern Gravel Island
Beaufort Sea

Shell's Activities in Alaska:

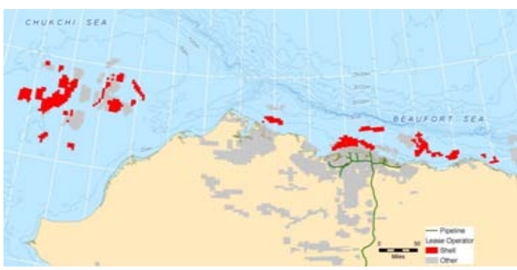
1964 ▶▶▶▶▶▶▶▶ 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 | 2005-08

Cook Inlet — Gulf of Alaska — Bering Sea — Beaufort Sea — Chukchi Sea — Lease Sales

Sakhalin Russia

- 30-50 m of water
- 3 concrete platforms
- Unique shape and geometry withstands seismic and ice conditions
- Production capacity of >300,000 barrels oil equivalent per day
- 300 km of sub arctic offshore pipelines

Alaska OCS Leasehold and C



Chukchi Sea

- 275 Shell OCS leases
- 3-D seismic 2006 – 08
- Shallow hazard survey in 2008
- Marine Mammal M&M 2006-08

Beaufort Sea

- 160 Shell OCS leases
- 3-D seismic 2007 – 08
- Shallow hazard survey 2006
- Ice gouge Survey 2008
- Unmanned Aerial Vehicle (UA

Alaska Native Involvement

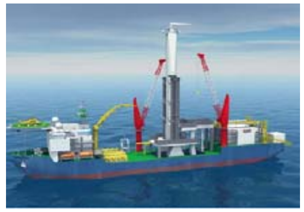
- Oil Spill Response crew
- Native Marine Mammal Observers
- Village Liaisons
- Comm Centers
- NSB Science Advisory
  - Drilling Fluids
  - Spill Response in Ice
- Dispersant Effects Workshop
- Discussion of Baseline Studies
- UAV Workshop

Shell Exploration & Production

Ice Classed Drilling Units

Future Activities

- Kulluk Rig – Shell Purchased in Jan 2006 (100 % Shell Owned)
- Discoverer Drillship – owned and operated by Frontier Drilling




Kulluk Rig

Discoverer Drillship

Shell Exploration & Production

Geotechnical Investigation

Future Activities

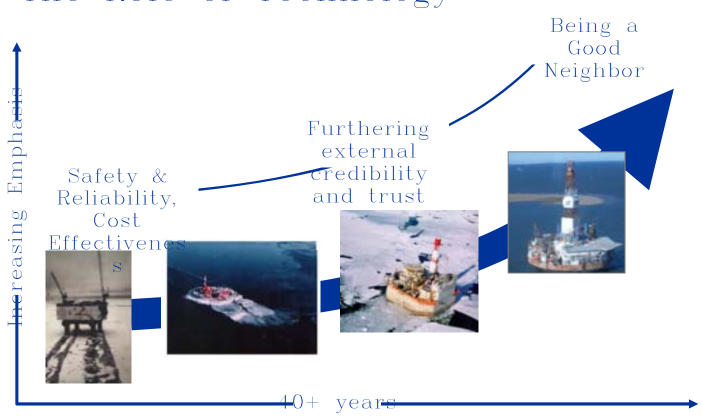
Purpose: To gather soil strength data to aid in feasibility and design of Future facilities.

Depth: Coreholes have a maximum depth of about 400’

Location: Camden Bay.

Shell Exploration & Production

The Role of Technology



Shell Exploration & Production

Challenges for responsible, successful development

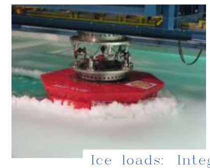
- Technical R&D
  - Safety, reliability, and cost effectiveness
- Environmental R&D
  - Reduce operational footprint for sustainability
- Social R&D
  - Maximize benefit and minimize impact to neighbors

Challenges – safety, reliability, and cost effectiveness

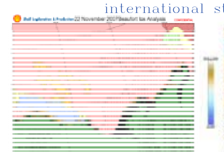
- Oil Spill Prevention and Response in Arctic Conditions
  - Detection and monitoring of oil under ice
  - Oil spill recovery from under ice
  - Oil spill trajectory in broken ice
  - Full-scale field validation of ice deflection to improve oil spill response efficiency
  - Improved mechanical recovery equipment for Arctic conditions
  - Dispersants use in Arctic (new dispersant formulations, application and mixing techniques, toxicity and effects)
  - In-situ burn residue recovery and effects
  - Marine mammal protection techniques in case of an oil spill

Shell Exploration & Production

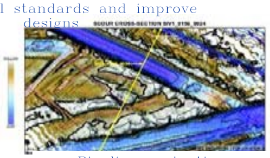
Challenges – safety, reliability, and cost effectiveness (Cont.)



Ice loads: Integrating model tests and field measurements: to validate international standards and improve designs



Ice detection and forecasting: applying technology to support field operations, while



Pipeline protection: Integrating finite element modeling, small scale tests, and field studies to improve

- Overcoming the physical environment has been the historic focus of technology
- As Industry moves to more difficult conditions, safety, reliability, and cost effectiveness remain at the forefront of

Shell Exploration & Production

Challenges – reduce operational footprint

- Coordination to reduce activity during the open water season, in order to avoid ecological sensitivities and subsistence use
- Operate quietly to minimize disturbance of marine mammals and subsistence use
- Marine mammal population status and distribution informs protections under ESA/MMPA
  - Regional surveys (aerial and acoustic), individual satellite-tags
  - Can Multi-species Habitat Conservation Plans be developed?
- Reduce manned activities, use technology for monitoring and measurement
  - Unmanned Aerial Vehicles (UAVs)
  - Autonomous Underwater Vehicles (AUVs)

Shell Exploration & Production

Challenges – reduce operational footprint (Cont.)

Operate quietly – sound mitigation

Kulluk during sound measurements

- Objective: reduce sound during all operations
- Approaches: new technology for seismic acquisition, equipment isolation and insulation, use of sound barriers, vessel and

Challenges – maximize benefits and minimize impact to neighbors

- Harness traditional knowledge to inform operations and minimize impact on subsistence use by local communities
- Regional programs to monitor contaminants in subsistence species of marine mammals
  - Making sure the "Garden" stays clean and productive
- Regional baseline environmental characterization

Challenges require synergy among diverse partners

- Industry partners
  - Oil in Ice JIP
  - Ice Forces on Structures JIP
  - OGP Sound and Marine Life JIP
  - Ecological Characterization of the Chukchi – Shell & Conoco
- Local, national, and international regulators
  - MMS Environmental Sciences Program and the Coastal Marine Institute at the University of Alaska – Fairbanks
  - Annual Open Water Meeting
  - U.S. Coast Guard OPA '90 R&D Program
- Scientific community
  - National Oceanographic Partnership Program (NOPP)
  - International Polar Year R&D

Being a Good Neighbor – Expanding Role for Technology!

- Maturing societal expectations create the impetus to take technology to another level
- Objective is to provide alternatives that eliminate or lessen "impacts" compared with conventional approaches
- Involve stakeholders to develop early and mutual understanding –

Name	Location	Description	Total Costs in Millions of $	Ak contractors and Ak share of spend	Stakeholders consulted
Acoustic Recorders	Chukchi & Beaufort	A large network of buoys that record the sounds of whales, seals, and walrus as well as seismic noise. This helps to understand the distribution, abundance, and migration routes as well as possible behavior changes in response to petroleum industry activity.	$15.2 mln	Norseman Maritime, LGL $2.8 mln	NSB, NMFS, AEWC
Marine Mammal Overflights	Chukchi & Beaufort	Trained marine biologists in aircraft who collect visual data on distribution, abundance, and behaviors of whales, seals, walrus and polar bears. Approximately on third of the biologists are Inupiat.	$7.7 mln	ASRC, LGL and Bald Mtn Air $1.7 mln	NSB, NMFS, AEWC
Marine Mammal Observers	Chukchi & Beaufort	Trained biologists on all marine vessels who collect visual data on distribution, abundance, and behaviors of whales, seals, walrus and polar bears. Approximately on third of the biologists are Inupiat.	$7.4 mln	ASRC, LGL $7.4 mln	NSB, NMFS, AEWC
Various Biological Studies	Chukchi & Beaufort	Studies of birds, fish, and benthic organisms near proposed drillsites in the Chukchi and Beaufort	$4.0 mln	Fairweather, Bering Marine, $2.5 mln	MMS
Drones	Beaufort	Research and Development program to develop use of Unmanned Aerial Systems ("drones") for studying distribution, abundance, and behaviors of whales, seals, walrus and polar bears	$3.5 mln	Village Corp of Barrow, Fairweather LGL, Norseman $2.5 mln	MMS, NSB, NMFS, AEWC
Walrus Tagging	Chukchi	Support for US Fish and Wildlife program to "tag" walrus with satellite tracking devices so their movements could be monitored	$0.5 mln	Norseman Maritime	USFWS, USGS
Marine Habitat Study	Beaufort, Chukchi and Bristol Bay	Ecoregional Assessment of Arctic Offshore. Detailed analysis of marine habitats	$0.5 mln	The Nature Conservancy	The Nature Conservancy
Ocean-current Research	Beaufort	National Oceanographic Partnership Program. Studies physical and biological impact of climate warming.	$0.2 mln	UAF	UAF
Polar Bear	Beaufort	Aerial Survey and Radio Tagging of Polar Bears	$0.1 mln	Nat'l Fish and Wildlife Fund; USGS	Nat'l Fish and Wildlife Fund; USGS

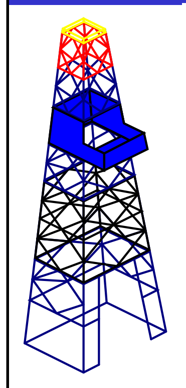
Shell Exploration & Production

Backup Slides

Shell Exploration & Production

Layers of Prevention

No single incident leads to the worst case blowout scenario



- Phase IV – Relief Well Operations
  Contingency plans in place
- Phase III – Mechanical Barriers
  Including special arctic barriers
- Phase II – Early Detection and Response
  Continuous Monitoring
- Phase I – Up Front Planning, Training, and Preparation
  Phase I is used to build a strong foundation

Shell Exploration & Production

Contingency Response Vessels & Equipment

Nanuq

Arctic Tanker

Arctic Endeavor

ASRC Energy Services
a subsidiary of Arctic Slope Regional Corporation

Equipment Stored on Deck

Kvichak Boats, Mini-barges, Skimmers, Boom, Heli-torch, etc.

Shell Exploration & Production

Oil in Ice JIP

Objective: Develop knowledge, methods and equipment for oil spill response in Arctic and ice-covered waters.

9 Projects, 25 subprojects, US $9–10 million, 3.5 years starting from September 2006.

Research topics: Oil fate and behavior, in-situ burning, mechanical recovery, dispersants, remote sensing, spill response guide, field tests.

Funding /support by Shell, StatoilHydro, Chevron, Total, ConocoPhillips, Agip KCO, BP.

Other participants: MMS, OSRI, ACS, CRRC, academia, research institutes, others.

JIP of the effect of dispersed oil on Arctic marine environment

Objective: To address stakeholders concerns about the effect of dispersed oil on the Arctic Environment and provide sufficient background for making informed response decisions through an Ecological Risk Assessment (ERA) framework.

Project cost is estimated at US $2 million over 2 years starting winter 2008.

NewFields manages this JIP with Shell, ExxonMobil, ConocoPhillips, and StatoilHydro providing funding.

Other participants: ADEC, NOAA, USCG, NSB, Canadian and Norwegian scientists.

Approach – Leverage Industry, Academia Government Agencies, etc.

Examples:

Marine sound	US Minerals Management Service, Gunderboom, Noise Control Engineering, University of New Hampshire, OTRC, MIT
Oil spill prevention and response	MMS, USCG, University of Alaska Fairbanks, American Petroleum Institute, MIT, JIPs
Ice Loading	ConocoPhillips, Demo 2000, TU-Delft, Memorial University, JIPs

5.1.10 Research Priorities in the Alaskan Arctic, Conoco Phillips, *Geoffrey Haddad*

Research Priorities in the Alaskan Arctic

U.S. – Canada
Northern Oil & Gas Research Forum
October 29, 2008

Geoff Haddad
Vice President – Exploration & Land

Cautionary Statement

FOR THE PURPOSES OF THE “SAFE HARBOR” PROVISIONS OF THE PRIVATE SECURITIES LITIGATION REFORM ACT OF 1995

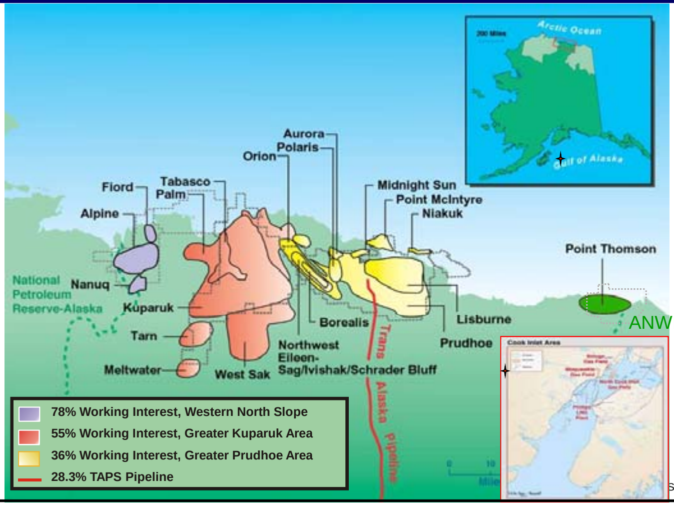
The following presentation includes forward-looking statements within the meaning of Section 27A of the Securities Act of 1933, as amended, and Section 21E of the Securities Exchange Act of 1934, as amended, which are intended to be covered by the safe harbors created thereby. You can identify our forward-looking statements by words such as “anticipates,” “expects,” “intends,” “plans,” “projects,” “believes,” “estimates,” and similar expressions. Forward-looking statements relating to ConocoPhillips’ operations are based on management’s expectations, estimates and projections about ConocoPhillips and the petroleum industry in general on the date these presentations were given. These statements are not guarantees of future performance and involve certain risks, uncertainties and assumptions that are difficult to predict. Further, certain forward-looking statements are based upon assumptions as to future events that may not prove to be accurate. Therefore, actual outcomes and results may differ materially from what is expressed or forecast in such forward-looking statements.

Factors that could cause actual results or events to differ materially include, but are not limited to, crude oil and natural gas prices; refining and marketing margins; potential failure to achieve, and potential delays in achieving, expected reserves or production levels from existing and future oil and gas development projects due to operating hazards, drilling risks, and the inherent uncertainties in interpreting engineering data relating to underground accumulations of oil and gas; unsuccessful exploratory drilling activities; lack of exploration success; potential disruption or unexpected technical difficulties in developing new products and manufacturing processes; potential failure of new products to achieve acceptance in the market; unexpected cost increases or technical difficulties in constructing or modifying company manufacturing or refining facilities; unexpected difficulties in manufacturing, transporting or refining synthetic crude oil; international monetary conditions and exchange controls; potential liability for remedial actions under existing or future environmental regulations; potential liability resulting from pending or future litigation; general domestic and international economic and political conditions, as well as changes in tax and other laws applicable to ConocoPhillips’ business. Other factors that could cause actual results to differ materially from those described in the forward-looking statements include other economic, business, competitive and/or regulatory factors affecting ConocoPhillips’ business generally as set forth in ConocoPhillips’ filings with the Securities and Exchange Commission (SEC), including our Form 10-K for the year ending December 31, 2007, as updated by our quarterly and current reports on Forms 10-Q and 8-K, respectively. ConocoPhillips is under no obligation (and expressly disclaims any such obligation) to update or alter its forward-looking statements, whether as a result of new information, future events or otherwise.

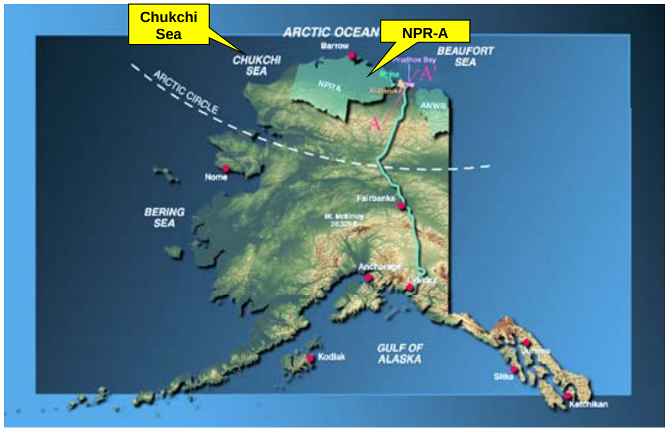
Outline

- ConocoPhillips’ Alaska Assets
- Exploration and Development in NPR-A and Chukchi
- Research Focus Areas
  - Onshore
  - Offshore

Alaska Region Assets

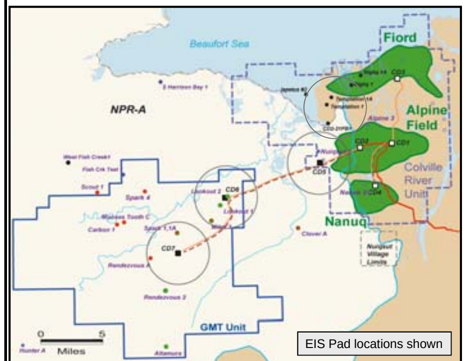


Current Focus for Exploration



Slide 5

Development Priorities: Alpine Satellites & the NPR-A



WNS CRU	First Oil
Alpine Field	2000
Fiord CD3	2006
Nanuq CD4	2006
Qannik CD2	2008

Future Satellites

Alpine West CD5

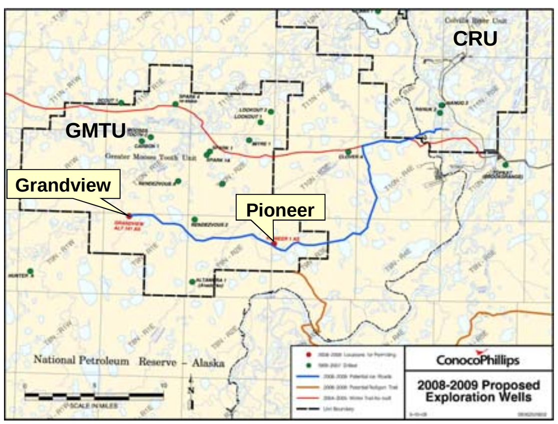
Lookout CD6

Fiord West

Rendezvous CD7

Slide 6

2009 Exploration



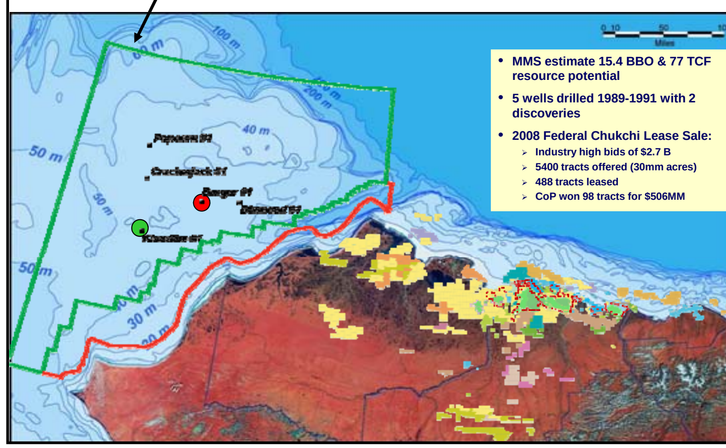
Exploration for 2009:

- 2 wells in NPRA
- Focusing on the Greater Moose's Tooth Unit (GMTU)
- Defining hydrocarbon resource potential within GMTU

Slide 7

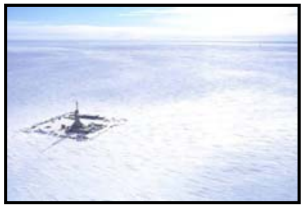
Chukchi Sea Overview

Chukchi Sea Program Area

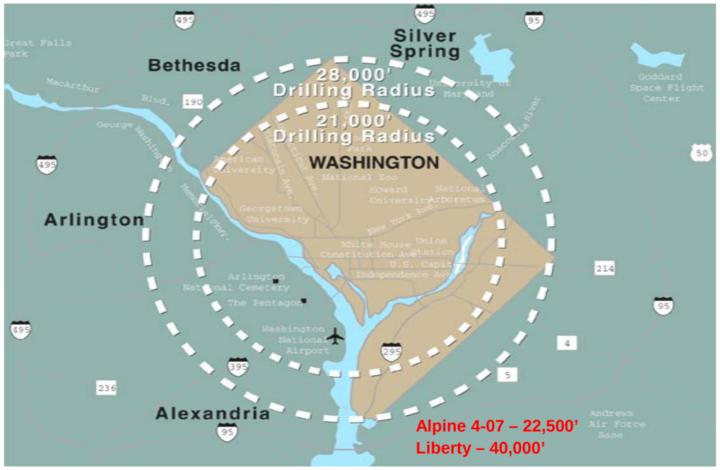


Key Alaska Arctic Research Areas

- **Onshore**
  - Minimize Environmental Impacts
    - Extended reach drilling
    - Small footprint developments
    - Collection of baseline environmental information
    - Remote monitoring
  - Extend Winter Tundra Travel
- **Offshore**
  - Minimize Environmental Impacts
    - Drilling Solutions
    - Acquisition of baseline environmental information
  - Ice-hardened Structures
  - Seabed Interaction

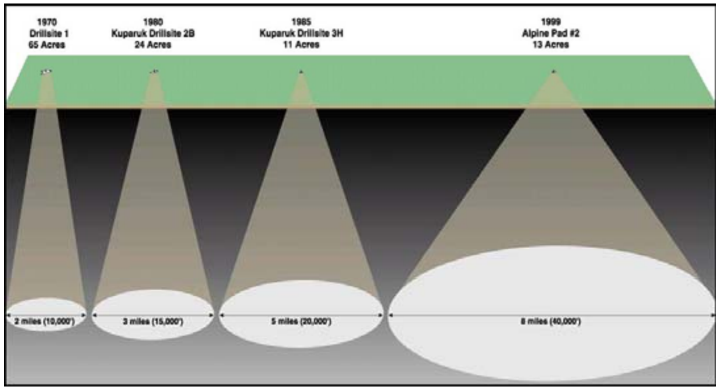


Extended Reach Drilling



Alaska North Slope Drillsite Evolution

Pad Size and Corresponding Subsurface Drillable Acres



Area = 3.14 sq. mi. (2,010 Acres)	Area = 7.065 sq. mi. (4,522 Acres)	Area = 19.625 sq. mi. (12,560 Acres)	Area = 50.24 sq. mi. (32,154 Acres)

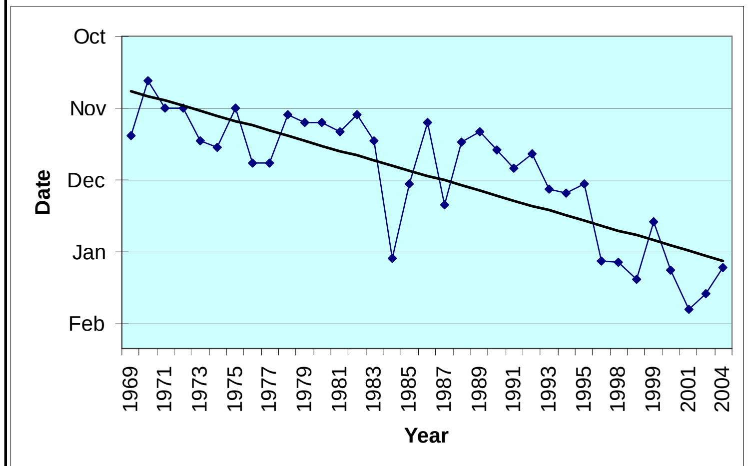
Alpine

- ***Largest onshore discovery in 20 yrs***
- ***Original footprint - 97 acres***
  - ***- Current w/Satellites – 161 acres***
- ***4 Drill Sites & Processing Plant***
- ***Approximately 120 wells***
- ***Roadless Development***
- ***Production: 120,000 BOPD***

Onshore Baseline Environmental Studies

- Wildlife Studies
  - Bird Surveys
  - Caribou Surveys
  - Fox Surveys
  - ADF&G Grizzly Bear Studies Support
  - USFWS Polar Bear Studies Support
- Fisheries Surveys
- Land Classification & Habitat Mapping
- Hydrological Studies
- Archaeological Surveys

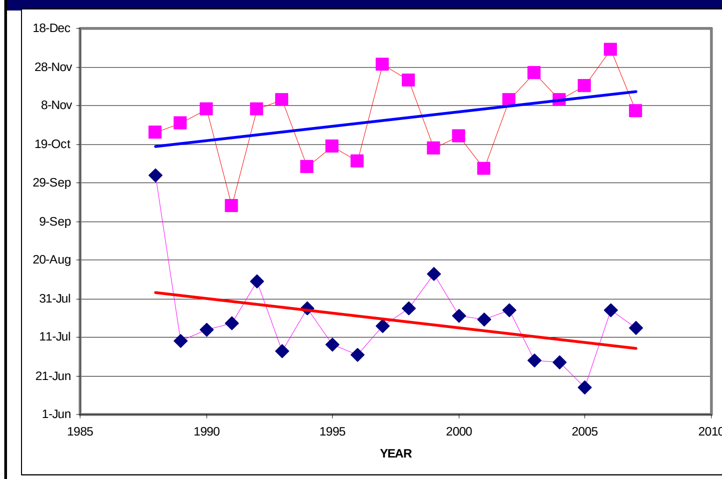
Winter Tundra Travel Opening Dates



Offshore Arctic Research – Future Drilling

- Drilling Issues
  - Older platforms not suitable or available
  - New build or retrofit
  - Ice hardened jackjup rigs may be a solution
- Spill Response Studies
  - Focus on prevention
  - Spill response in the Arctic is an area of industry research
  - We participate in Joint Industry Program studies

Changes in Chukchi Sea Ice

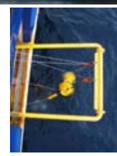


Source Fairweather July 2008 Report

Chukchi Baseline Environmental Studies

- Integrated Environmental Program:
  - Marine Mammals
  - Seabirds
  - Zooplankton
  - Benthos
  - Contaminants
  - Physical Oceanography
  - Unmanned Aerial Systems
  - Acoustic Signature
- 3 Cruises off Wainwright:
  - Mid-July - late October, 2008



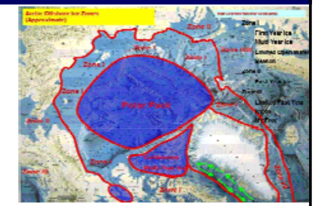





Arctic Research – Surface Facilities

Gravity Based Structures (GBS)

- Still conceptual in the Arctic
- Massive structures: +40,000 ton topsides & 500,000 ton bases
- Constructability and logistics are large cost drivers



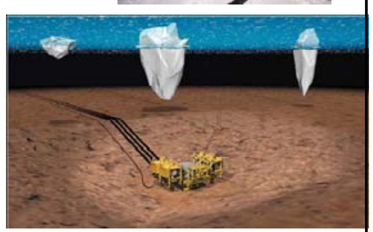

Arctic Research – Sub-Surface Facilities

Facilities for Subsea Development

- Required technology for marginal developments
- Excellent technology base
- Ultra-high integrity systems required
- Subsea multi-phase pumping potential
- Ice scour concerns

Understanding the Environment for Design

- Ice scour studies
- Weather and oceanography studies (wind, waves, currents)
- Seasonal ice movement



5.1.11 Industry Activities and Research Needs, Alaska Oil and Gas Association,

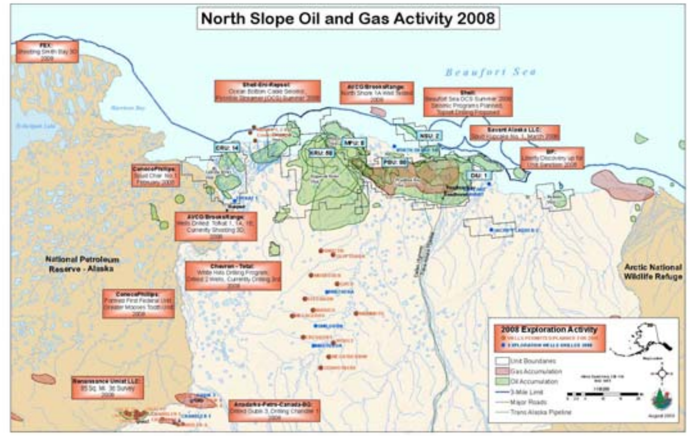
Marilyn Crockett

United States and Canada Northern Research Forum:
Current Status and Future Directions for the Beaufort Sea, North Slope and Mackenzie Delta

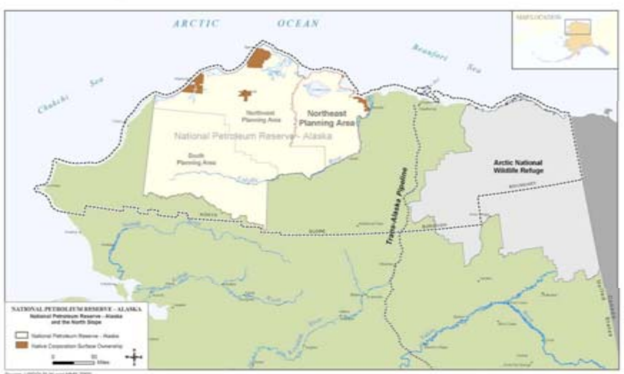
Industry Activities and Research Needs

October 29, 2008

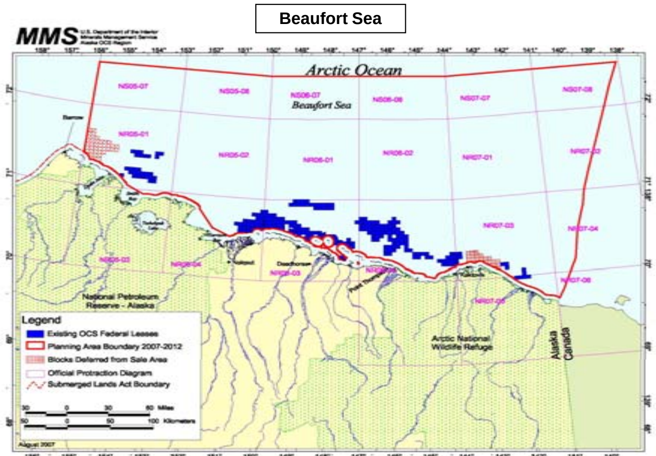
Marilyn Crockett
Executive Director
Alaska Oil & Gas Association



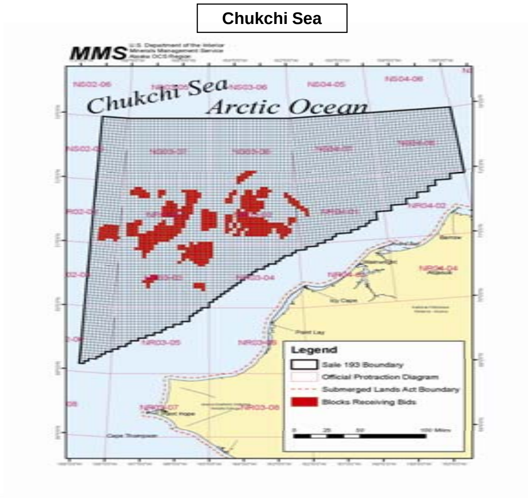
National Petroleum Reserve-Alaska



Beaufort Sea



Chukchi Sea



AOGA Looking Ahead

The Toolbox for Oil and Gas Development in Sensitive Areas in Arctic Alaska

- Good Environmental Reputation
- 3-D Seismic
- Extended Reach Drilling
- Directional Drilling
- Horizontal Completions
- Wildlife and Fisheries Studies
- Roadless Development
- Predictable Permitting Systems
- Performance Accountability
- Remote Sensing
- Habitat Mapping
- Inter-Agency Cooperation
- Coiled Tubing
- Rehabilitation
- Advanced Drilling Fluids
- Air Quality Monitoring
- Modular Drilling Rigs

The Toolbox for Oil and Gas Development in Sensitive Areas in Arctic Alaska (cont.)

- Water Quality Baseline Studies
- Good Community Relationships
- Knowledgeable Agency Staff
- Downhole Separation Technology
- Zero Tolerance for Incidental Damage from Seismic
- Grind and Inject Technology
- Ice Roads and Ice Pads
- Great Rocks
- Multilateral Completions
- Leak Detection Systems
- Rolligons
- A Little Luck

Baseline Studies

- Water quality and volume in lakes proposed for water sources
- Fish species present in lakes, streams and rivers
- Hydrology studies
- Habitat mapping for purpose of staging spill response equipment
- Caribou studies
- Subsistence surveys
- Archaeological/cultural surveys
- Bird nesting and brood rearing surveys (numerous bird species)
- Vegetation studies
- Evaluation of presence of threatened or endangered species

Endangered Species Act

Listed as Endangered under the Endangered Species Act:

Bowhead Whale

Northern Right whale

Leatherback turtle

Short-tailed albatross

Black-footed albatross

Listed as Threatened under Endangered Species Act:

Spectacled eider

Stellar's eider

Polar bears

Under Consideration for Endangered Species Act Protection:

Yellow-billed Loon

Ribbon Seal

Bearded, Ringed, and Spotted Ice Seal

Pacific Walrus

Research Needs

- Population data on ESA listed species
- Baseline data
- Underwater sound and potential impacts on species

Research Challenges

- Coordination/collaboration among research entities
- Prioritization
- Government Funding
- Publication; peer review of study results

Opportunities

- Research Symposiums
- North Slope Science Initiative
- Funding Partnerships

Contact Us

www.aoga.org

907-272-1481

5.1.12 Northern Oil and Gas Forum '08, MGM Energy Corp., *Gary Bunio*

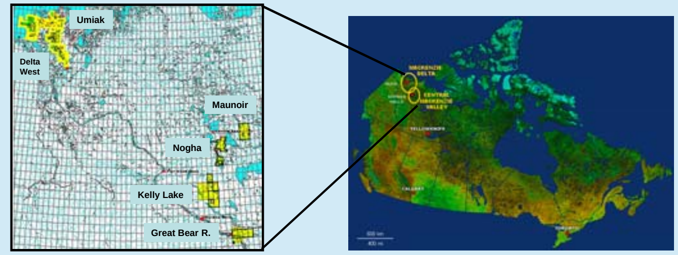
Northern Oil and Gas Research Forum ‘08

Gary Bunio
VP Operations
MGM Energy Corp.

October 29th, 2008

MGM Energy Corp.

- **MGX, on Toronto Exchange**
- **434 Bcf mean net contingent and prospective resource**
  - Additional 229 Bcf mean net contingent and prospective resource after Farm-In completion
- **Multiple prospects**
- **> 1,000,000 gross hectares of land**



A Significant and Balanced Portfolio in Northern Canada

2008/09 Drilling Program

- **Three or four wells planned, ~150 km of road, well leases, airstrip**
- **Barge and stage all equipment by October 10th, 08**
- **Commence November 15th, 2008, Complete work by April 10th, 2009**
- **Capital budget of C$74.0 million**

The most active explorer in Canada’s North

Ongoing Research Programs

- **Canadian Arctic Science Station**
  - Sustainable Resource Development
  - Environmental Science and Stewardship
  - Climate Change
  - Healthy and Sustainable Communities
- **NRCan Program of Energy Research and Development**
- **Proposed Western Arctic Research Centre**

Recognize Current Canadian Research Efforts

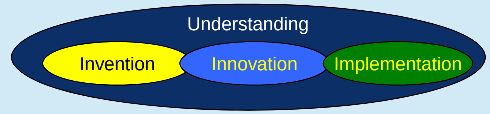
Why do Research?

- **Science is an accretion of knowledge over generations**
- **Science is a method of creating knowledge from observations**
- **Traditional knowledge is also created from observations over generations**
- **Knowledge is never complete or perfect**
- **Northern communities wish to have responsible development**
- **All of us wish to support communities towards that objective**

"If you don't know where you are going, any road will take you there."

- Lewis Carroll, Alice in Wonderland

Research Model



- **Understanding: Baseline or pre-competitive research**
  - Basic Engineering Science: Materials; Resource Recovery
  - Environmental Baselines
  - Incorporates traditional knowledge
- **Invention: Creation of new concepts**
  - Identify "what's missing", what is the gap?
  - The gap MUST be measureable to be useful
  - Address the problem
- **Innovation: Adaptation of inventions to existing issues**
  - eg: Subsea completions in arctic conditions
- **Implementation: Initial commercialization**

"If I have seen further it is by standing on the shoulders of giants.."

- Isaac Newton, *Letter to Robert Hooke*

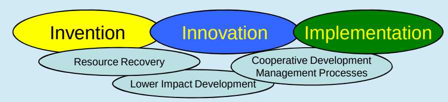
Basic (Precompetitive) Research

- **Regional Environmental Assessment in the Mackenzie Valley & Delta**
  - Today
  - Including the past 20,000 years of climactic cycles since the ice age
  - Include traditional knowledge of residents
- **Permafrost behavior**
  - Civil Engineering
  - Restoration
- **Driven by Science and Communities to further understanding**

"Science is organized knowledge."

- Herbert Spencer, Education

Applied Research



- **Resource recovery**
  - Reservoir access
  - Hydrate gas recovery
- **Engineering and Science to lower impacts**
  - Use less metal, energy, materials to get out more oil or gas
  - Lower footprint
  - Appropriate balancing of risks
- **Cooperative Development Management Process**
  - Wasteful regulatory and management processes
  - Residents, government, regulators and industry cooperation
  - Driven by Communities, Government, Regulators and Industry

The goal is responsible development

What to Research

- **Three biggest problems facing Northern Energy Development?**
  - Timelines?
  - Infrastructure?
  - Labour?
  - Regulatory Framework?

"The Goal: A process of ongoing improvement."

- Eli Goldratt, The Goal

9

What to Research

- **Three biggest problems facing Northern Energy Development?**
- **No one ever says "management" or "leadership"**
  - The fact that management is missing, is missing
  - Yet, if we were better manager / leaders ….
    - Shared Goals
    - Clear Process
    - Effective and Accountable Timelines
    - Measurable Benefits and Results
  - … these issues could be resolved.
- **Refine how research resources are allocated**
  - Deliver knowledge – environmental baselines, reduced footprints
  - Deliver technology – reduced costs, increased recovery
- **For responsible development of northern resources**

MGM is Northern Energy

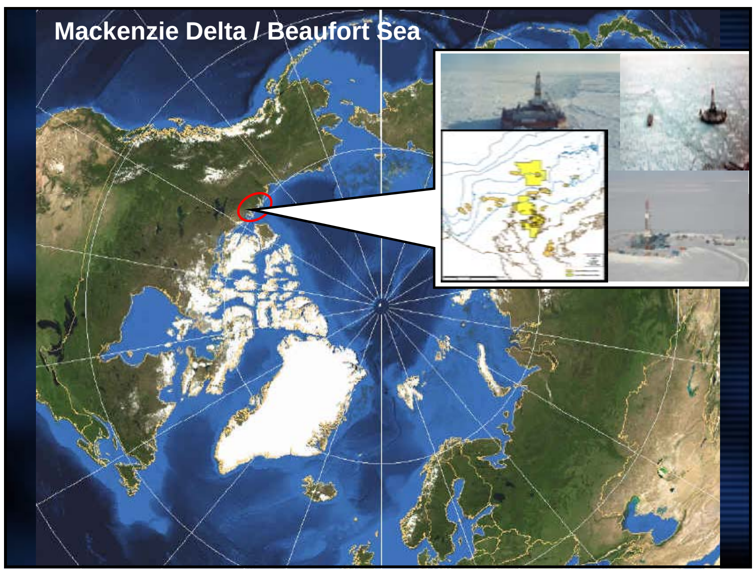
10

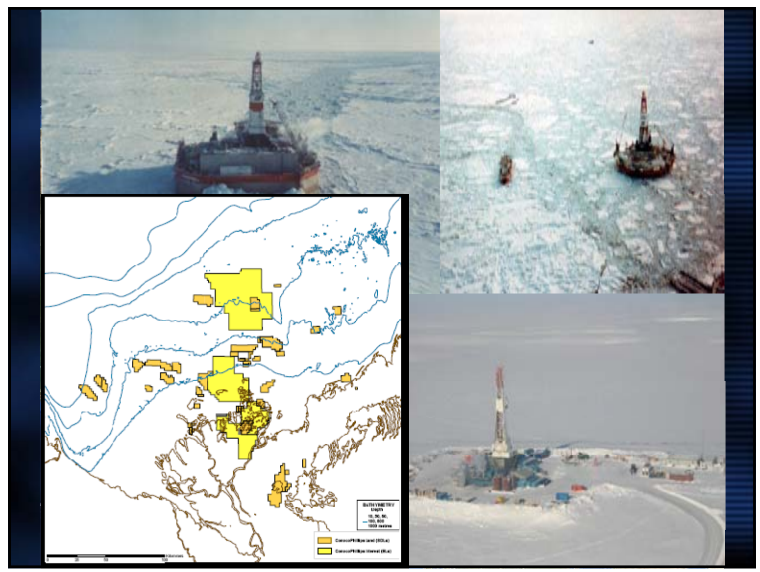
5.1.13 Research Priorities in the Canadian Arctic, Conoco Phillips, *Bob Bleaney*

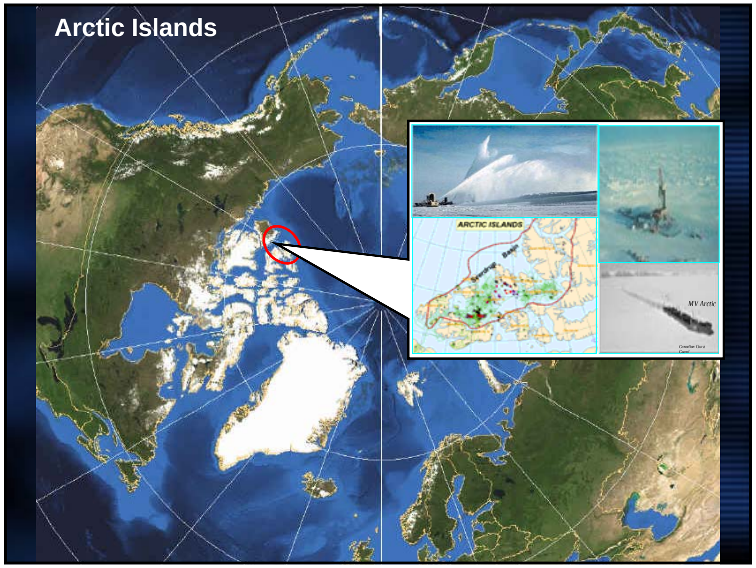
ConocoPhillips

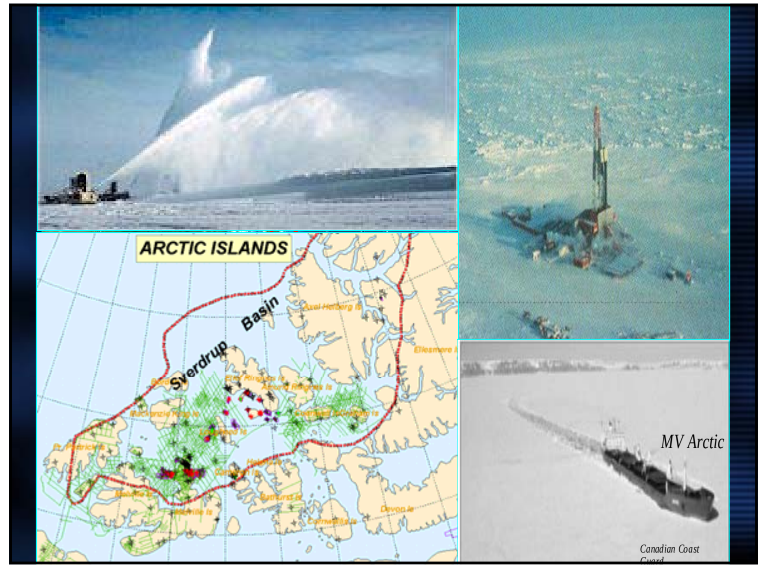
Research Priorities in the Canadian Arctic

Bob Bleaney
Manager – Commercial and Regulatory Affairs
Northern Oil and Gas Research Forum '08
October 29, 2008
Anchorage

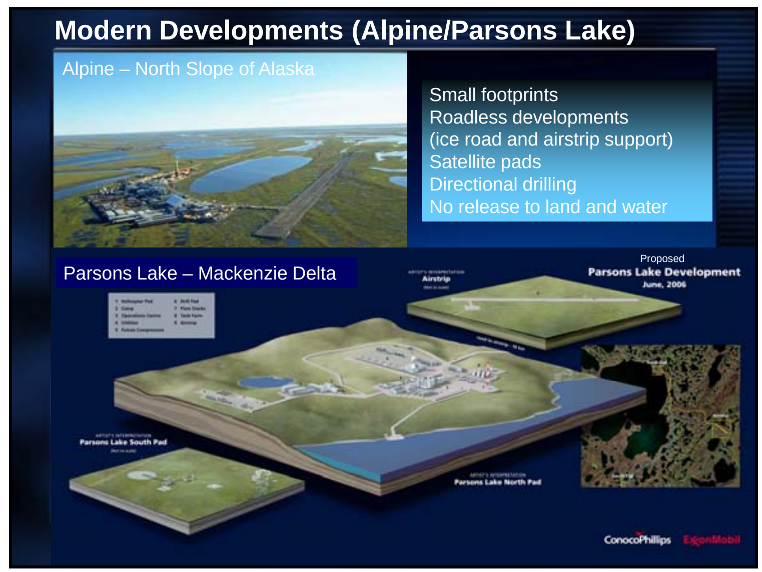





Arctic Islands
ARCTIC ISLANDS
MV Arctic


ARCTIC ISLANDS
Sverdrup Basin
MV Arctic
Canadian Coast Guard


Key Arctic Challenges - Onshore
• Tundra/Permafrost Preservation
• Narrow Weather Windows
• Logistics & Transportation
• Infrastructure
• Sensitive Environment
7


Modern Developments (Alpine/Parsons Lake)
Alpine – North Slope of Alaska
Small footprints
Roadless developments
(ice road and airstrip support)
Satellite pads
Directional drilling
No release to land and water
Parsons Lake – Mackenzie Delta
Proposed
Parsons Lake Development
June, 2006
Airstrip
Parsons Lake South Pad
Parsons Lake North Pad
ConocoPhillips
ExxonMobil

Research Application Examples

Parsons Lake Development

- Extended reach drilling to reduce surface footprint
- Ice road (seasonal) and airstrip (year-round)
- Heavy haul ice-road design to support transport of very large modules – reduced cost and schedule

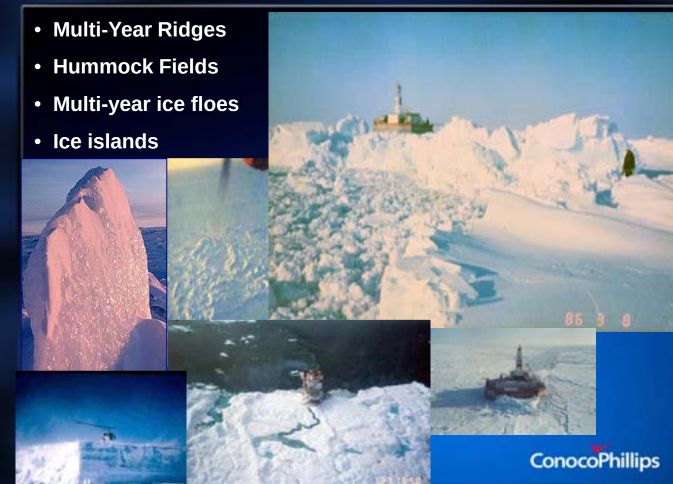
Key Arctic Challenges - Offshore

- Ice-Structure/Seabed Interaction
- Sensitive Marine Environment
- Safety

First Year Ice Features

Multi Year Ice Features

- **Multi-Year Ridges**
- **Hummock Fields**
- **Multi-year ice floes**
- **Ice islands**



2008 Open Water

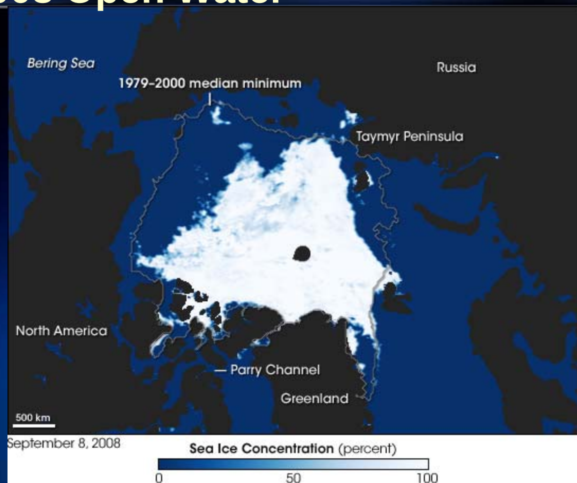


Image from: http://earthobservatory.nasa.gov

Key CPC Research Focus

- Cost Reduction Programs
  - Drilling
  - Infrastructure
  - Product Transportation
  - Operations/Logistics
- HS&E/Regulatory Improvements
- Extreme Ice Load Prediction & Risk Mitigation Program

Suggested Regional Research Priorities

- Reduce costs for access to the Canadian Arctic
  - Use of existing and emerging technologies
- Support the Canadian Beaufort Regional Environmental Assessment initiative
  - Federal government led, multi-stakeholder undertaking
  - Develop a comprehensive Biophysical and Socio-Economic database for regional baselines
  - Future research should consider dovetailing into REA framework

Suggested Regional Research Priorities

- Ice environment
  - Extreme ice features data acquisition
  - Climate change
- Navigation/Transportation Routing
  - Seasonal and more extended access with ice strengthened vessels for up to 12 months/year
  - Prediction of sea ice conditions
  - Establish safe navigable shipping routes and moorages for a variety of vessels and environmental conditions
  - Develop emergency and spill response capabilities


Thank You

5.1.14 Northern Canada Activity and Role of Research and Development, Canadian Association of Petroleum Producers,

Paul Barnes

Northern Canada Activity and Role of Research & Development

Presentation to:
U.S.-Canada Northern Oil and Gas Research Forum

Paul Barnes
Canadian Association of Petroleum Producers

October 29, 2008

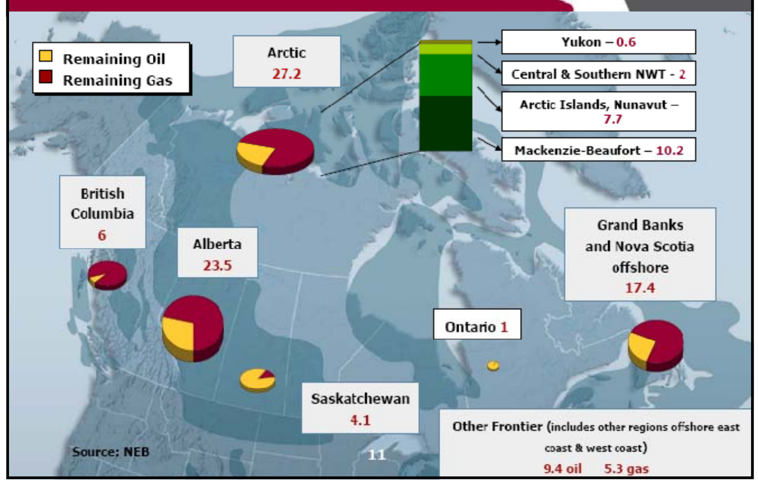
Overview

- Who is CAPP
- Northern Canada petroleum industry activity
- Challenges of operating in Northern Canada
- Using R&D to address the challenges
- Concluding remarks

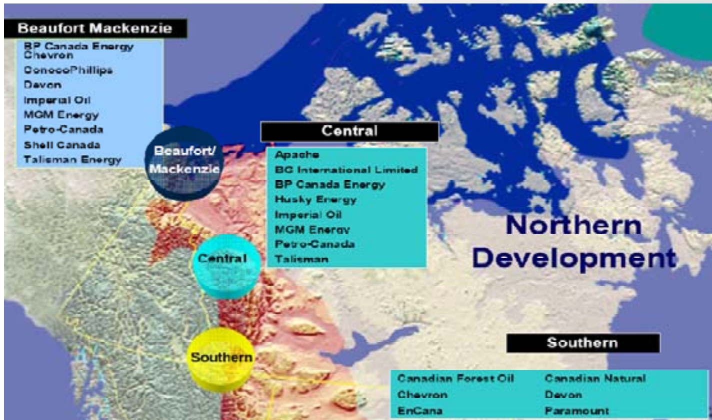
Who is CAPP

- **We are the voice of Canada's Upstream Oil and Gas Industry**
  - To enhance the well being and sustainability of the upstream Canadian oil and gas industry in a socially, environmentally and technically responsible and safe manner
- **130 producer member companies**
  - Explore for, develop and produce natural gas, natural gas liquids, crude oil, synthetic crude oil, bitumen and elemental sulphur throughout Canada
- **CAPP members produce more than 95 per cent of Canada's natural gas and crude oil**
- **150 associate members**
- **Offices in Calgary, Alberta and St. John's, Newfoundland & Labrador**

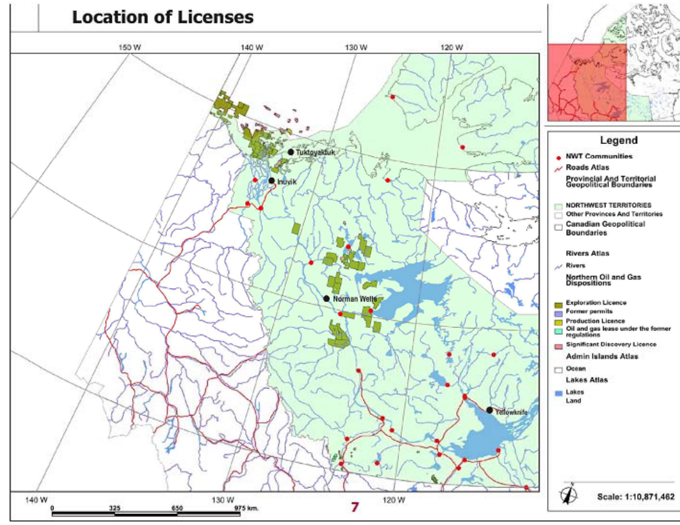
Ultimate Potential, Conventional Resources Oil and Gas Billions of Barrels Oil Equivalent

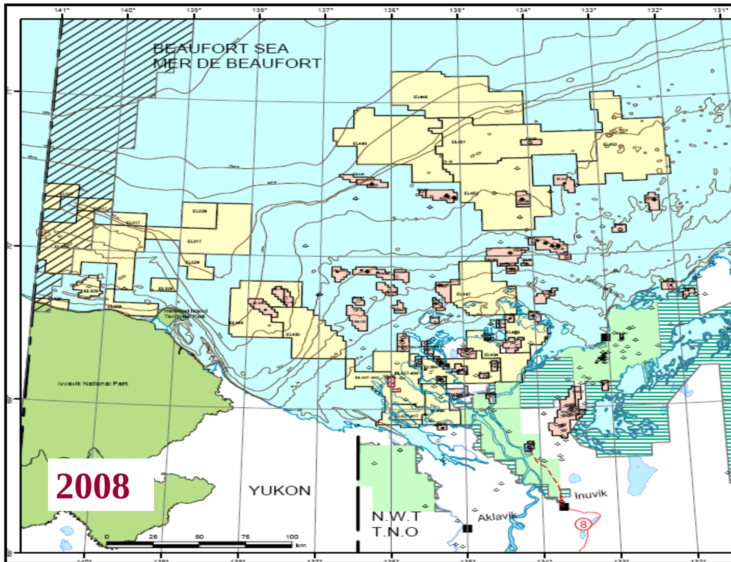


CAPP Members North of 60



Location of Licenses

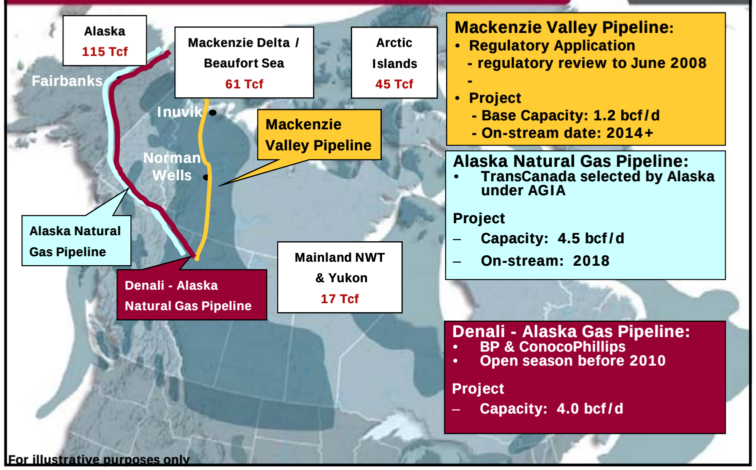




Recent Leasing Activity –Beaufort/Delta

	Work Commitment (in millions)
2001	0
2002	$14
2003	0
2004	$62
2005	0
2006	$51
2007	$598
2008	$1,200

Northern Natural Gas: Ultimate Potential and Proposed Gas Routes



Challenges of Operating in Northern Canada

- **Regulatory System**
  - Complex and time consuming
  - Uncertainty over outcomes
  - Lack of coordination among regulatory agencies
- **Technical / Infrastructure**
  - Resource recovery in arctic conditions
  - MG Pipeline not yet approved
  - Limited activity where infrastructure exists
- **Environment**
  - High cost, harsh weather
  - High standards for environment and social stewardship
  - Serious geological risk

Research and Development

- **Research and Development is key to overcoming the challenges of operating in the North**
- **Research Drivers**
  - Recovery of conventional and unconventional resources in frontier areas and new basins
  - Address regulatory challenges
  - Provide information that will facilitate project level assessment
  - Provide information to assist in understanding the physical and biological environments
  - Address rising stakeholder expectations regarding environmental and social performance

Research and Development

- **Canadian Government is supportive of Northern R&D effort**
  - ARS, science vessels, directed R&D funding
- **Collaboration is needed between Industry/Government R&D funders**
  - Reduces financial risk of R&D
  - Leveraging other funds/infrastructure
  - Proof of legitimacy
  - More funding = larger scope, higher quality
- **CAPP is fostering alliances with research stakeholders in order to advocate and advance interests in these strategic areas (e.g. participate in forums, research fund groups, arctic research station discussions, etc.)**
- **Strongly advocate for partnering to maximize the impact of R&D in the North and welcome opportunities to work with Canadian and U.S. partners in this area.**

Research and Development - Conclusion

- **Canadian Government has placed high priority on Canada's North by focusing on:**
  - Strengthening sustainable northern communities
  - Supporting individual and community economic self sufficiency
  - Creating incentive for developing infrastructure
  - Supporting claim to arctic sovereignty and security through physical presence
- **Industry is supportive of Canadian Government northern goals and believe that oil and gas activity and associated R&D will be playing an integral part of Canada's broader vision for the north**

5.2 TECHNICAL – ENGINEERING

5.2.1 Alaskan Beaufort and North Slope Solid Waste Disposal Under the UIC Program, *Thor Cutler*

LEG, LHG, LG, CPG, Environmental Scientist, U.S. Environmental Protection Agency. Email: Cutler.Thor@epa.gov

The Underground Injection Control (UIC) program is currently being used to manage solid waste in the Alaskan oilfields where the environmental conditions are sensitive and unique. The North Slope Arctic permafrost environment, geology, and hydrology present unique challenges for underground injection of waste and materials. Injection well design parameters based on geological and engineering/reservoir/down-hole constraints call for specialized construction, operations, and management to assure safe and protective operations for the workers and the environment.

The United States Environmental Protection Agency (EPA) and the Alaska Oil and Gas Conservation Commission (AOGCC) are responsible for the application and regulation of Class-I (EPA) and Class-II (AOGCC) injection wells in Alaska. The *Safe Drinking Water Act* and other laws set limits and conditions for underground injection. Under the regulatory framework established by the Federal EPA, the Class-II well program delegated to the State must meet or exceed federal regulatory standards. Over 1,200 Class-II injection wells (of which over 90% are enhanced oil recovery wells) are in use. These Class-II wells manage fluids extracted from the subsurface including produced brines and natural gas which must be re-injected because surface discharge is not allowed.

Class-I injection capability is critical to the development of oil and gas resources located in the North Slope. Class-I wells may accept all fluids eligible for Class-II injection plus other fluids that are non-hazardous. This capability of deep injection disposal, commonly one to two miles below the sensitive Arctic tundra surface, is an important component of a waste management strategy that integrates two goals: achieving zero surface discharge and reducing overall environmental impact.

North Slope operators have combined mechanical grinding and deep well injection to dispose of waste streams from oil and gas drilling and production activities. This in turn eliminates the traditional use of reserve pits for storage or disposal of drilling wastes, reduces the industrial footprint in the fragile Arctic environment, and provides an integrated approach to managing wastes from camp sewage systems, drilling, production, and maintenance operations. Fracture slurry injection technology has been successfully implemented in the North Slope of Alaska over the past 20 years to safely dispose produced solids, viscous fluids/sludge, tank bottoms, contaminated soils and drill cuttings. There are currently 15 active Class-I wells located at North Slope facilities and in the Cook Inlet areas.

In the future, EPA and industry will use UIC injection wells throughout the nation to address green house gases as climate change is a critical environmental issue of our times. EPA recently published a proposed new Class VI rule for carbon dioxide (CO_2) geosequestration that builds on the existing standards for deep injection wells while incorporating the challenges posed by CO_2 injection. The proposed geosequestration rule process is currently in the public comment stage. Injection of CO_2 for enhanced oil recovery is a long-standing industry practice. When a gas pipeline is built to Alaska, CO_2 may be separated in the future from the natural gas and either injected deep for geosequestration purposes or utilized for enhanced oil recovery.

U.S. and Canada Northern Oil and Gas Research Forum:
Current Status and Future Directions in the Beaufort Sea,
North Slope and MacKenzie Delta
Anchorage, Alaska Oct 28-30 2008

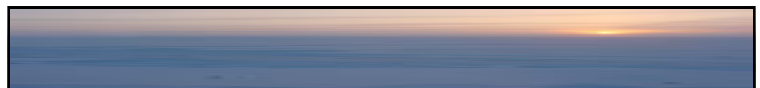
Underground Injection Control – Deep Injection of Oilfield Wastes

Thor Cutler, US EPA **cutler.thor@epa.gov**

EPA's **Underground Injection Control** (UIC) Alaska Waste Management: *Outline*

- Background
- Permitted Class I wells reduces Risk & Arctic Footprint
- Fracture Slurry Injection = No Mud Pits
- Carbon Capture and Storage "Geosequestration" of CO_2 Proposed New Rule Comment Period Open

See: Federal Register July 25, 2008



UIC Background

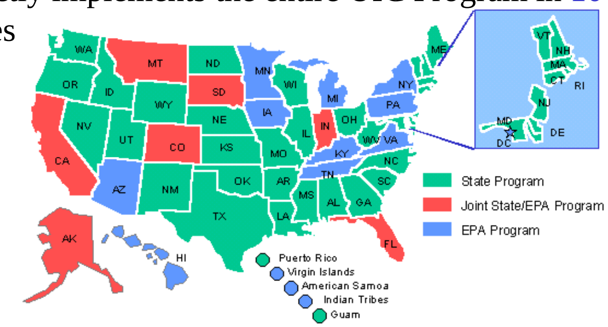
- The 1974 Safe Drinking Water Act (Reauthorized in 1996) SDWA
  - SETS Minimum federal regulations for *protection* of Underground Sources of Drinking Water (USDWs)
  - USDW defined:
    - Any aquifer or portion of an aquifer that contains water that is less than 10,000 total dissolved solids or contains a volume of water such that it is a present, or viable future, source for a Public Water Supply System

UIC Background

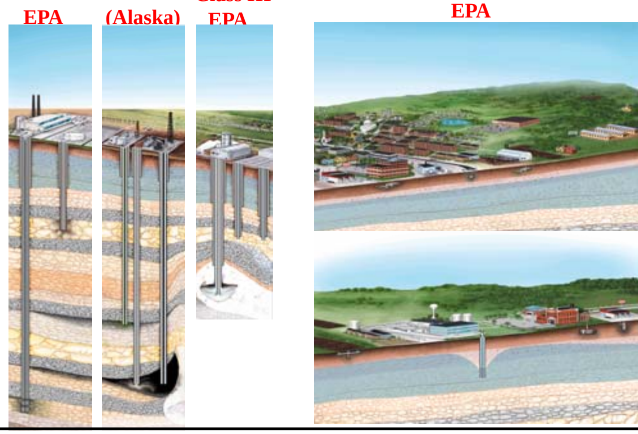
- UIC Program regulates underground injection of *all* fluids – liquid, gas, or slurry
  - Designation as a commodity does not change SDWA applicability
  - Some natural gas (hydrocarbon) storage, oil & gas production, and some hydraulic fracturing fluids exempted
- Existing UIC program provides a regulatory framework (baseline) for the Geologic Sequestration of CO_2

UIC Background: *Primacy*

- 33 States have primary enforcement authority (primacy) for the UIC program; EPA and States share program implementation in 7 States; EPA directly implements the entire UIC Program in 10 states



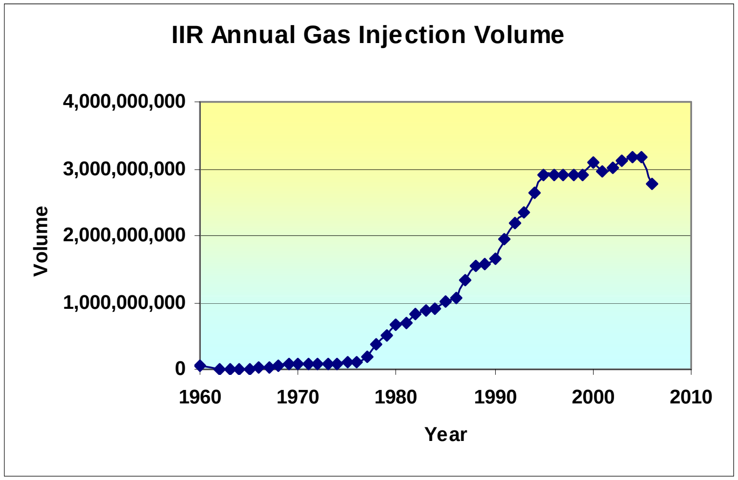
UIC Background: *UIC Well Classes*



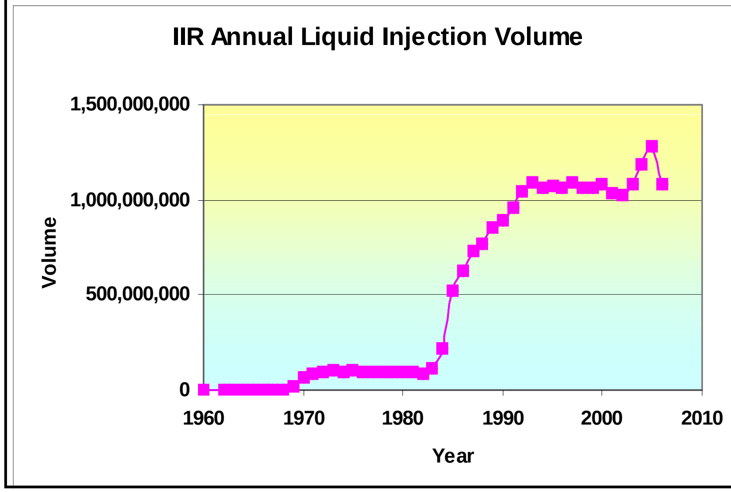
Safe Drinking Water Act Protects Groundwater and Ensures Fluids Are Injected Safely and Remains Where They Are Injected

- EPA sets minimum standards, manages (3000 wells in AK) Classes 1,3,4,5, new proposed Class 6 injection wells &All Tribal and oversight of State delegated Program
- Alaska Oil and Gas Conservation Commission manages over 1200 Class II enhanced oil recovery, storage and disposal injection wells. (With Federal EPA oversight)

3 Billion Cubic Feet Gas/Year Injected



Over 1 Billion Barrels Liquid/Year Injected



Class I Critical To Remote Arctic Fields

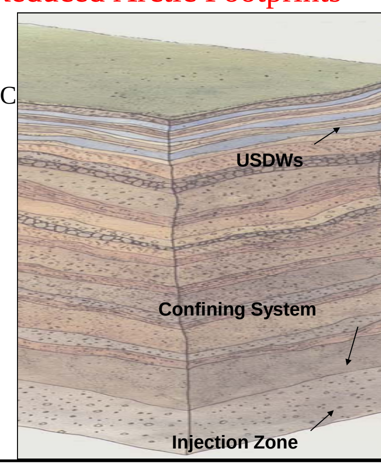
- Eligible Class II fluids: accept fluids generated (source): "up from down hole" unique to O/G exploration and production. (EOR, disposal, storage)
- Class I fluids include more sources: Non-Hazardous fluids, municipal waste, stormwater, RO waste, cuttings slurry, tank bottoms… plus Class II fluids.
- More stringent Class I wells (First well drilled) at remote New Fields, manage more wastes on site: **Onsite Class-1 disposal** **reduces risks** from spills/handling and transport (and road construction) impacts.

(EPA Mission: Human Health & Environment)

Class I Framework Critical to reduce surface Impacts: Zero Discharge and Reduced Arctic Footprints

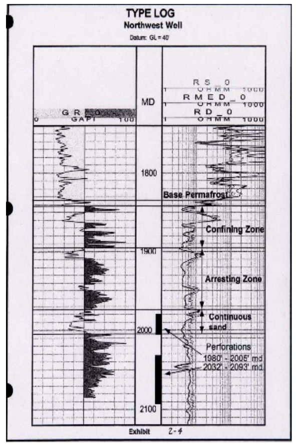
CLASS I is the most Stringent UIC Permit Program
Elements

Site Characterization
Area Of Review
Well Construction
Mechanical Integrity
Testing
Monitoring
Closure



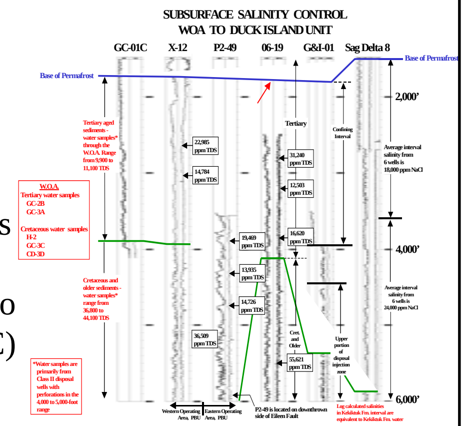
Unique Permafrost Subsurface

- Frozen soils and interstitial fluids are over 1000 feet thick near the coast.
- Base of the permafrost exceeds 1800 feet below the surface at Pad-3.
- Permafrost needs protection from melting.
- Cuttings Deep injection protects permafrost surface



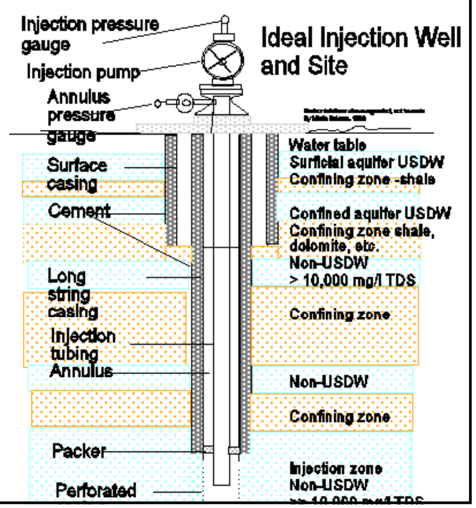
WOA to Duck Island Lower Tertiary and Cretaceous

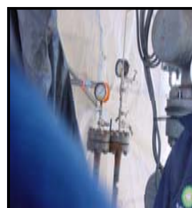
- Average interval salinities of confining intervals is 24,000 mg/l for lower Tertiary and Cretaceous sections from 3500 (permafrost base) to 6000 bgs (AOGCC)



Class I Permits: Best practices prevent leaks

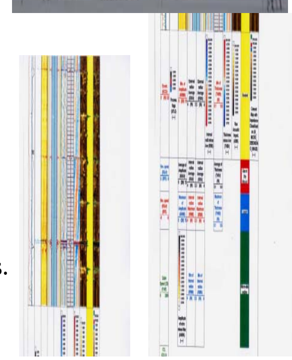
- Proper well construction.
- Tubing & packer.
- Mechanical integrity testing.
- "Arctic type lite" cements for first 1500-1800 feet (compressive strengths of 500 psi only).
- Class G cements below permafrost.





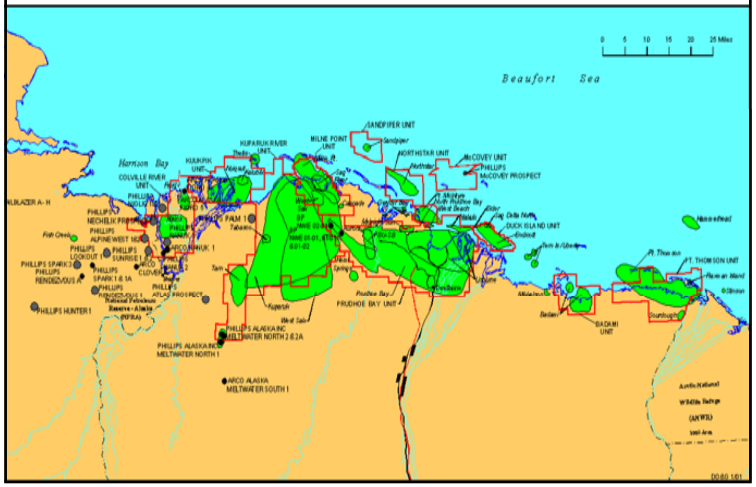
Class I Well Permit sets Mechanical Integrity Tests

- Internal Mechanical Integrity Tests
  tubing and packer (Standard Annulus Pressure Test)
- External Mechanical Integrity Test
  Oxygen Activation (**OA**) log methods with the Water Flow Log (**WFL**) and Temperature logs or Borax pulse neutron (**PNL**) logs with Temp logs. (Not RAT)
- Cement Logs for construction inspections.
- Step Rate Tests are important for wells operating over the fracture pressure.



North Slope Active Oil Fields

>-- 150 miles --<



Class I Permit Framework:

Allows Waste Managed and Injected **DEEP on Site**.

Less Handling: Safer for workers

Less Surface Transportation

Less Environmental Surface Impact

- Less surface travel: Less risk of damage to sensitive tundra, lakes, streams and ocean
- Less Spills: handling risk transport risk less
- Less dependence on GRAVEL ROAD systems and bridges (fewer gravel pits)
- Less dependence on ICE ROAD and barge (freshwater for ice needs are reduced)
- Less air emissions from vehicles
- Zero Discharge to surface tundra and ocean

Class I Onsite Disposal = Less dependence on Surface Transportation/Roads

- Rologon tundra travel is costly.
- Surface transportation adds potential for surface spills.
- Ice roads are available only several months each spring that connect outlying fields.

Gravel Drilling Pad Footprints Are Reduced

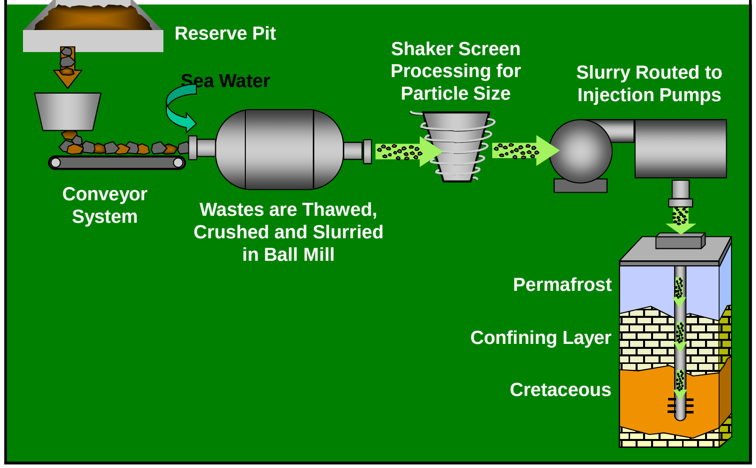
Drilling Technology Improvements

Reserve pits are removed/replaced with Class I

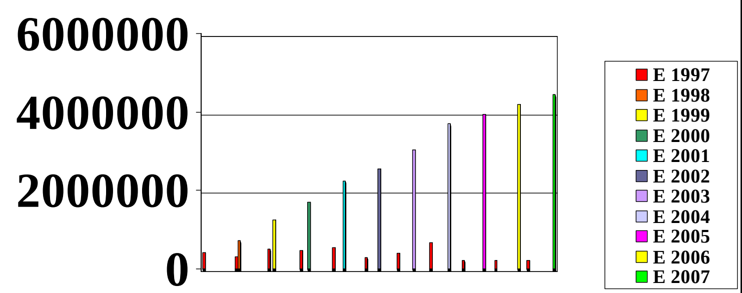
Grind and Inject Disposal

- Operators strive toward zero discharge to surface environments and Beaufort Sea Class I Injection ie RO waters
- Over 212 reserve pits Injected (Class I accepts non-haz fluids)
- Mud pits are replaced with small or mobile grind and inject systems to handle solids injectate to Class I wells

FSI Wells – North Slope of Alaska
Grind and Inject Project: Process (Figure from BPXA)



4.45 Million Cubic Yards
SOLIDS INJECTED to date



Grind and Inject Ball Mill (G&I)

- Ball mill and injection system operates in winter when surface waters are frozen.
- Long term maintenance is done during summer.

EPA Class I Framework for UIC Program
Permitted Oversight assures
Sound Well Integrity of Large scale
Fracture Slurry Injection

For solids placement, Class I Slurry wells operate **above the formation fracture pressure (modelled).**

<u>To reduce potential risks</u>: Sound Well Integrity includes:

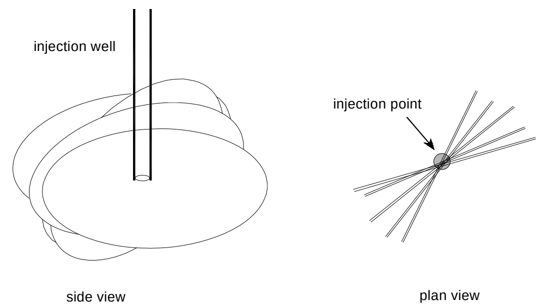
- Operations: For large volume disposal utilize more than one well to exploit cyclic injection benefits in terms of fracture growth and geometry (injection domain), and reduced system stresses.
- Best outcomes obtained with new wells designed for FSI.
- Rule out wells candidates with questionable integrity (tubulars or cement job).

EPA Class I UIC Program Oversight assures
Sound Well Integrity of Large scale FSI

To reduce potential risks: Sound Well Integrity includes:

- Good cement bonding be verified.
- Monitor well performance and system behavior.
- Well testing/logging such as Step Rate Tests, Pressure Falloff, Temp surveys and daily temp/pressure data are needed to verify mechanical integrity (both internal and external) on a regular (annual or bi-annual) basis.
- Also run caliper surveys of tubing and exposed section of casing to monitor corrosion/erosion impacts.

Series of Vertical Planar Fractures with Different Azimuths
Depicting the Disposal Domain Concept (based on Moschovidis et al. 1993)
(after Veil and Dusseault, 2003)



North Slope Drilling Pad **Large Footprint**

Class I Permitted Northstar Oilfield
SMALL Footprint,
Beaufort Sea

- **SMALL Footprint FIVE ACRES**
- **Zero Discharge to Ocean as 5 Billion Gallons** will be injected over 20 years at Northstar

Ooguruk Oil Field, SMALL FOOTPRINT (6 acres) Beaufort Sea (zero discharge)

EPA UIC Class I Program Framework-Mission:

Human Health and the Environment

- **Smaller Arctic footprint**
- **Zero surface discharge to Beaufort/tundra**
- **Class I Well = Waste is managed ONSITE**
  - ***reduces risk & dependence on roads/bridges**
- **Class I Permits: Well integrity/operational standards**
- **Class I framework modified to utilize:**
  - ***Fracture/Cuttings Slurry Injection = No mud pits/ reduces gravel pad**
  - ***Proposed New Rule Comment Period Open Now: Geosequestration of CO2 "Class 6 UIC Well" (first US federal climate mitigation regulation)**
    - Fed. Register July 25, 2008 Public Comment Period Open NOW

Proposed Rule: Carbon Dioxide Injection and Geologic Sequestration Rule

Public Comment Period is Open, and Closes November 2008

Office of Ground Water and Drinking Water
USEPA Office of Water

CO2 Sequestration Experience Weyburn Oilfield Saskatchewan, Canada

- **Canada's largest (20 Mt) sequestration project started 10/2000; Project life 20 -25 years**
- **CO2 supplied via a 205 mile long pipeline from a synfuels (coal gasification) plant in North Dakota**
- **Will Produce 122 million bbls of EOR oil over life**
- **Demonstrated CO_2 sequestration with current tech.**
- **Understanding CO_2 movement, Monitoring tech.**

EPA's Proposed GS Rule: *Approach to Rulemaking*

Special Considerations for GS

- Large Volumes
- Buoyancy
- Viscosity (Mobility)
- Corrosivity

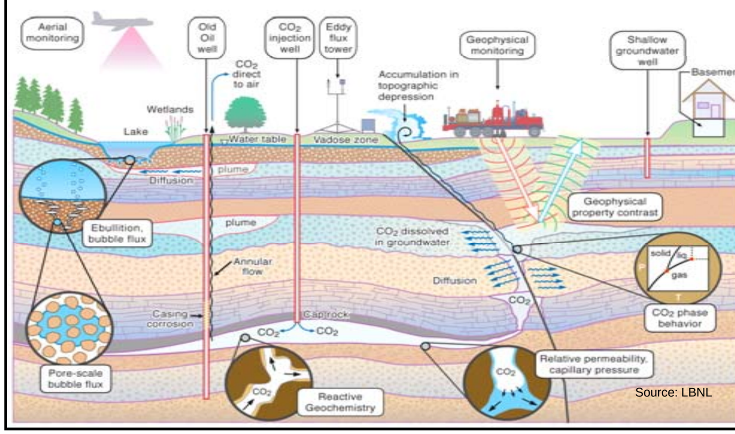
→

UIC Program Elements

- Site Characterization
- Area Of Review
- Well Construction
- Well Operation
- Site Monitoring
- Well Plugging and Post-Injection Site Care
- Public Participation
- Financial Responsibility
- Site Closure

Develop new well class for GS – Class VI

Storage Effectiveness is Critical



EPA's Proposed GS Rule: *Schedule*

Activity	Milestone
Technical Workshops, Data Collection & Analysis	Ongoing
Stakeholder Meetings	December 2007/February 2008
Interagency Review of Proposed Rule	Late May - Early June 2008
Administrator's Signature of Proposed Rule	July 15, 2008
Public Comment Period for Proposed Rule	July – November 24,2008
Notice of Data Availability (if appropriate)	2009
Final UIC Rule for GS of CO_2	Late 2010 / Early 2011

Thank you!

More information about the UIC Program

- cutler.thor@epa.gov
- EPA Geologic Sequestration of Carbon Dioxide Website – http://www.epa.gov/safewater/uic/wells_sequestration.html
- Code of Federal Regulations: Underground Injection Control Regulations 40 CFR 144-148 – http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?sid=d6ee71a544eca89c533c825135913f13&c=ecfr&tpl=/ecfrbrowse/Title40/40cfrv22_02.tpl

UIC Class I Program Protects the Environment

- **Smaller Arctic footprint**
- **Zero surface discharge to Beaufort**
- **Waste is managed onsite**
  ***reduces dependence on roads/bridges**
- **Well integrity required**
- **Permits set operational standards**
- **Class I framework modified to utilize Fracture Slurry Injection = eliminates mud pits**
- **Class I framework modified for proposed Geosequestration of CO2**
  - Fed. Register July 25, 2008 Public Comment Period Open NOW

5.2.2 Ice Engineering Issues for Beaufort Sea Development, *Garry Timco*

Ph.D., Group Leader, Cold Regions Technology, Canadian Hydraulics Centre, National Research Council of Canada, Ottawa, ON, Canada. Email: garry.timco@nrc.gc.ca

There are large proven oil and gas resources in the Beaufort Sea which have not yet been developed. Because of the harsh environment in this region, many technical challenges must be overcome to safely and economically develop these resources. The challenges are wide-ranging. The Canadian Hydraulics Centre (CHC) of the National Research Council of Canada in Ottawa has been building on their experience obtained in the Beaufort Sea during the 1970’s and 1980’s exploration period. Since that time, they have established a Centre of Ice-Structure Interaction in Ottawa and have been actively addressing many of the ice engineering challenges that will be faced in the Beaufort Sea.

This presentation will give an overview of their activities. They touch virtually every aspect of the Beaufort Sea ice engineering issues. An update will be given on the understanding of ice loads and local pressures on wide caisson structures. It will be shown that there is good knowledge and understanding in this area with respect to loads from first-year ice. A quick overview of the physical and numerical approaches that the CHC use for estimating ice loads will be shown. Techniques will be discussed to look at means of reducing ice loads for production structures using Ice Rubble Generators. Information will be presented on the results of numerous Arctic field trips to measure the strength, thickness, salinity, temperature and movement of the multi-year ice in many regions in the Arctic. Marine transportation will play a key role both in terms of marine support and possibly moving the hydrocarbons to market. The CHC has been working with Transport Canada to revise the Arctic Shipping Pollution Prevention Regulations. Forecasting of ice movement is also important for marine operations and the CHC has developed the forecast models used by the Canadian Ice Service. These are being extended to predict pressured-ice regions in real time in the Arctic. Pipelines buried in the seabed might also be an option for moving the hydrocarbons to markets. The CHC has investigated seabed scour by ice through dedicated laboratory tests and a sophisticated Particle-in-Cell numerical model. Safe evacuation of personnel is a key component and the CHC has done considerable research in this area, especially with respect to ice environments and their implications on potential evacuation approaches, and in establishing Guidelines for on-ice Evacuation Shelters. Finally, some thoughts on key research issues will be presented, both for exploration and production structures in the Beaufort Sea.


Ice Engineering Issues for Beaufort Sea Development
Dr. Garry Timco
Canadian Hydraulics Centre
National Research Council of Canada
Ottawa, Ont. K1A 0R6 Canada
CHC
NRC·CNRC


Offshore Structures
1 - What are the ice conditions at the site?
2 - What are the design ice loads?
3 - Can we reduce the ice loads?
4 - How will we get the hydrocarbons out?
5 - How can we ensure safety of personnel onboard?


A Look at the Beaufort Sea
• The ice in the Beaufort Sea is extremely hazardous for offshore structures, ships and pipelines
• Understanding ice forces & pressures, ice behaviour and how to "use" the ice to our advantage is the key to offshore development


Exploration Platforms
To date, there have been over 140 offshore exploration wells drilled in the Canadian and American Beaufort Sea
This has given us a wealth of information (and some knowledge) about operating in this harsh environment

Previous Exploration Platforms

NRC Centre of Ice/Structure Interaction

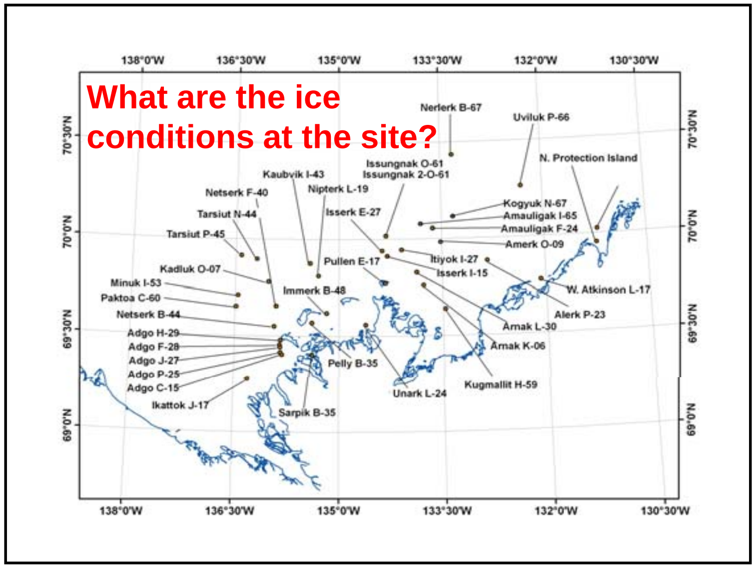
- In the mid-1980s, the Centre of Ice/Structure Interaction was established at the NRC Canadian Hydraulics Centre (CHC) in Ottawa
- Sponsored by Program of Energy Research and Development (PERD)
- Direct involvement with the Oil Industry:
  - Gulf Canada Resources Ltd.
  - Canmar (Dome Petroleum)
  - Imperial Oil (ESSO)
- NRC Centre contains all Beaufort Sea data and reports

Key NRC-CHC Personnel

The Canadian Hydraulics Centre is a Technology Centre (Business Unit) of the National Research Council of Canada

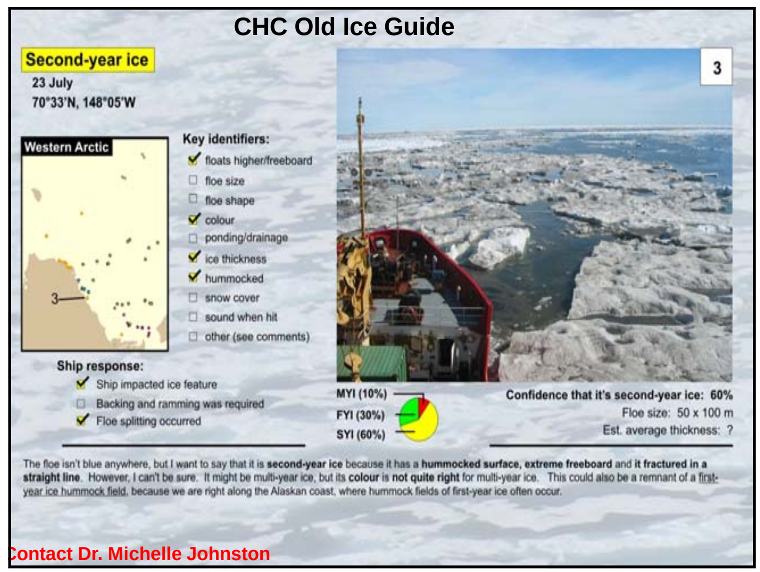
Dr. Bob Frederking
Dr. Mohamed Sayed
Dr. Michelle Johnston
Mrs. Ivana Kubat
Mrs. Anne Barker
Dr. Paul Barrette
Mrs. Anne Collins
Ms. Denise Sudom
Dr. Garry Timco (GL)

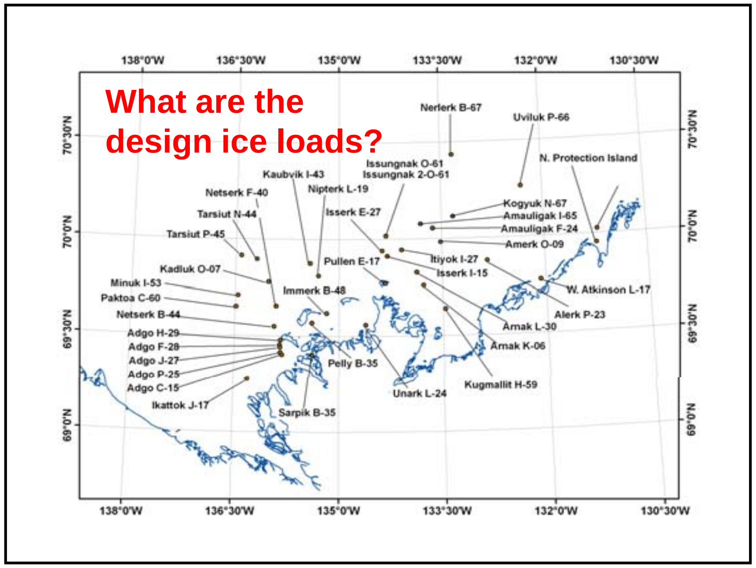
Cold Regions Technology: Four Methodologies

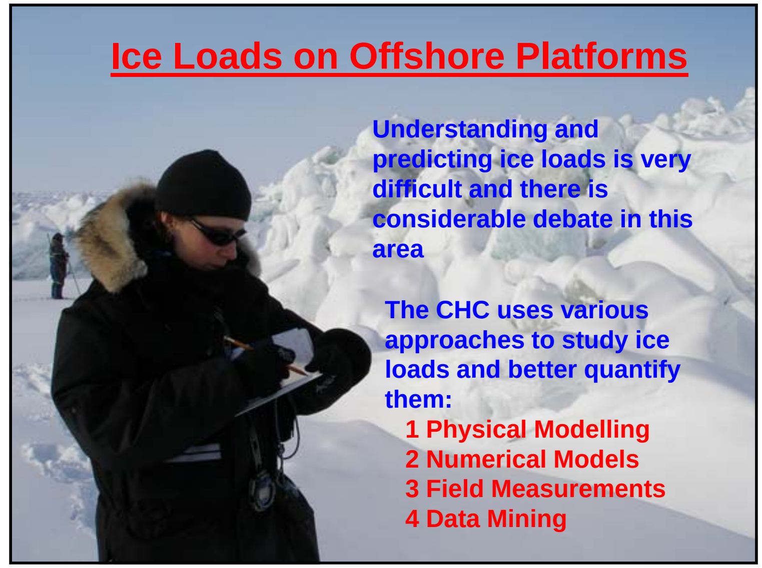

What are the ice conditions at the site?
138°0'W
136°30'W
135°0'W
133°30'W
132°0'W
130°30'W
70°30'N
70°0'N
69°30'N
69°0'N
Nerlerk B-67
Uviluk P-66
N. Protection Island
Issungnak O-61
Issungnak 2-O-61
Kaubvik I-43
Nipterk L-19
Netserk F-40
Tarsiut N-44
Isserk E-27
Tarsiut P-45
Kogyuk N-67
Amauligak I-65
Amauligak F-24
Amerk O-09
Itiyok I-27
Isserk I-15
Pullen E-17
Kadluk O-07
Minuk I-53
Paktoa C-60
Immerk B-48
W. Atkinson L-17
Alerk P-23
Netserk B-44
Arnak L-30
Arnak K-06
Adgo H-29
Adgo F-28
Adgo J-27
Adgo P-25
Adgo C-15
Pelly B-35
Ikattok J-17
Sarpik B-35
Unark L-24
Kugmallit H-59

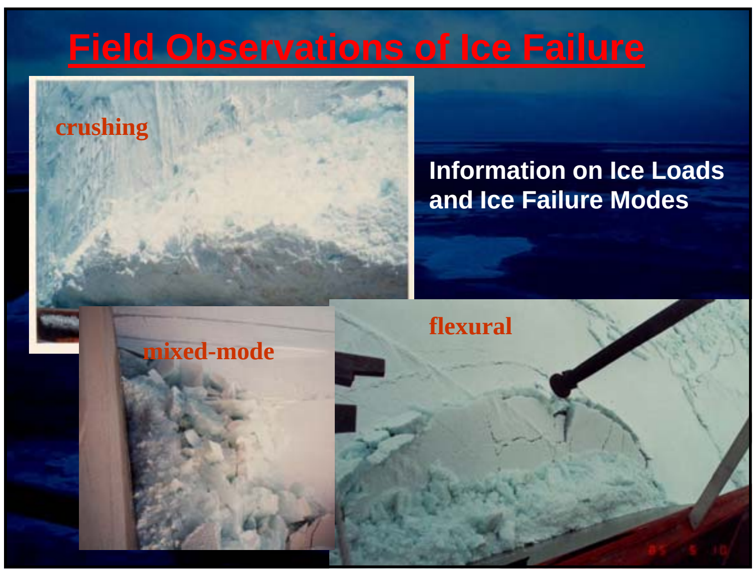

Multi-Year Ice
Multi-year ice is either directly (or indirectly) involved in 75% of the ship damage incidents in the Canadian Arctic (Kubat and Timco, 2000)
Multi-year ice causes the highest loads on offshore structures (Timco and Johnston, 2003)
15 Captains identified the detection of multi-year ice as the key concern for year-round shipping in the Arctic (Timco et al., 2005)

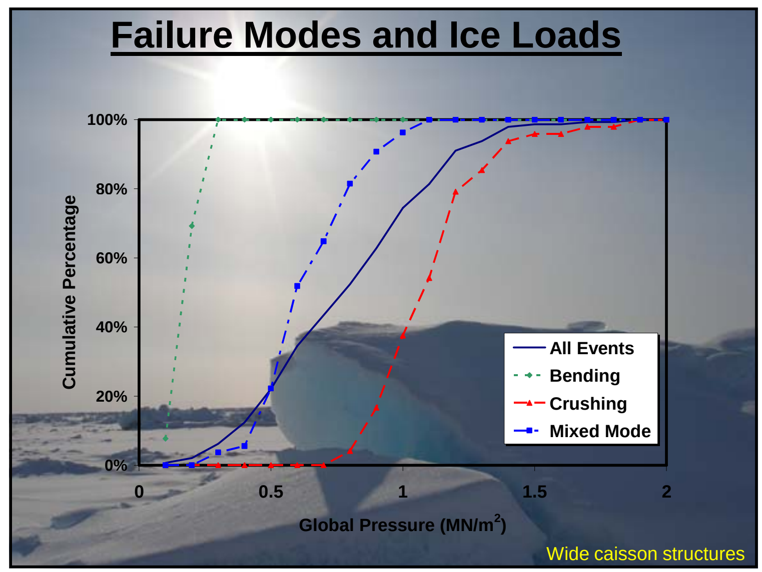

Field Measurements of Multi-year Ice
The CHC has carried out field measurements on multi-year ice for several years:
• Thickness (drilling and EM)
• Salinity
• Temperature
• Grain structure
• In situ Strength
• Floe size
• Internal temperature during decay
• Drift of ice floes
• Techniques for identifying Old Ice
Contact Dr. Michelle Johnston


CHC Old Ice Guide
Second-year ice
23 July
70°33'N, 148°05'W
3
Western Arctic
Key identifiers:
floats higher/freeboard
floe size
floe shape
colour
ponding/drainage
ice thickness
hummocked
snow cover
sound when hit
other (see comments)
Ship response:
Ship impacted ice feature
Backing and ramming was required
Floe splitting occurred
MYI (10%)
FYI (30%)
SYI (60%)
Confidence that it's second-year ice: 60%
Floe size: 50 x 100 m
Est. average thickness: ?
The floe isn't blue anywhere, but I want to say that it is second-year ice because it has a hummocked surface, extreme freeboard and it fractured in a straight line. However, I can't be sure. It might be multi-year ice, but its colour is not quite right for multi-year ice. This could also be a remnant of a first-year ice hummock field, because we are right along the Alaskan coast, where hummock fields of first-year ice often occur.
Contact Dr. Michelle Johnston

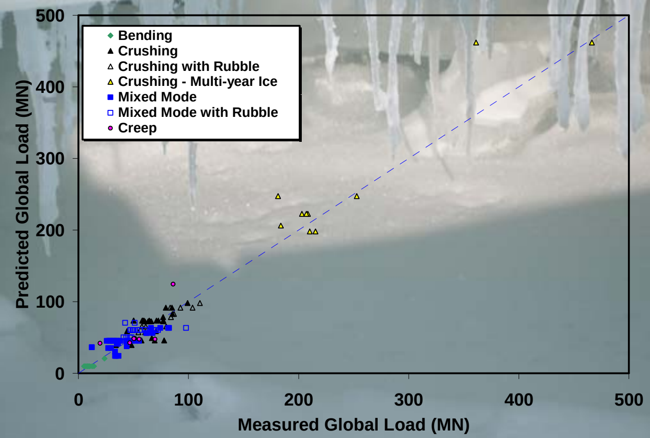

What are the design ice loads?
138°0'W
136°30'W
135°0'W
133°30'W
132°0'W
130°30'W
70°30'N
70°0'N
69°30'N
69°0'N
Nerlerk B-67
Uviluk P-66
N. Protection Island
Issungnak O-61
Issungnak 2-O-61
Kaubvik I-43
Netserk F-40
Nipterk L-19
Tarsiut N-44
Isserk E-27
Kogyuk N-67
Amauligak I-65
Amauligak F-24
Amerk O-09
Tarsiut P-45
Pullen E-17
Itiyok I-27
Isserk I-15
Kadluk O-07
Minuk I-53
Immerk B-48
W. Atkinson L-17
Paktoa C-60
Netserk B-44
Alerk P-23
Amak L-30
Adgo H-29
Adgo F-28
Adgo J-27
Adgo P-25
Adgo C-15
Pelly B-35
Arnak K-06
Kugmallit H-59
Unark L-24
Ikattok J-17
Sarpik B-35


Ice Loads on Offshore Platforms
Understanding and predicting ice loads is very difficult and there is considerable debate in this area
The CHC uses various approaches to study ice loads and better quantify them:
1 Physical Modelling
2 Numerical Models
3 Field Measurements
4 Data Mining


Field Observations of Ice Failure
crushing
Information on Ice Loads and Ice Failure Modes
mixed-mode
flexural


Failure Modes and Ice Loads
100%
80%
60%
40%
20%
0%
Cumulative Percentage
0
0.5
1
1.5
2
Global Pressure (MN/m²)
All Events
Bending
Crushing
Mixed Mode
Wide caisson structures

Predictive Equations for Ice Loads



Contact: Dr. Garry Timco

How Well Can We Predict Ice Loads?

The Structure

Vertical-sided with 100 m diameter in Arctic waters. Assume that it is perfectly rigid and that it has a low friction coating.

The Ice

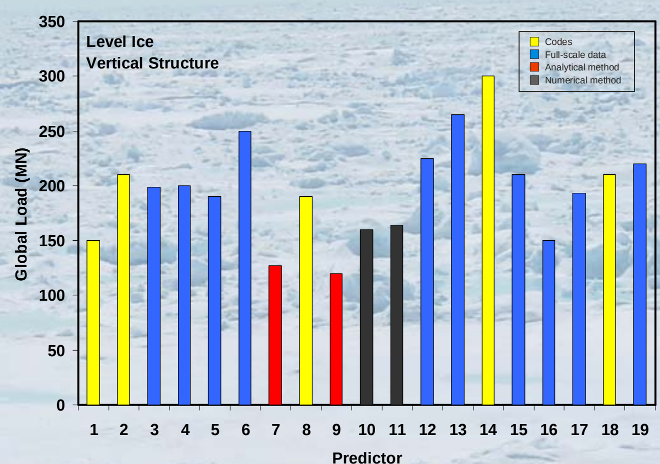
Different ice scenarios were used including level ice, first-year ridge, multi-year floe.

The Question

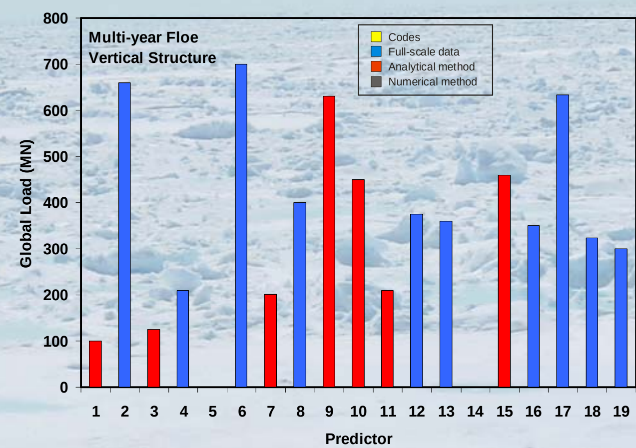
What is the Design Load for this situation?

This question was asked to over 20 international experts in ice mechanics

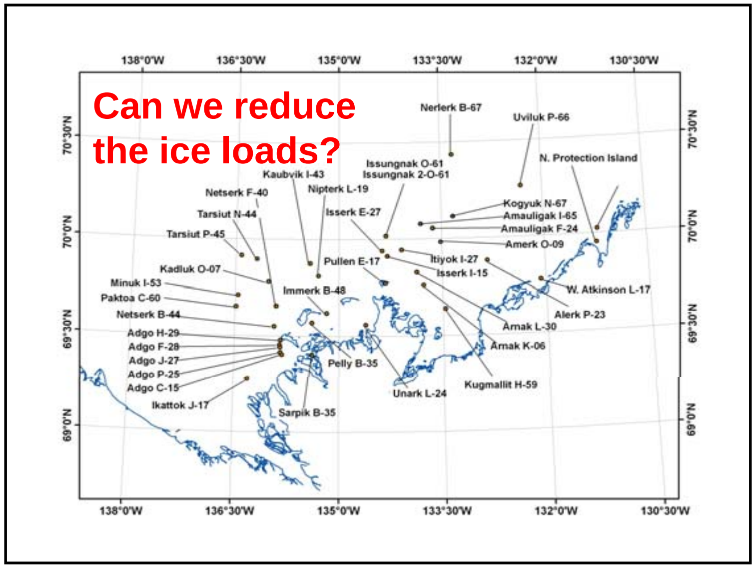
Predictions for First-Year Level Ice

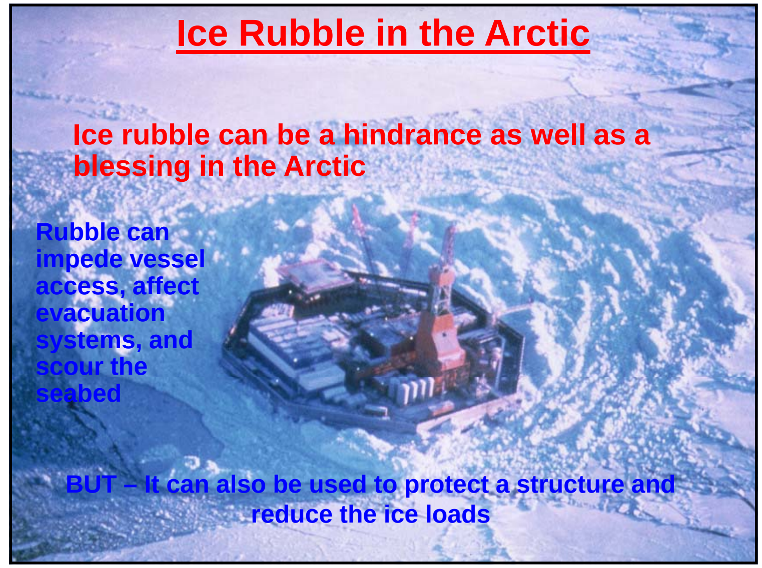


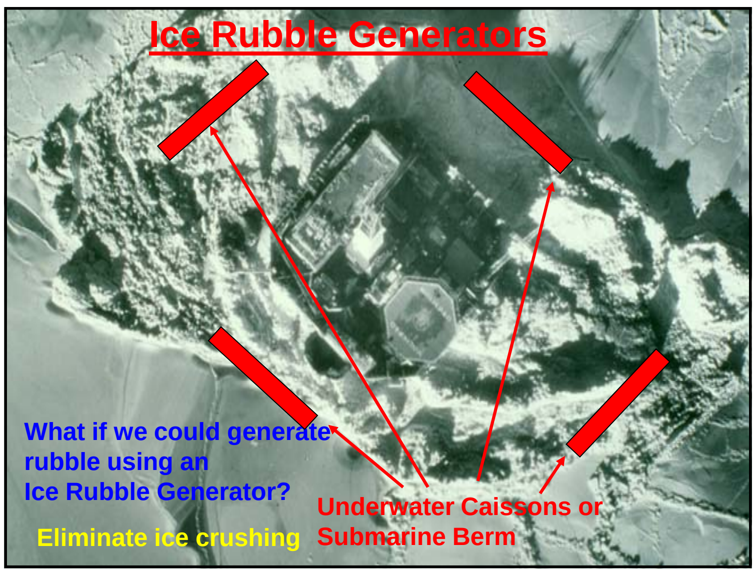
Predictions for Multi-Year Ice

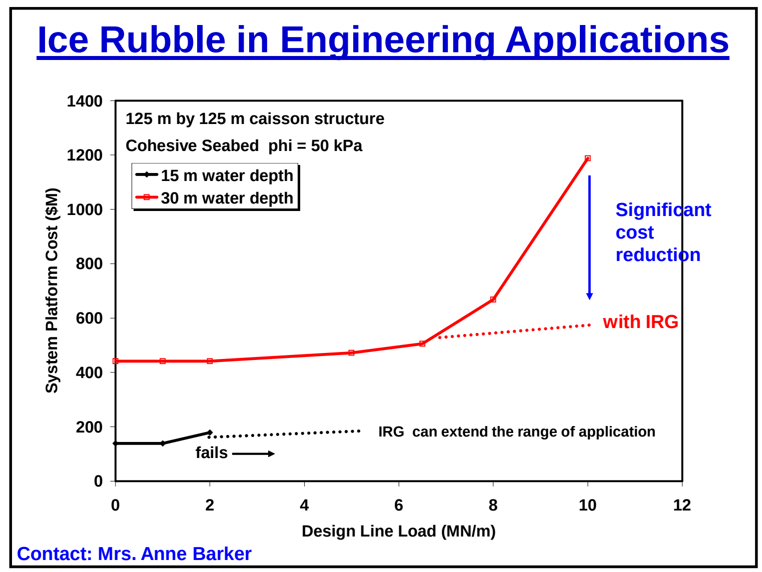


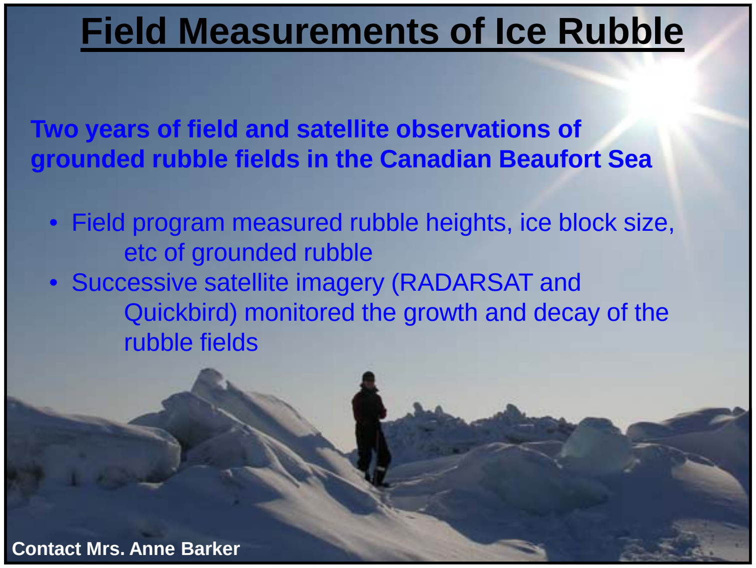
Contact Dr. Bob Frederking ---JIP project

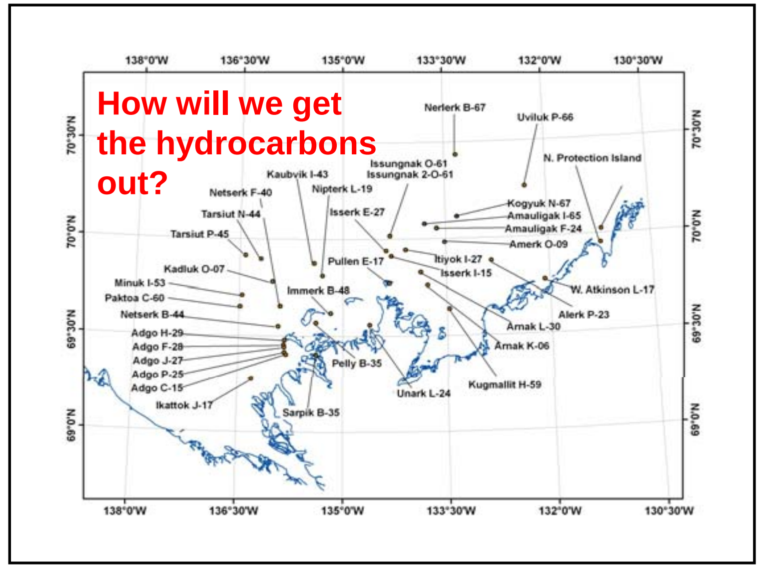

Can we reduce
the ice loads?
138°0'W
136°30'W
135°0'W
133°30'W
132°0'W
130°30'W
70°30'N
70°0'N
69°30'N
69°0'N
Nerlerk B-67
Uviluk P-66
N. Protection Island
Issungnak O-61
Issungnak 2-O-61
Kaubvik I-43
Netserk F-40
Nipterk L-19
Tarsiut N-44
Isserk E-27
Tarsiut P-45
Kogyuk N-67
Amauligak I-65
Amauligak F-24
Amerk O-09
Pullen E-17
Itiyok I-27
Isserk I-15
Kadluk O-07
Minuk I-53
Paktoa C-60
Netserk B-44
Immerk B-48
W. Atkinson L-17
Alerk P-23
Adgo H-29
Adgo F-28
Adgo J-27
Adgo P-25
Adgo C-15
Arnak L-30
Arnak K-06
Pelly B-35
Ikattok J-17
Unark L-24
Kugmallit H-59
Sarpik B-35

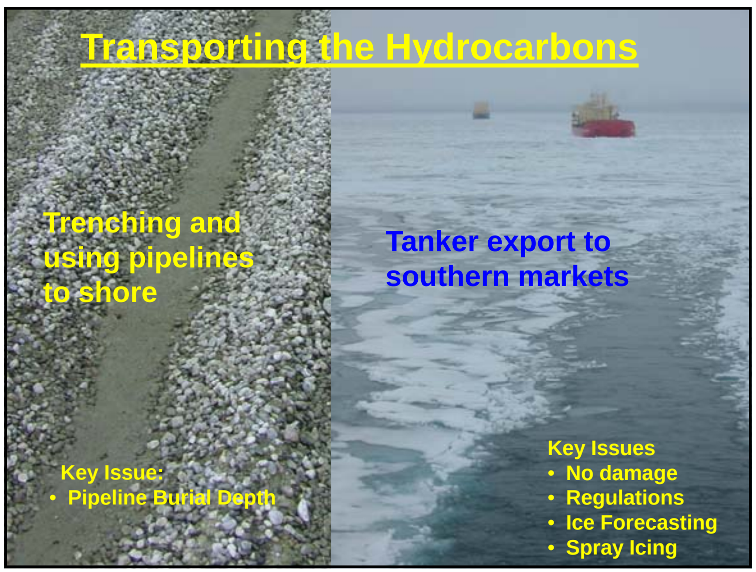

Ice Rubble in the Arctic
Ice rubble can be a hindrance as well as a blessing in the Arctic
Rubble can impede vessel access, affect evacuation systems, and scour the seabed
BUT – It can also be used to protect a structure and reduce the ice loads

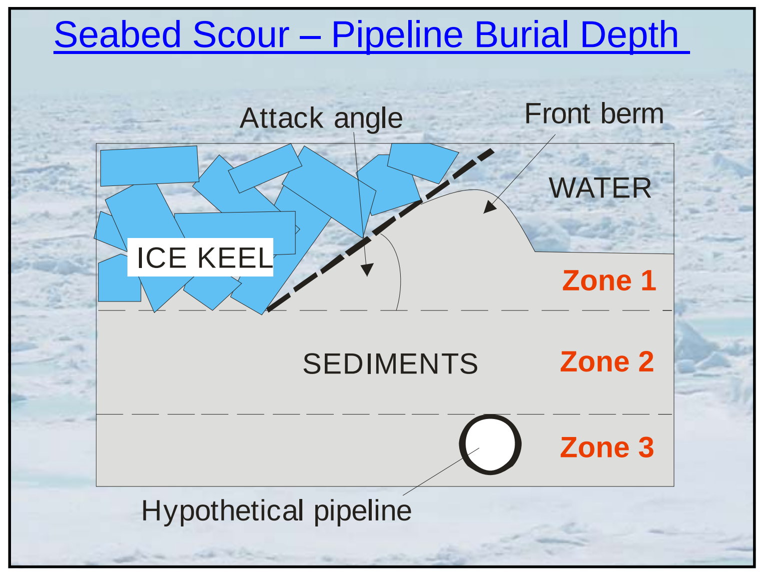

Ice Rubble Generators
What if we could generate rubble using an
Ice Rubble Generator?
Eliminate ice crushing
Underwater Caissons or
Submarine Berm

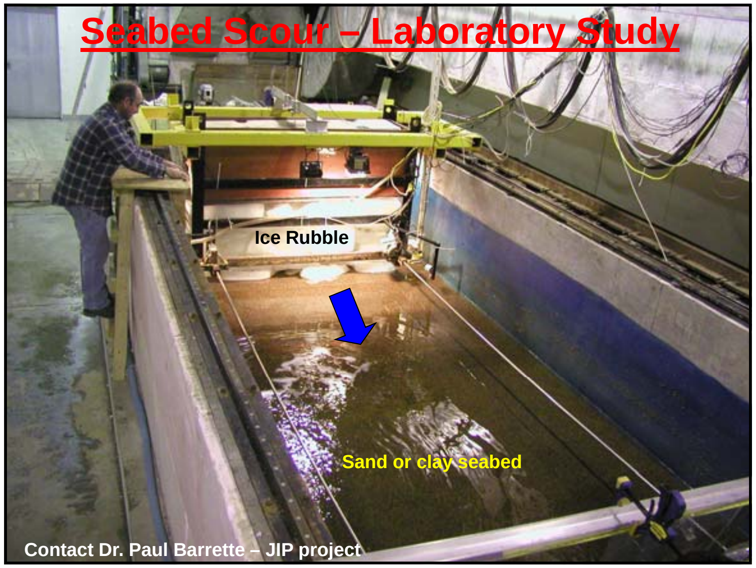

Ice Rubble in Engineering Applications
125 m by 125 m caisson structure
Cohesive Seabed phi = 50 kPa
15 m water depth
30 m water depth
System Platform Cost ($M)
0
200
400
600
800
1000
1200
1400
Design Line Load (MN/m)
0
2
4
6
8
10
12
Significant cost reduction
with IRG
IRG can extend the range of application
fails
Contact: Mrs. Anne Barker

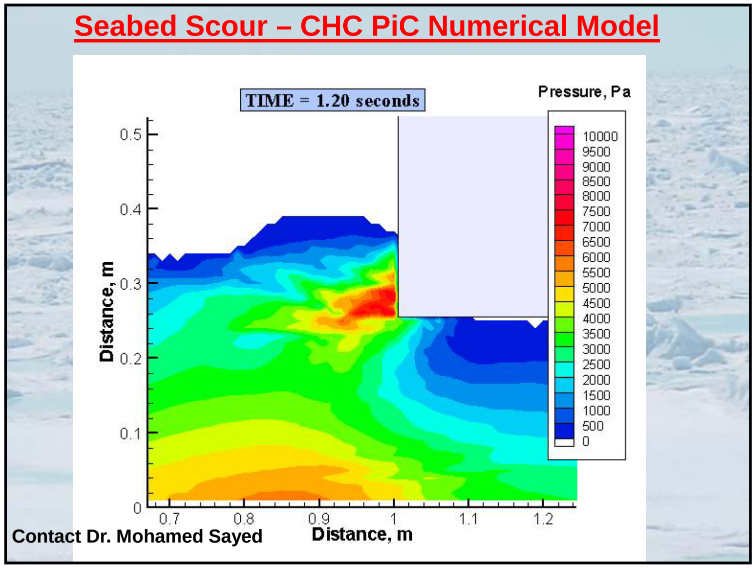

Field Measurements of Ice Rubble
Two years of field and satellite observations of grounded rubble fields in the Canadian Beaufort Sea
• Field program measured rubble heights, ice block size, etc of grounded rubble
• Successive satellite imagery (RADARSAT and Quickbird) monitored the growth and decay of the rubble fields
Contact Mrs. Anne Barker


How will we get the hydrocarbons out?
138°0'W
136°30'W
135°0'W
133°30'W
132°0'W
130°30'W
70°30'N
70°0'N
69°30'N
69°0'N
Nerlerk B-67
Uviluk P-66
N. Protection Island
Issungnak O-61
Issungnak 2-O-61
Kaubvik I-43
Nipterk L-19
Netserk F-40
Tarsiut N-44
Isserk E-27
Tarsiut P-45
Kogyuk N-67
Amauligak I-65
Amauligak F-24
Amerk O-09
Itiyok I-27
Isserk I-15
Pullen E-17
Kadluk O-07
Minuk I-53
Paktoa C-60
Immerk B-48
W. Atkinson L-17
Netserk B-44
Alerk P-23
Arnak L-30
Adgo H-29
Adgo F-28
Adgo J-27
Adgo P-25
Adgo C-15
Arnak K-06
Pelly B-35
Ikattok J-17
Unark L-24
Kugmallit H-59
Sarpik B-35


Transporting the Hydrocarbons
Trenching and using pipelines to shore
Tanker export to southern markets
Key Issue:
• Pipeline Burial Depth
Key Issues
• No damage
• Regulations
• Ice Forecasting
• Spray Icing


Seabed Scour – Pipeline Burial Depth
Attack angle
Front berm
WATER
ICE KEEL
Zone 1
SEDIMENTS
Zone 2
Zone 3
Hypothetical pipeline

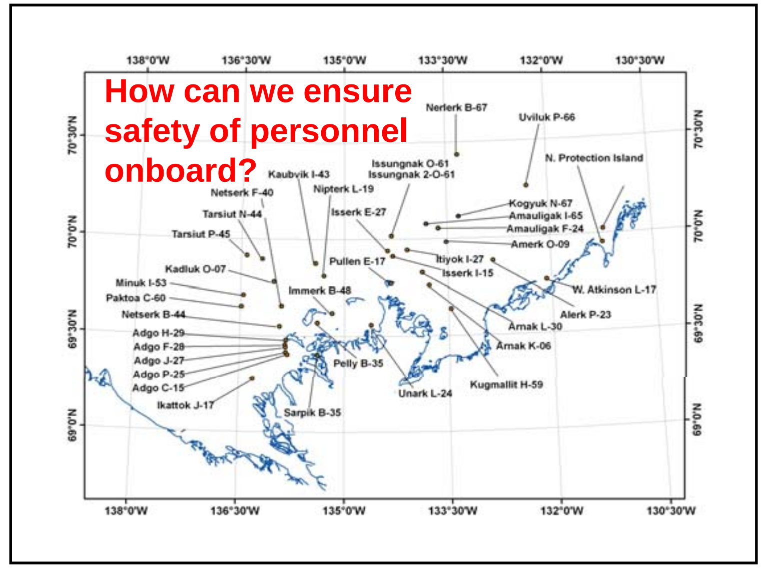

Seabed Scour – Laboratory Study
Ice Rubble
Sand or clay seabed
Contact Dr. Paul Barrette – JIP project

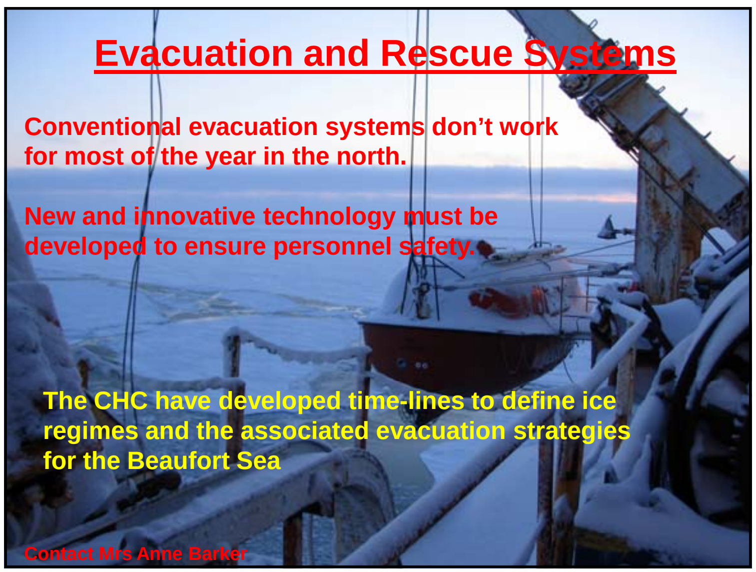

Seabed Scour – CHC PiC Numerical Model
TIME = 1.20 seconds
Pressure, Pa
Distance, m
Distance, m
Contact Dr. Mohamed Sayed

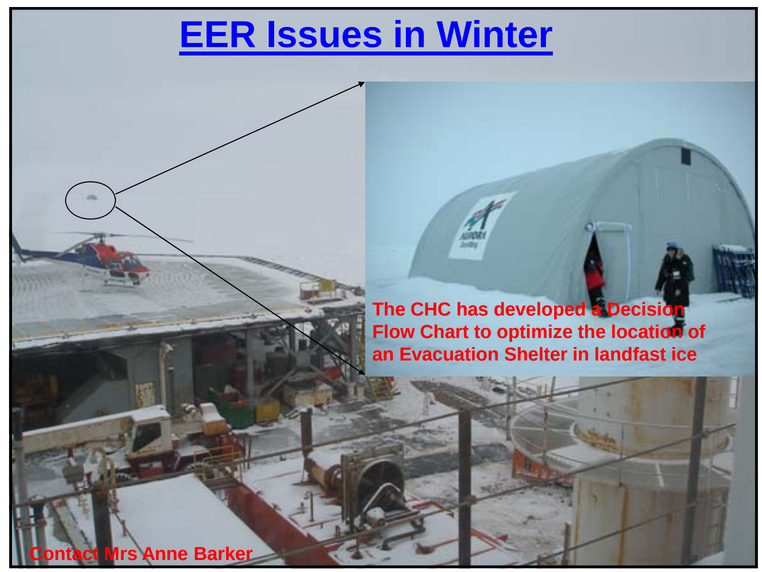

Safe Navigation through Ice-covered Waters
CHC
TP 14732E
Discussion Paper
Regulatory Update for Shipping in Canada's Arctic Waters: Options for an Ice Regime System
G.W. Timco and I. Kubat
Polar Class 7 Vessel
1986
Technical Report CHC-TR-045
March 200
Contact Dr. Garry Timco or Mrs. Ivana Kubat


Forecasting of Pressured Ice
Contact Mrs. Ivana Kubat


Spray Icing
CHC/NRC has complied a database of marine spray icing events
Contact Mrs. Ivana Kubat


How can we ensure safety of personnel onboard?
138°0'W
136°30'W
135°0'W
133°30'W
132°0'W
130°30'W
70°30'N
70°0'N
69°30'N
69°0'N
Nerlerk B-67
Uviluk P-66
N. Protection Island
Issungnak O-61
Issungnak 2-O-61
Kaubvik I-43
Nipterk L-19
Netserk F-40
Tarsiut N-44
Isserk E-27
Kogyuk N-67
Amauligak I-65
Amauligak F-24
Amerk O-09
Tarsiut P-45
Pullen E-17
Itiyok I-27
Isserk I-15
Kadluk O-07
Minuk I-53
Paktoa C-60
Immerk B-48
W. Atkinson L-17
Alerk P-23
Netserk B-44
Arnak L-30
Arnak K-06
Adgo H-29
Adgo F-28
Adgo J-27
Adgo P-25
Adgo C-15
Pelly B-35
Unark L-24
Kugmallit H-59
Ikattok J-17
Sarpik B-35


Evacuation and Rescue Systems
Conventional evacuation systems don't work for most of the year in the north.
New and innovative technology must be developed to ensure personnel safety.
The CHC have developed time-lines to define ice regimes and the associated evacuation strategies for the Beaufort Sea
Contact Mrs Anne Barker

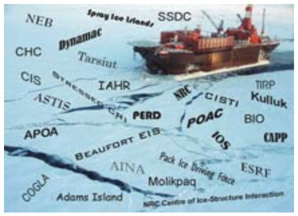

EER Issues in Winter
The CHC has developed a Decision Flow Chart to optimize the location of an Evacuation Shelter in landfast ice
Contact Mrs Anne Barker

Beaufort Sea Historical Information

CHC CANADIAN HYDRAULICS CENTRE / CENTRE D'HYDRAULIQUE CANADIEN

Overview of Historical Canadian Beaufort Sea Information

G.W. Timco and R. Frederking



NRC Canadian Hydraulics Centre
Technical Report CHC-TR-057

October 2008

The NRC-CHC has written and overview report on the historical information from the Beaufort Sea

Electronic copies can be found on their website www.chc.nrc.ca and follow the links through Cold Regions and Reports

Key Research Areas for the Arctic

- Research for Exploration Systems

- Research for Production Systems:
  - Extreme Ice Features
  - Rubble (broken) Ice – Friend or Foe?
  - Design Considerations
  - Operational Considerations

Key Research - Exploration Systems

Some Key Issues:

- Seismic Issues
- Sliding resistance of spray ice pads
- Same season relief well capability
- Transportation infrastructure
- Defining design ice loads
- Ice rubble protection in deeper waters
- Emergency evacuation and rescue issues

Design Issues for Production Systems

- Global and local ice loads (probabilistic approach) – site specific
- Grounded rubble / spray ice for protection or on-ice storage
- Stability of grounded rubble
- Transportation issues & ice management
- Seabed scour (pipelines)
- Climate change issues
- Design of suitable evacuation and rescue systems
- Extreme Ice Features

Extreme Ice Features

- Multi-year ice, second-year ice, ice ridges, hummock fields, large isolated floes and stamukha
- Define design criteria for the platform, shipping and pipelines
- No clear picture of the physical properties, mechanical properties, floe size, decay, etc.

Key Research:
(1) Consolidate available information, &
(2) Field measurements of ice properties

Operational Requirements for Production Systems

- Safe transportation of personnel and goods
- Non-polluting offloading and shipping of the hydrocarbons
- Optimized vessel routing to reduce time and interaction with extreme ice features
- Ice management around the structure
- Climate change issues
- Emergency evacuation and rescue operational issues

CHC Website

The Canadian Hydraulics Centre of NRC maintains a website with over 250 reports and papers related to cold regions technology.

It can be found at www.chc.nrc.ca and follow the Cold Regions Technology path

Final Comments

Canada has considerable expertise with ice engineering issues

- There are still many unsolved problems that cannot be solved overnight
- Continued co-ordinated research in this area is the key to understanding and addressing these issues

Timing is a key ingredient – the (now grey hair) experience from the 1970s and 80s must be cultivated and utilized

5.2.3 Ice Road Construction and Recovery on Tundra Ecosystems, National Petroleum Reserve, Alaska (NPR-A), *Scott Guyer, Bruce Keating & John Payne*

Alaska State Office, Bureau of Land Management, Anchorage, Alaska. Email: sguyer@ak.blm.gov

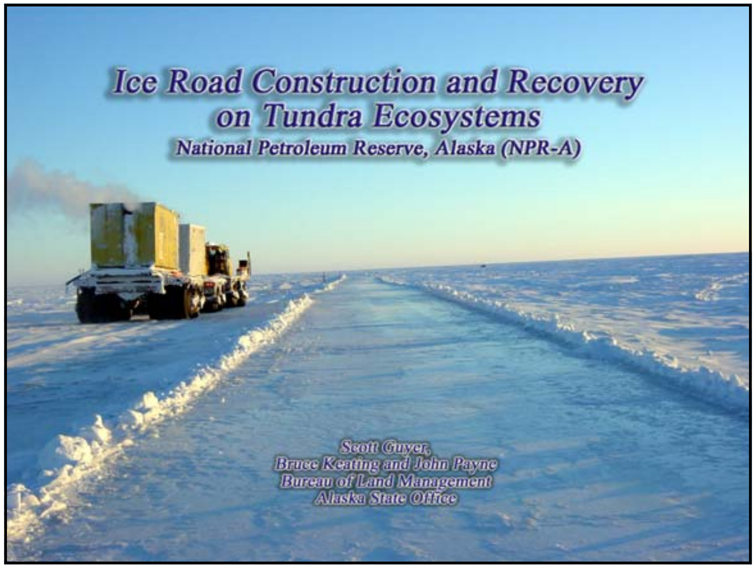
Over the last decade oil companies have been using ice roads and ice pads to support exploratory drilling in Alaska's National Petroleum Reserve (NPR-A). Ice roads are used during the winter to haul equipment and supplies to the drill sites, which are later removed from the sites before the ice thaws in the spring. Ice roads are constructed by packing snow into a road base, and then using water and ice shavings from local lakes to build up the ice surface. The construction and use of ice roads by the petroleum industry has provided access to environmentally sensitive areas.

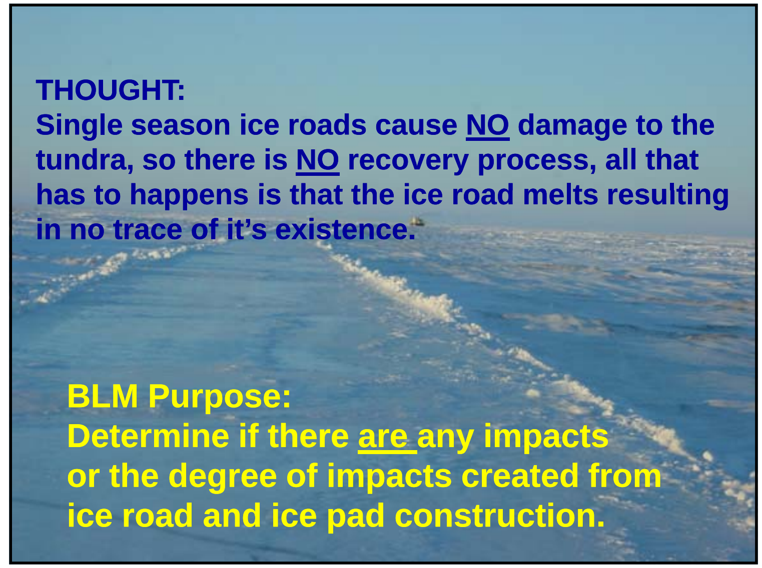
The case study was a 37.5 mile long ice road, built in 1978 from the Kikiakrorak River to the Inigok drill site (Kik-Inigot). Color infrared (CIR) photography, taken in the spring of 1979 of the Kik-Ingiot road, was used to identify and locate ice road traces.

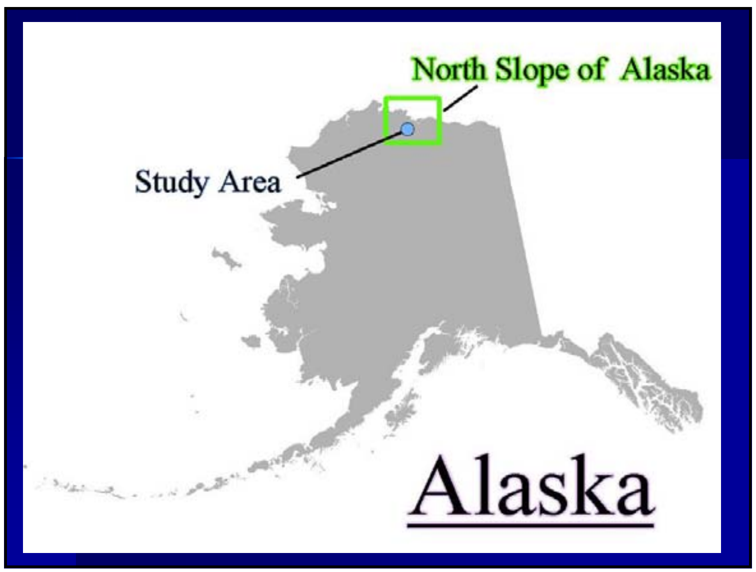
Field examination compared the results of a one-year 2001 ice road and a one-year 2002 ice road near Nuiqsut, Alaska, to the one-year 1978 Kik-Inigok ice road constructed 24 years earlier. Data were gathered on the profiles of the surface terrain, depth to permafrost, and vegetation. In March of 2003 a tour of Puviaq exploratory drill site was conducted. The ice pad trace at Puviaq was observed during a site visit in July of 2003 to determine whether the impact of ice road and ice pads were the same.

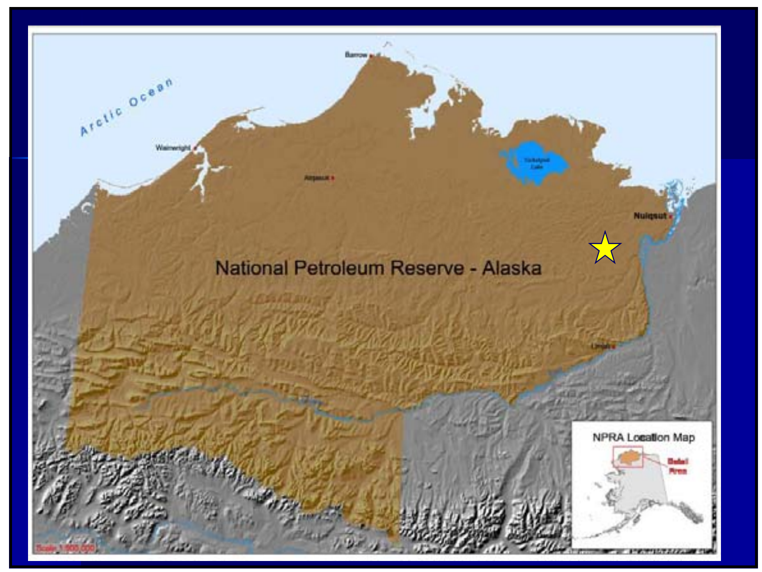
The 2001 and 2002 ice roads and Puviaq ice pad showed that shrubs, forbs and tussocks froze when encased in the ice road and under the ice pad. It was observed that more significant disturbance occurred where ice roads covered the drier upland sites with little or no evidence of disturbance observed on the moist wetland sites. Comparison of the data collected across the 1978 Kik-Inigok ice road showed a full recovery and restoration of shrubs, forbs and tussocks, which were vigorous and in good condition.

The data suggests that tundra vegetation under a single-year ice road and pad completely recovers and returns to its natural state over a 24 year period of time.


Ice Road Construction and Recovery
on Tundra Ecosystems
National Petroleum Reserve, Alaska (NPR-A)
Scott Guyer,
Bruce Keating and John Payne
Bureau of Land Management
Alaska State Office


THOUGHT:
Single season ice roads cause NO damage to the tundra, so there is NO recovery process, all that has to happens is that the ice road melts resulting in no trace of it's existence.
BLM Purpose:
Determine if there are any impacts or the degree of impacts created from ice road and ice pad construction.


North Slope of Alaska
Study Area
Alaska

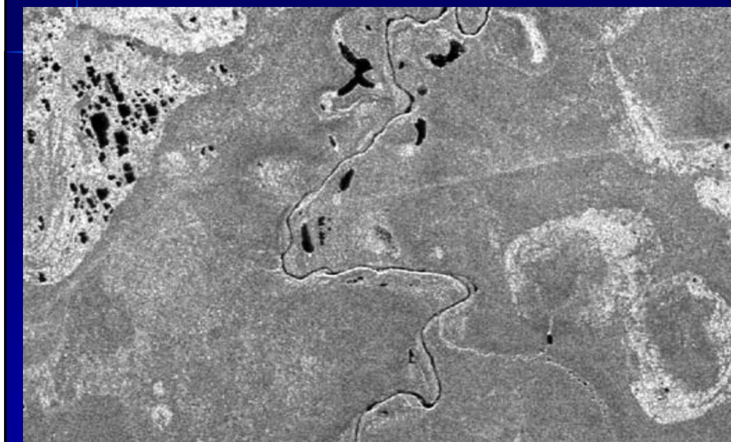

Arctic Ocean
National Petroleum Reserve - Alaska
NPRA Location Map

METHODOLOGY:

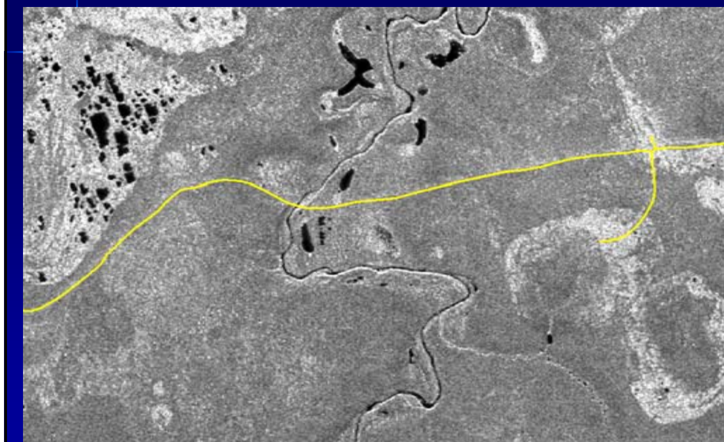
- Use NTM Imagery as source to determine ice road location.
- Compare current IceRoad(2002) impacts to the recovery of a 1978 Ice Road.
- Analyze Permafrost depth
- Establish Vegetation Transects



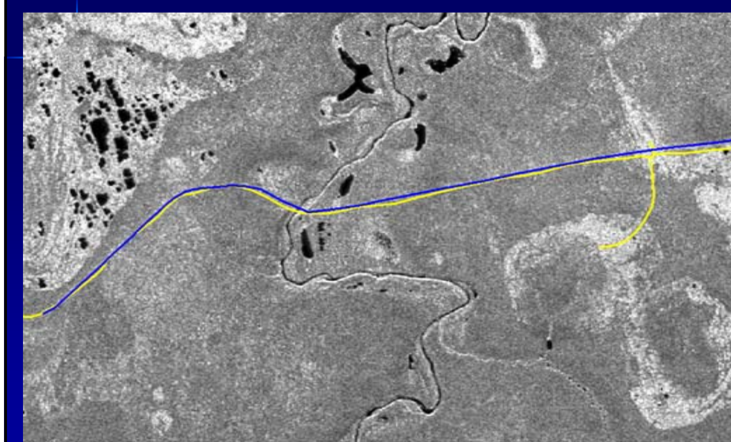

2001 IFSAR Image Magnitude Base Map
National Petroleum Reserve-Alaska



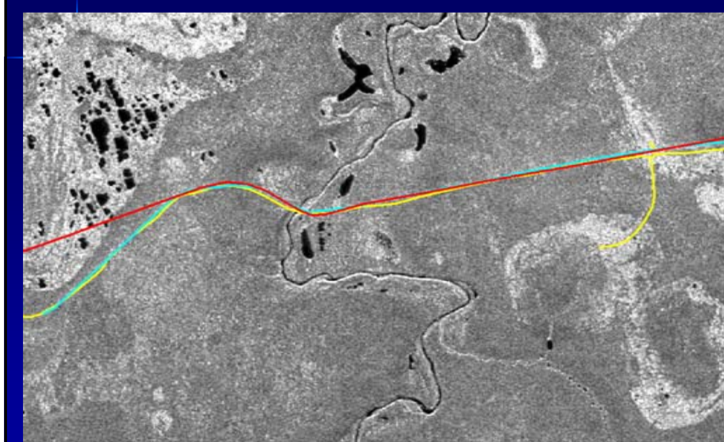
GOUO 2000 Ice Roads
National Petroleum Reserve-Alaska



GOUO 2000 2001 Ice Roads
National Petroleum Reserve-Alaska

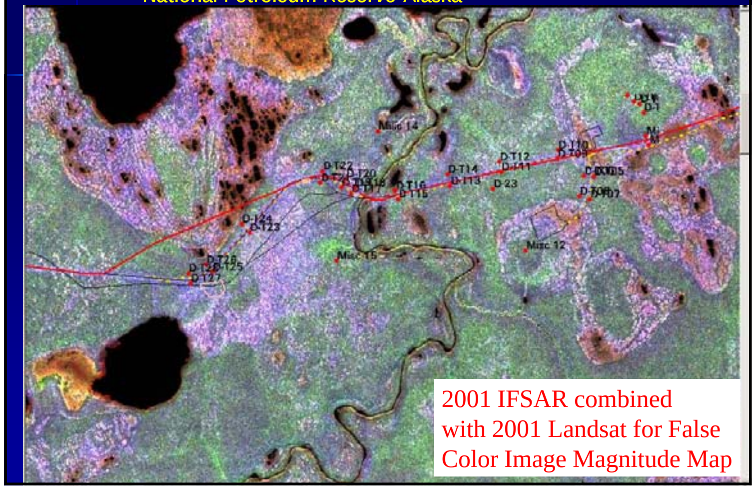


GOUO 2000 2001 2002 Ice Roads
National Petroleum Reserve-Alaska



GOUO 2002 Ice Road and Trails

National Petroleum Reserve-Alaska



2001 IFSAR combined with 2001 Landsat for False Color Image Magnitude Map

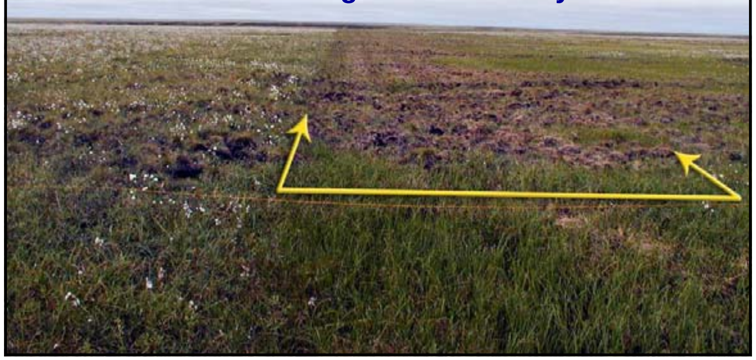
Survey Equipment

Laser Alignment LB-9
(Laser Leveler)

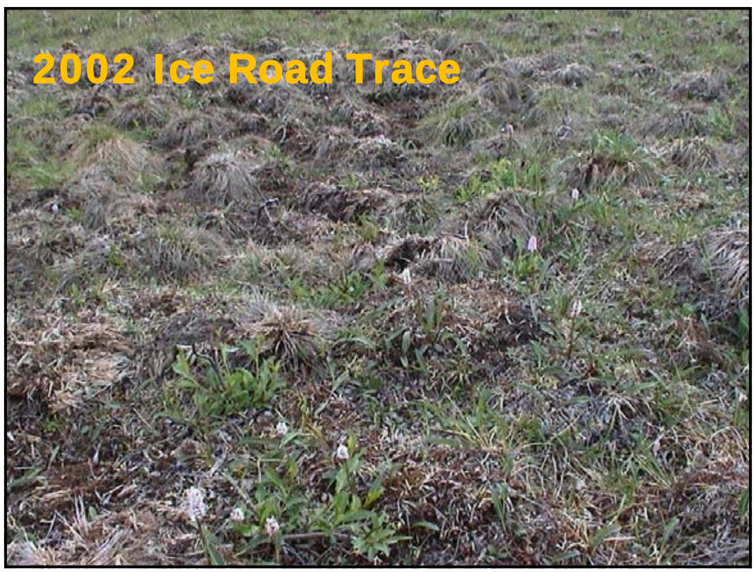
Trimble ProXR-GPS
& Steel Permafrost probe

Data Collected:

- -profiles of surface terrain
- -depth to permafrost
- -vegetation percent cover
- -vegetation severity index

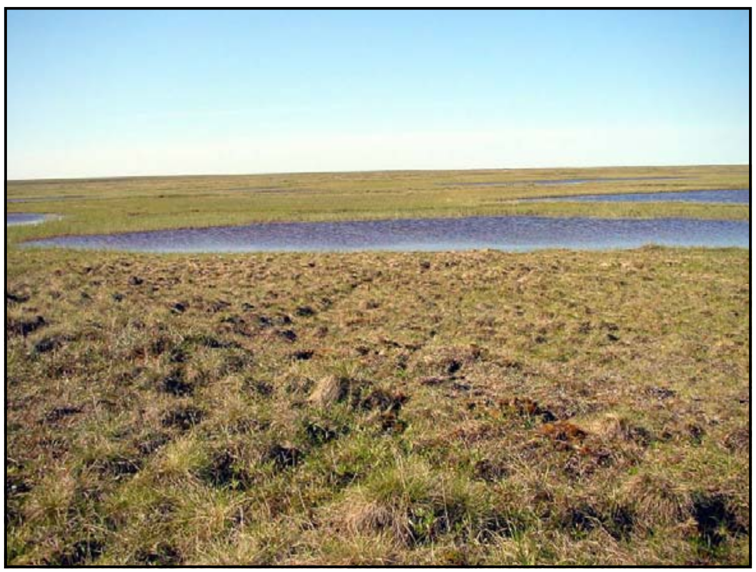
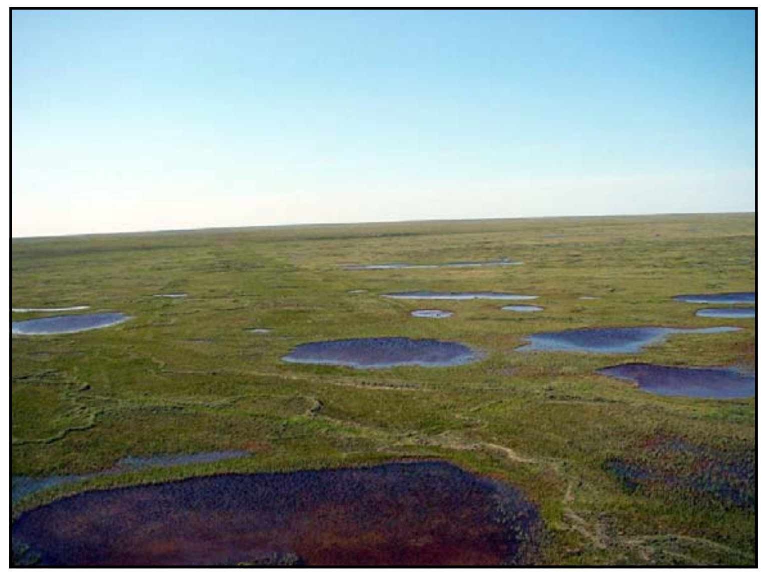



Ice Road trace…


2002 Ice Road Trace



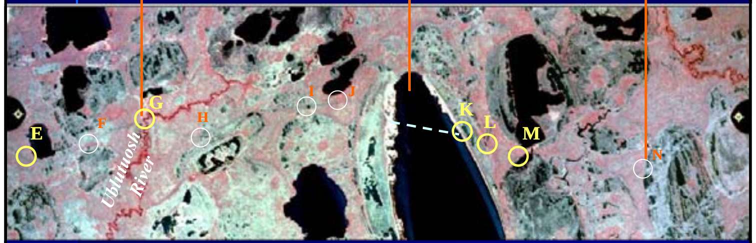


Inigok Ice Road 1978

- 37.5 miles of ice road.
- Construction began Feb. 1 and ended March 8.
- Gravel was hauled each day for 38 days.
- Total gravel hauled 132,000 tons.
- 35,000,000 gallons of water use to construct the road.

NASA CIR Photo Date: July 1979

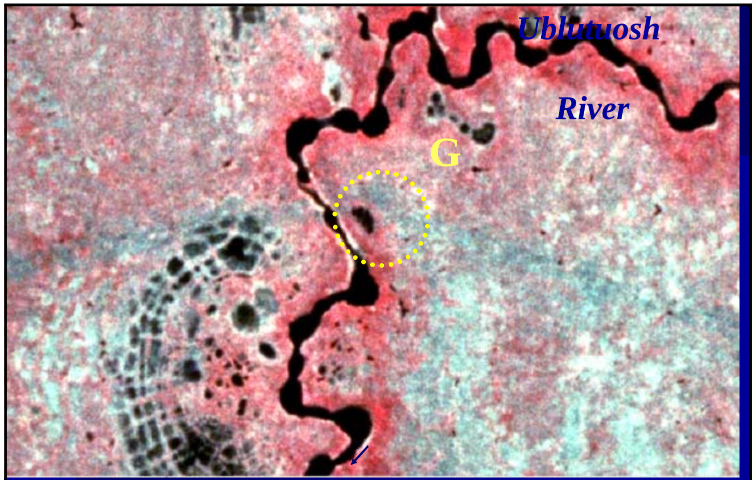


Approximately 4 miles

Sites E to N

N

Yellow Letters are Transect Locations

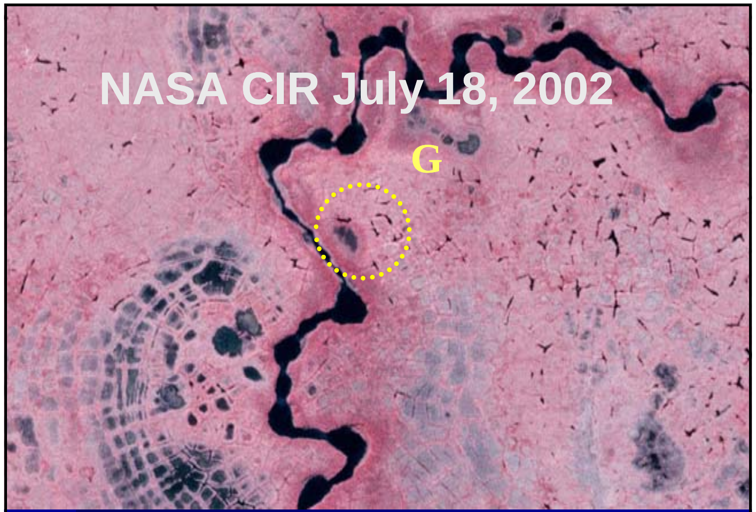


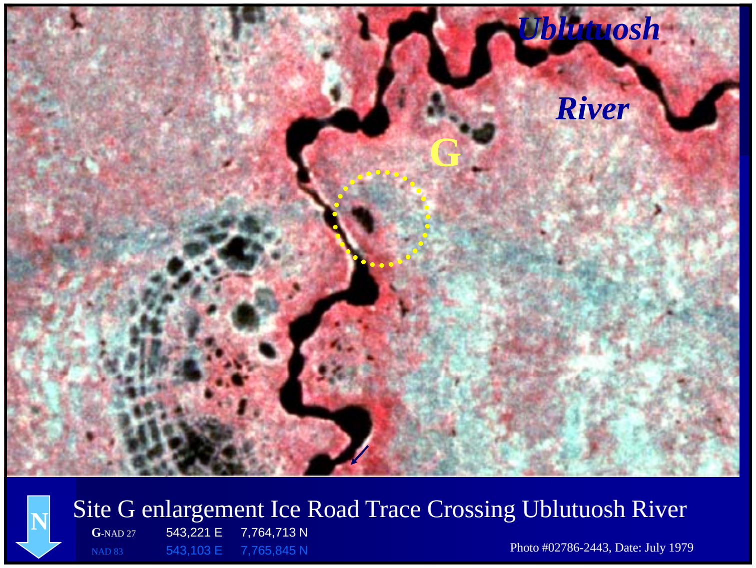
N

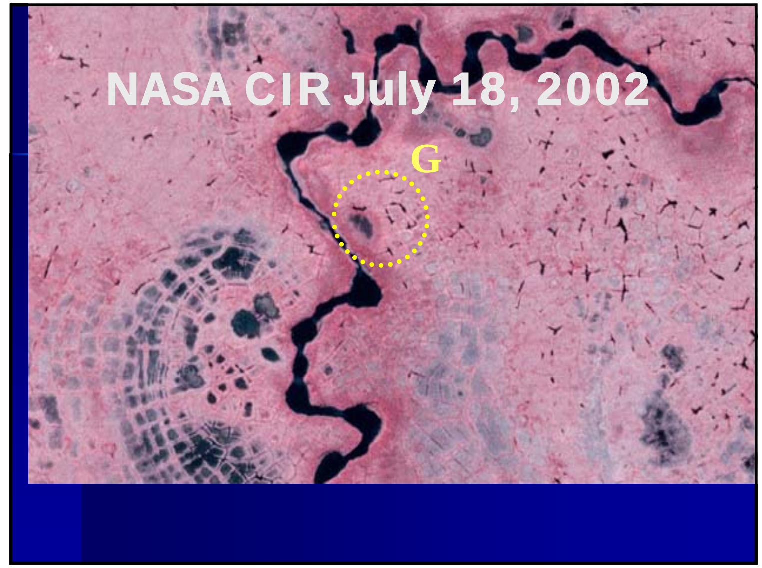
Site G enlargement Ice Road Trace Crossing Ublutuosh River

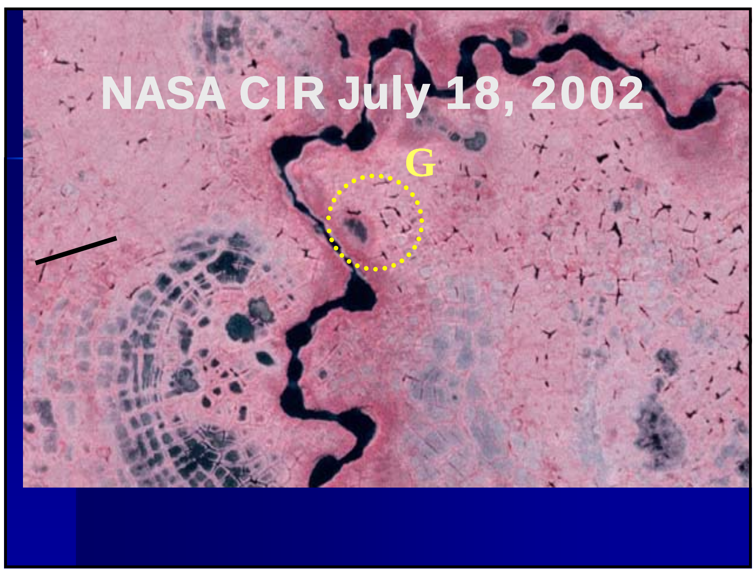
G-NAD 27	543,221 E	7,764,713 N
NAD 83	543,103 E	7,765,845 N

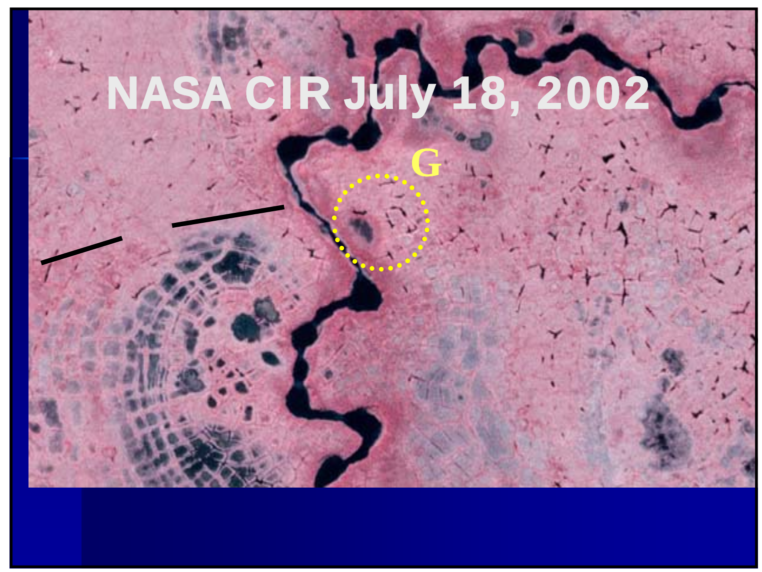
Photo #02786-2443, Date: July 1979

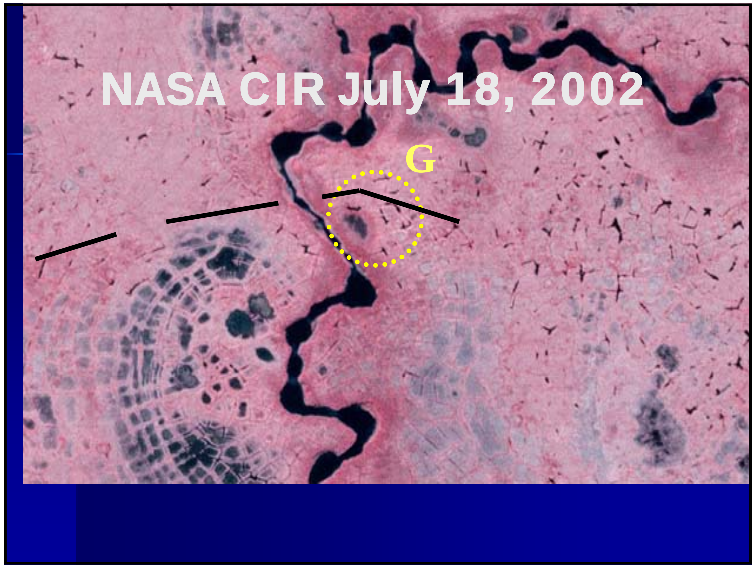


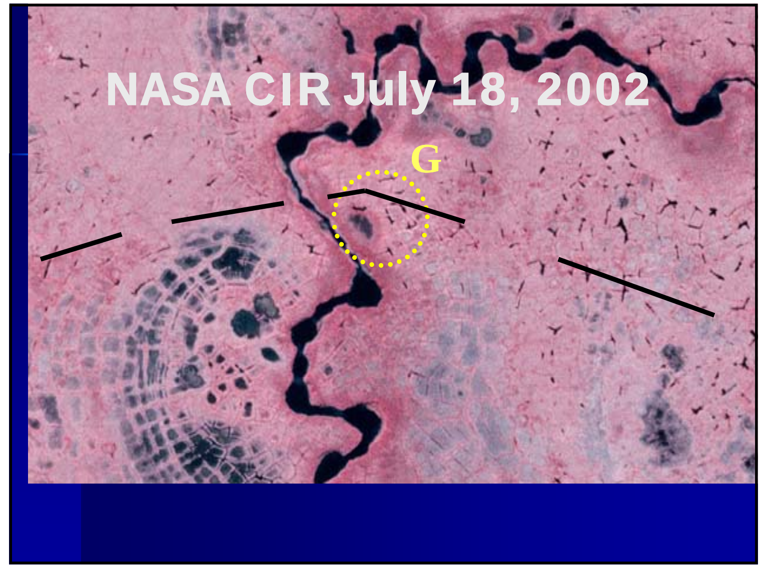

Ublutuosh
River
G
N
Site G enlargement Ice Road Trace Crossing Ublutuosh River
G-NAD 27 543,221 E 7,764,713 N
NAD 83 543,103 E 7,765,845 N
Photo #02786-2443, Date: July 1979

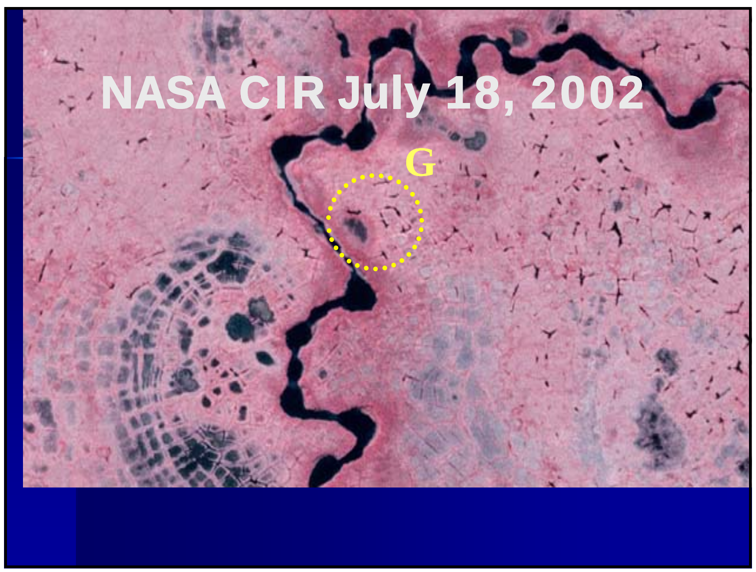

NASA CIR July 18, 2002
G

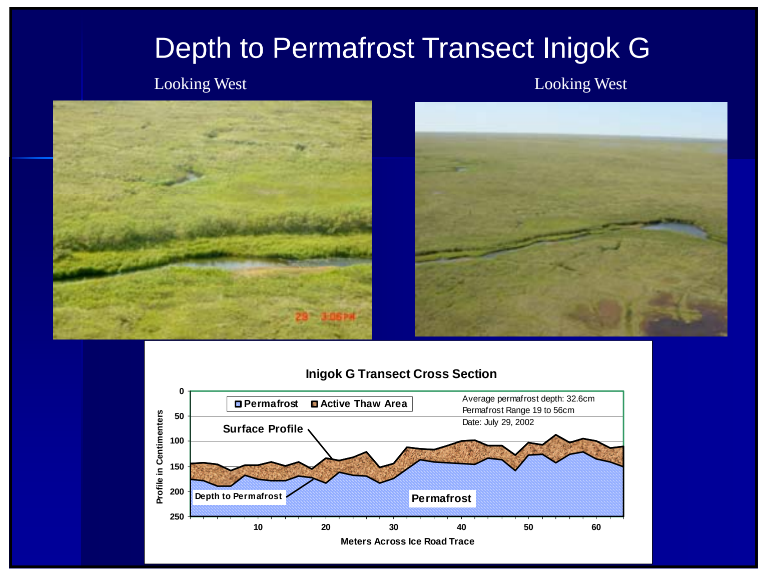

NASA CIR July 18, 2002
G


NASA CIR July 18, 2002
G


NASA CIR July 18, 2002
G


NASA CIR July 18, 2002
G


NASA CIR July 18, 2002
G

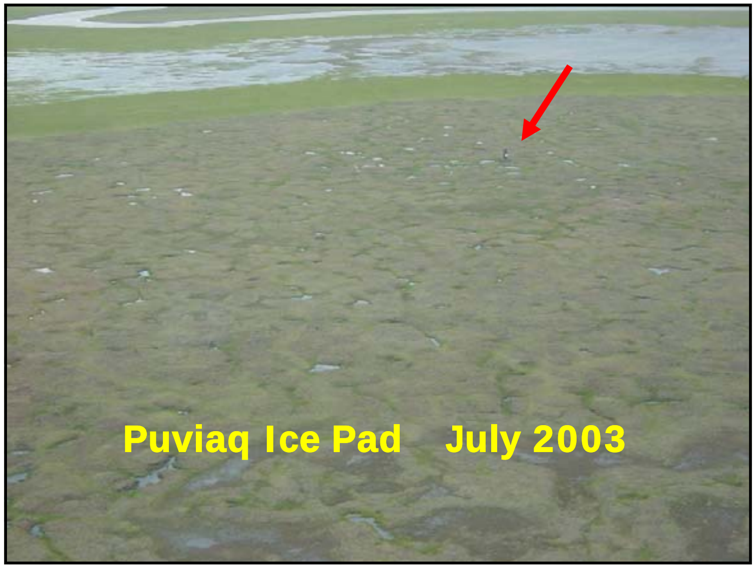

Depth to Permafrost Transect Inigok G
Looking West
Looking West
Inigok G Transect Cross Section
Permafrost
Active Thaw Area
Average permafrost depth: 32.6cm
Permafrost Range 19 to 56cm
Date: July 29, 2002
Surface Profile
Depth to Permafrost
Permafrost
Profile in Centimeters
0
50
100
150
200
250
10
20
30
40
50
60
Meters Across Ice Road Trace

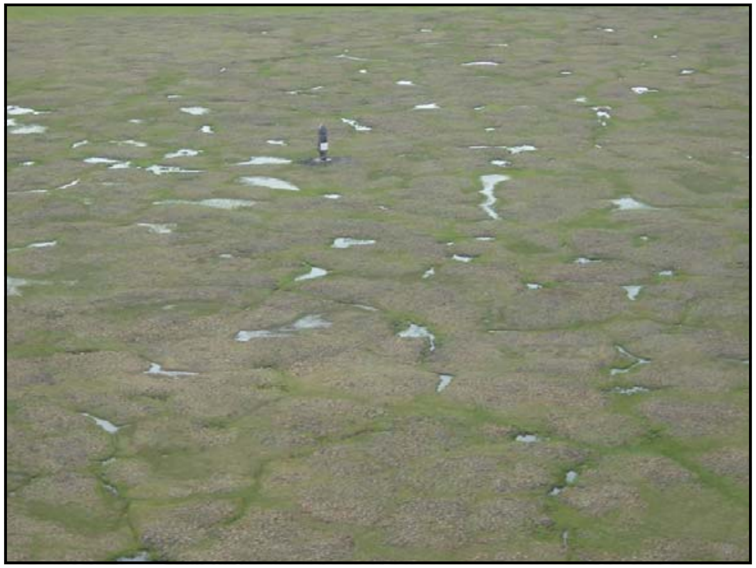

Inigok G- Photos
29 2:17PM


Inigok G- Photos-1
29 2:37PM


29 2:17PM


Puviaq Ice Pad March 2003


Puviaq Ice Pad July 2003



Results & Impacts:

- Delay in Plant Phenology
- Physical impacts from construction
- Thermal impacts to plants
- Thermokarsting- no evidence
- No impact to permafrost
- No impact to wet sedge sites

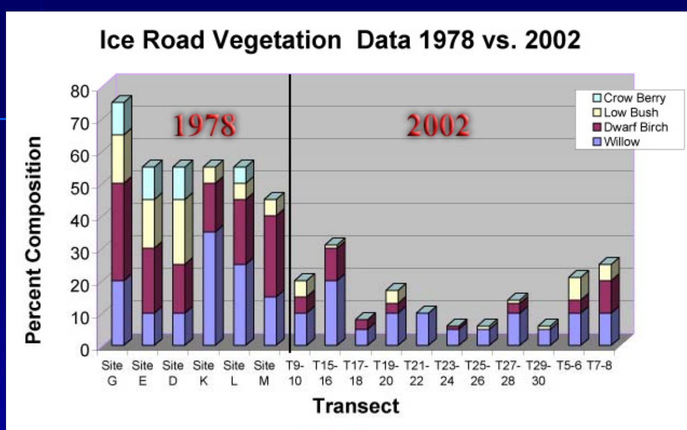
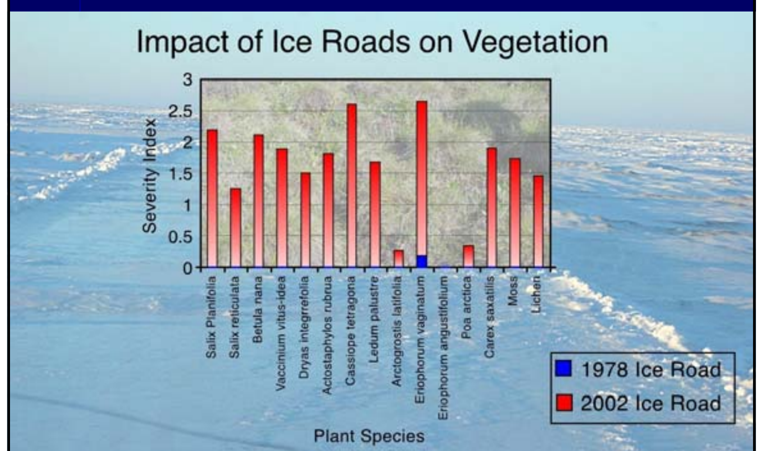
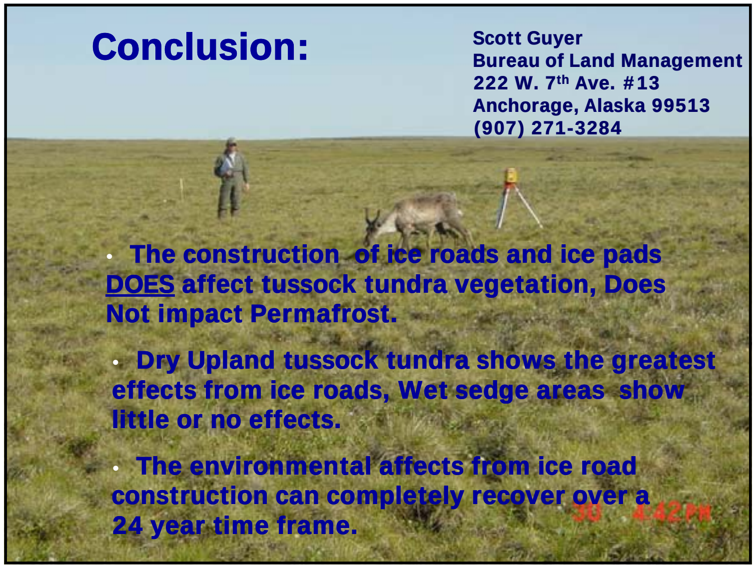


Table 1




Conclusion:
Scott Guyer
Bureau of Land Management
222 W. 7th Ave. #13
Anchorage, Alaska 99513
(907) 271-3284
• The construction of ice roads and ice pads DOES affect tussock tundra vegetation, Does Not impact Permafrost.
• Dry Upland tussock tundra shows the greatest effects from ice roads, Wet sedge areas show little or no effects.
• The environmental affects from ice road construction can completely recover over a 24 year time frame.

5.2.4 Speculation on the Origin and Persistence of Thick Multi-Year Ice in the Arctic, *Humfrey Melling*

Ph.D., Senior Scientist, Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, BC.
Email: Humfrey.Melling@dfo-mpo.gc.ca

The Canadian federal Programme for Energy Research and Development (PERD) has supported projects to maintain continuous observation of pack-ice thickness at several sites in the Beaufort Sea since 1990. The result is the longest record of ice thickness, drift velocity and ridging from any location worldwide. The Canadian record is rivaled only by Norwegian efforts in the Greenland Sea. Our unique time series is being used to guide offshore engineering and development in ice-prone waters world-wide.

In common with satellite-based surveillance of pack-ice extent, these data reveal dramatic variations in the thickness and drift of pack ice at annual and inter-annual-to-decadal period. At least where these observations have been made, in the eastern Beaufort Sea, the amplitude of inter-annual variation exceeds that of progressive change. One important consequence of this reality is that long-term trend cannot be calculated with useful accuracy. A second is that strategic, engineering and regulatory decisions must be guided by the wide range of conditions encompassed by known variability, not by relatively small and poorly constrained changes in average conditions.

In recognition of the significance of long-period variation, the present incarnation of the Beaufort ice monitoring project is named “Decadal variation in marine hazards”. The project has diversified from its initial sole focus on pack ice to embrace two topics of high significance to Arctic coastal communities and to Arctic offshore development, namely the dynamics of coastal fast ice and the interlinked variation of ice conditions, storm surges and wind waves.

Dramatic decline in the multi-year-ice covered area of the Arctic has promoted speculation that all such ice may soon be gone. However, recent incidental observations have revealed the continued presence of very thick old floes on the North American side of the Arctic. If the Arctic ice pack is melting away, what process can explain these observations? I argue that the apparent paradox of thick floes within shrinking pack ice can be explained in terms of a dominant role for ice-field deformation in the origin of such floes. Ice deformation is extreme in the stamukhi zone, where pack ice and fast ice interact strongly. I present data from Canadian research suggesting that thick multi-year ice floes may persist in a warming Arctic, provided that the pattern of atmospheric circulation continues to force young ice away from the Siberian side and older ice up against the shorelines of the Canadian Archipelago.

The origin and persistence of thick multi-year ice in the Arctic

USA / Canada Northern Oil and Gas Research Forum
28-30 October 2008
Anchorage AK. USA

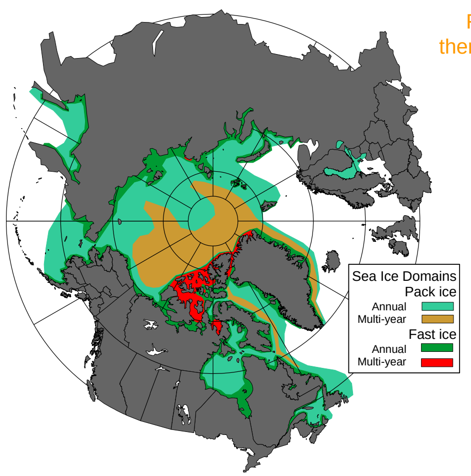
Humfrey Melling
Institute of Ocean Sciences
Fisheries & Oceans Canada

Fisheries and Oceans / Pêches et Océans

Outline of talk

- Sea ice domains in the Arctic
- Sea ice thickness … satellites can't do it
- Beaufort long-term ice-hazard observations (Canadian Program of Energy R & D)
- Arctic-wide ice-thickness monitoring (see poster)
- Change in seasonal (i.e. first-year) pack ice
- Change in multi-year pack ice & extreme features

Domains of Arctic sea ice



From the public's viewpoint there is one domain of sea ice … & that one is in decline

- Actually there are four domains of sea ice in the Arctic
- 2 principal sea-ice types (first-year, multi-year), with
- 2 states of mobility (active pack ice, static fast ice)
- The energy balance & dynamics are different within each domain
- Climate-change impacts are likely different too

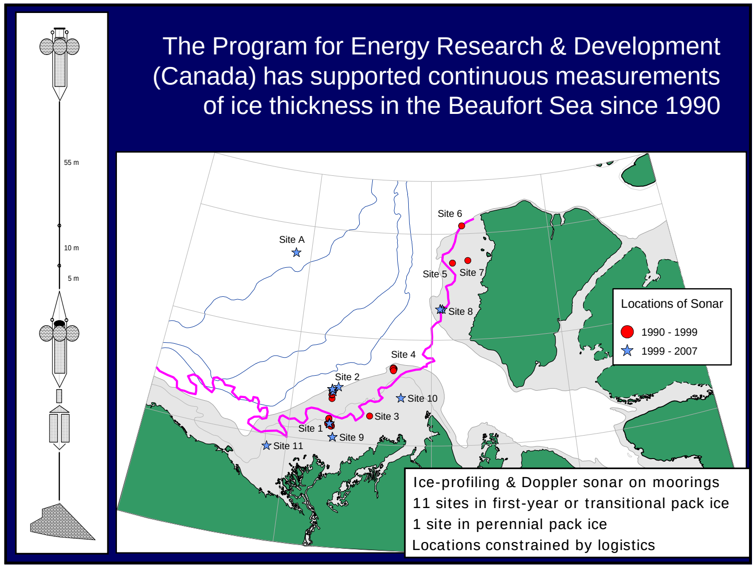
Why the concern with multi-year ice?

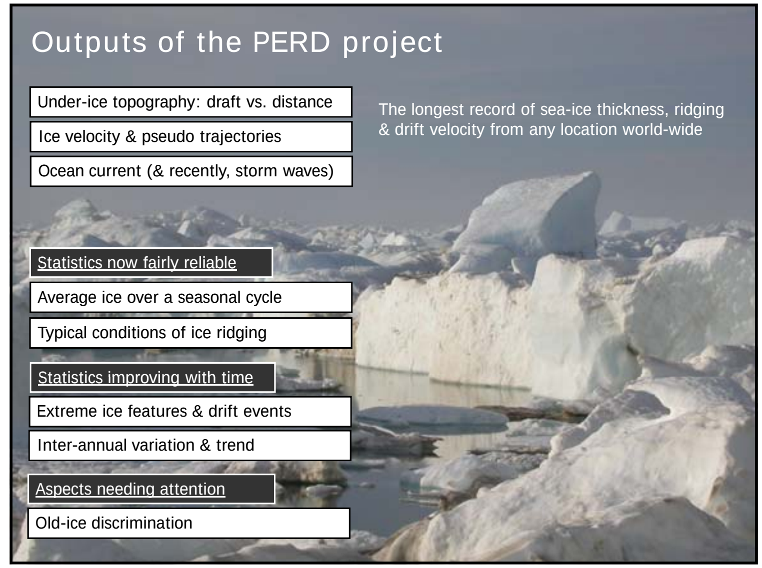
The strongest forces on offshore structures, seabed installations & ships are exerted by multi-year ice

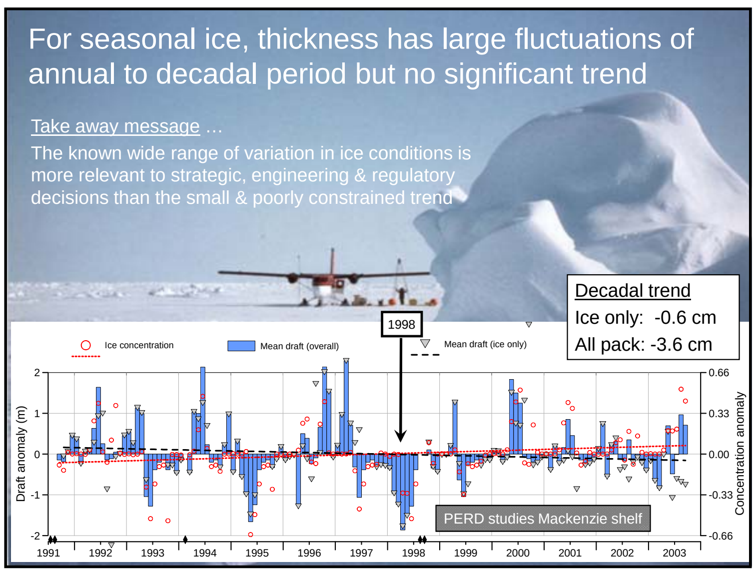
Hazard increases with the thickness & drift speed of the feature

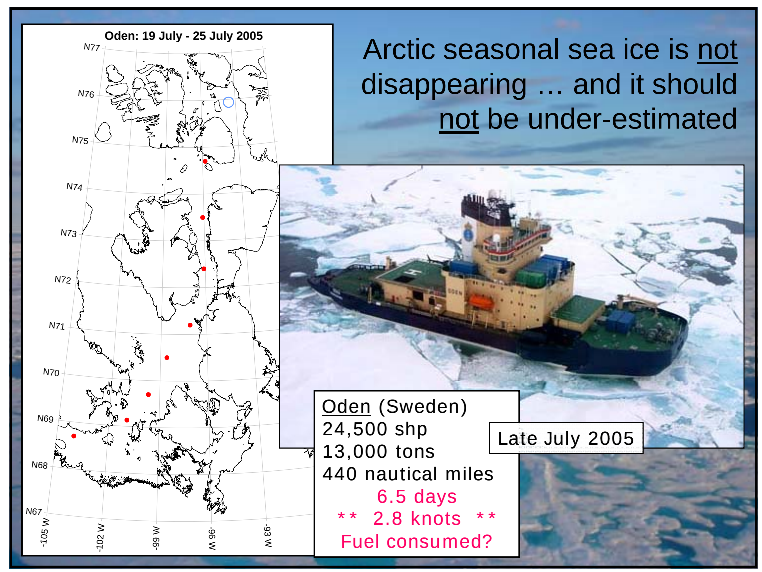
Hazardous features are generally too small for detection from space.
Neither can ice thickness be measured from space

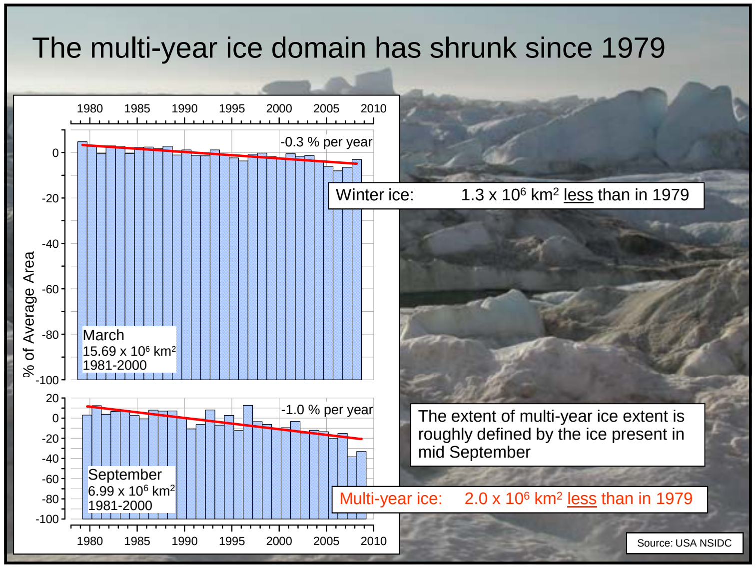
Sub-sea sonar does have the resolution to detect & capability to measure the dimensions of hazardous features in sea-ice

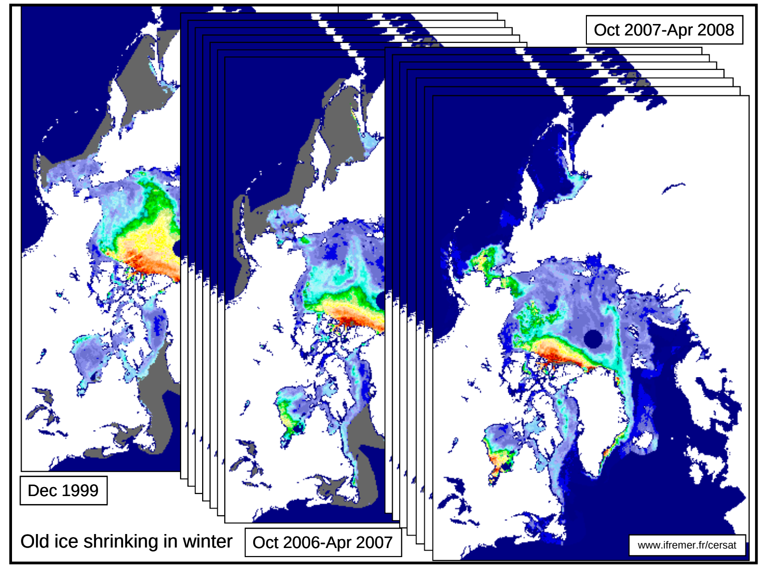

The Program for Energy Research & Development (Canada) has supported continuous measurements of ice thickness in the Beaufort Sea since 1990
55 m
10 m
5 m
Site A
Site 6
Site 5
Site 7
Site 8
Site 4
Site 2
Site 10
Site 3
Site 1
Site 9
Site 11
Locations of Sonar
1990 - 1999
1999 - 2007
Ice-profiling & Doppler sonar on moorings
11 sites in first-year or transitional pack ice
1 site in perennial pack ice
Locations constrained by logistics

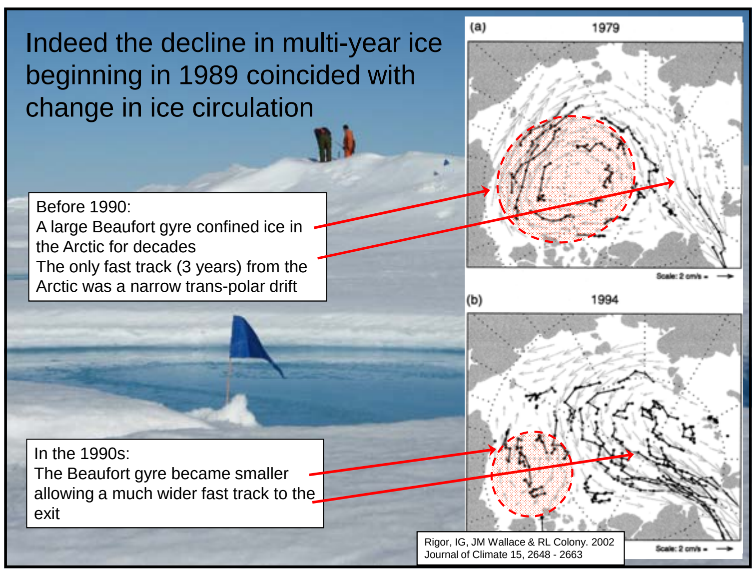

Outputs of the PERD project
Under-ice topography: draft vs. distance
Ice velocity & pseudo trajectories
Ocean current (& recently, storm waves)
The longest record of sea-ice thickness, ridging & drift velocity from any location world-wide
Statistics now fairly reliable
Average ice over a seasonal cycle
Typical conditions of ice ridging
Statistics improving with time
Extreme ice features & drift events
Inter-annual variation & trend
Aspects needing attention
Old-ice discrimination

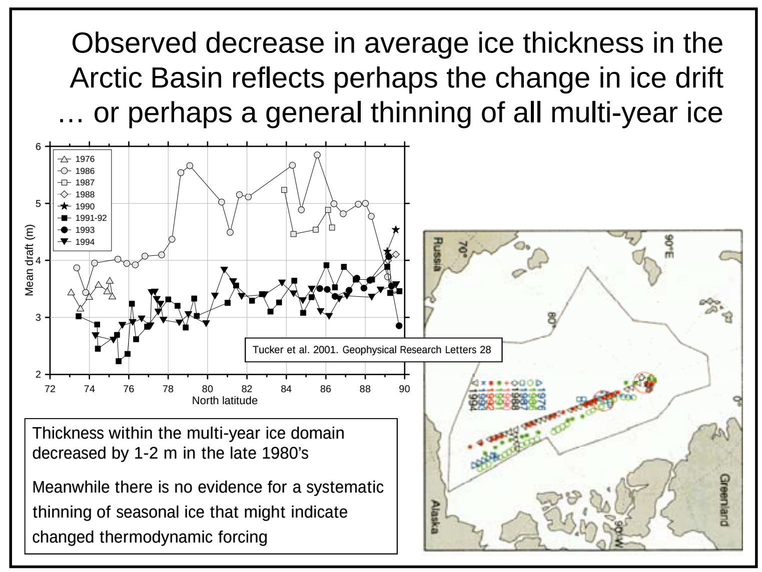

For seasonal ice, thickness has large fluctuations of annual to decadal period but no significant trend
Take away message …
The known wide range of variation in ice conditions is more relevant to strategic, engineering & regulatory decisions than the small & poorly constrained trend
Decadal trend
Ice only: -0.6 cm
All pack: -3.6 cm
1998
Ice concentration
Mean draft (overall)
Mean draft (ice only)
Draft anomaly (m)
Concentration anomaly
PERD studies Mackenzie shelf
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003


Oden: 19 July - 25 July 2005
N77
N76
N75
N74
N73
N72
N71
N70
N69
N68
N67
-105 W
-102 W
-99 W
-96 W
-93 W
Arctic seasonal sea ice is not disappearing … and it should not be under-estimated
Oden (Sweden)
24,500 shp
13,000 tons
440 nautical miles
6.5 days
** 2.8 knots **
Fuel consumed?
Late July 2005


The multi-year ice domain has shrunk since 1979
-0.3 % per year
Winter ice: 1.3 x 10⁶ km² less than in 1979
% of Average Area
March
15.69 x 10⁶ km²
1981-2000
-1.0 % per year
September
6.99 x 10⁶ km²
1981-2000
The extent of multi-year ice extent is roughly defined by the ice present in mid September
Multi-year ice: 2.0 x 10⁶ km² less than in 1979
Source: USA NSIDC

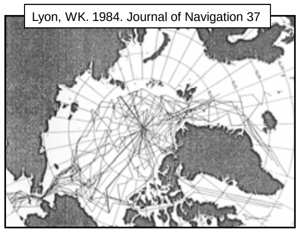

Oct 2007-Apr 2008
Dec 1999
Old ice shrinking in winter
Oct 2006-Apr 2007
www.ifremer.fr/cersat


Indeed the decline in multi-year ice beginning in 1989 coincided with change in ice circulation
Before 1990:
A large Beaufort gyre confined ice in the Arctic for decades
The only fast track (3 years) from the Arctic was a narrow trans-polar drift
In the 1990s:
The Beaufort gyre became smaller allowing a much wider fast track to the exit
(a) 1979
(b) 1994
Rigor, IG, JM Wallace & RL Colony. 2002
Journal of Climate 15, 2648 - 2663


Observed decrease in average ice thickness in the Arctic Basin reflects perhaps the change in ice drift … or perhaps a general thinning of all multi-year ice
Mean draft (m)
North latitude
Tucker et al. 2001. Geophysical Research Letters 28
Thickness within the multi-year ice domain decreased by 1-2 m in the late 1980's
Meanwhile there is no evidence for a systematic thinning of seasonal ice that might indicate changed thermodynamic forcing
Russia
Alaska
Greenland

Before 1985 there was a vast reservoir of very thick ice in the Arctic Ocean Sonar

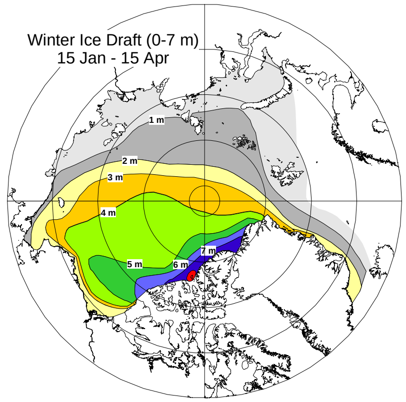
Lyon, WK. 1984. Journal of Navigation 37



Upward-looking sonar on US Navy submarines measured sea-ice draft

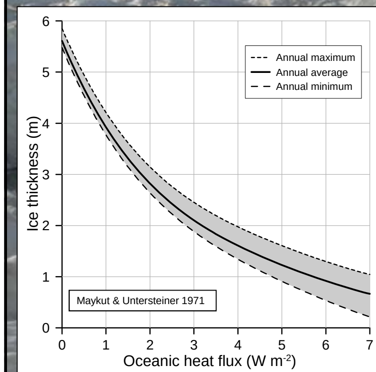
Thickness is 10-15% larger.

Note how the Beaufort & Chukchi Seas were influenced by very thick ice from the Canadian Arctic coast



Bourke, RH & RP Garrett. 1987. Cold Regions Science and Technology 13

How was very thick multi-year ice created & maintained in past times?



<u>Thermodynamic growth & decay</u>
The rate of growth in winter slows as ice thickens
The rate of decay in summer is the same for thick & thin ice
… depends on area not thickness

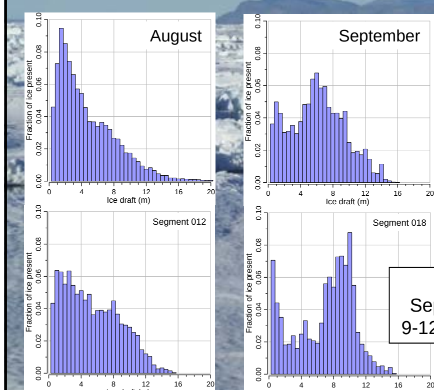
Multi-year floes reaches maximum thickness when growth in winter equals decay in summer

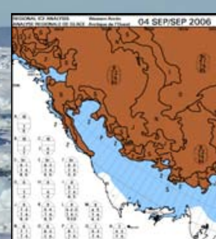
The time to reach maximum is long … 10 years or more

The graph shows that …
1) It has always been a tricky to maintain multi-year ice in the Arctic
2) It is very difficult to create very thick multi-year ice by thermodynamic processes

Have very thick multi-year floes disappeared from the Arctic after 35 years of climate warming?

Incidental observations suggest … **No**

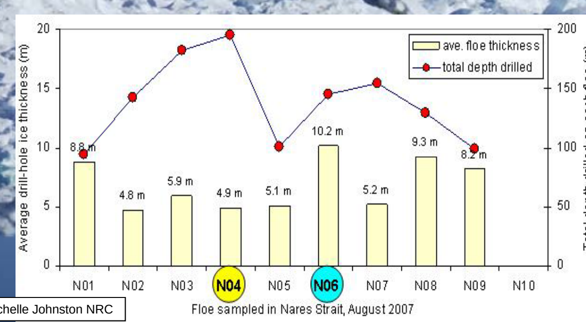




Beaufort Sea
September 2006
9-12 m thick floes

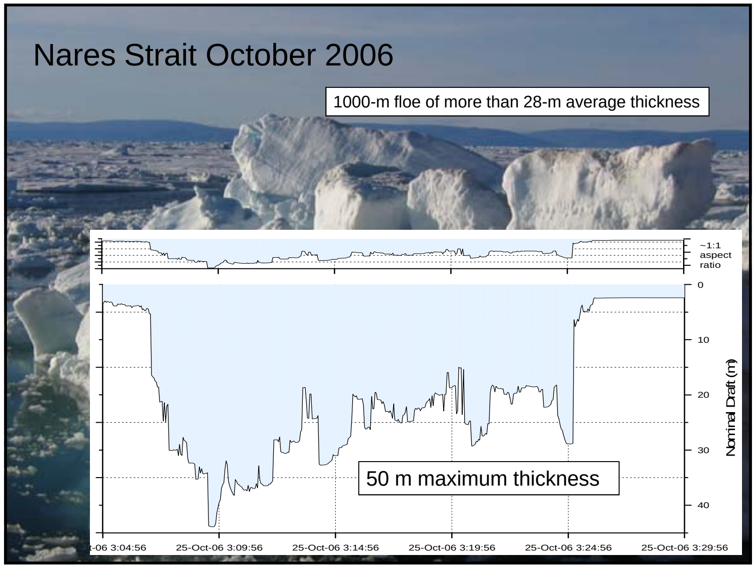
Canadian High Arctic August 2007

5-10 m average thickness of multi-year ice floes drilled in Nares Strait



Data courtesy of Michelle Johnston NRC

Nares Strait October 2006

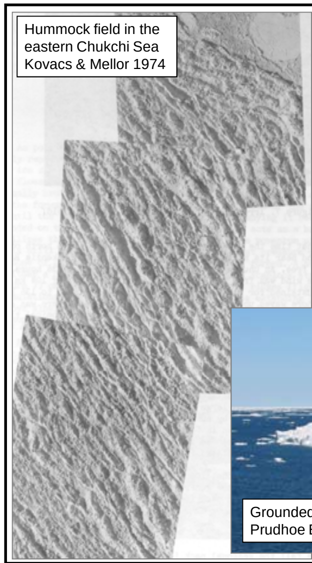


The process that forms very thick multi-year ice must bypass thermodynamic constraints

There is an obvious candidate mechanism …

Accumulation of ice rubble at the interface between pack ice & fast ice along the western margin of the Canadian polar shelf

Pictures show multi-year hummock fields along the fast-ice margin between Prince Patrick and Ellef Ringnes Islands
Hoar 1980 APOA Rev 3(2)



Hummock field in the eastern Chukchi Sea
Kovacs & Mellor 1974

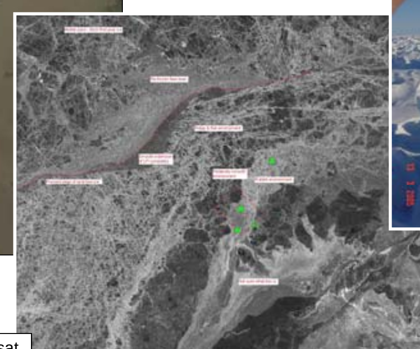
Hummock fields in the Beaufort & Chukchi Seas are better documented than those in the Canadian high Arctic

Hummock fields are built by storm winds
There is no reason to believe that their creation will cease in a warmer climate

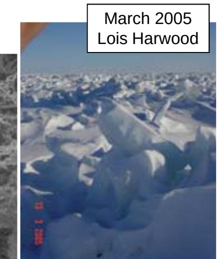
Grounded stamukha
Prudhoe Bay 2002

A single Beaufort storm in January 2005 created a rubble field up to 30 km wide covering 6000 km^2

11 July 2005
MODIS

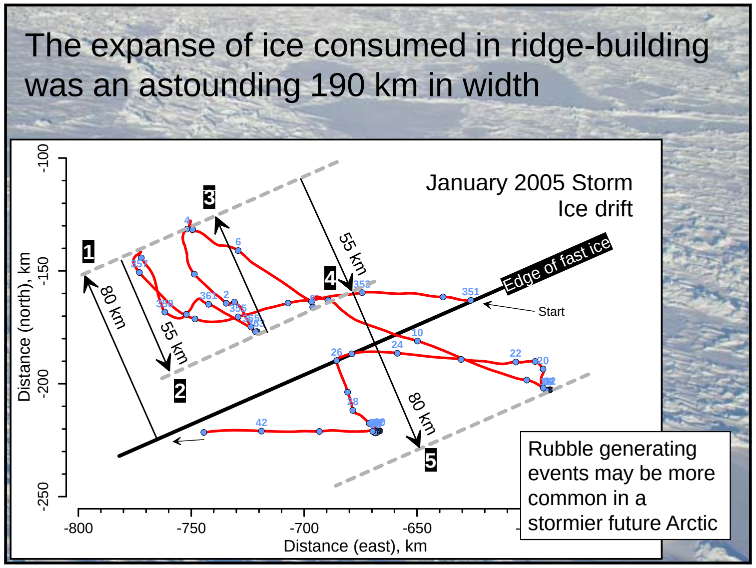


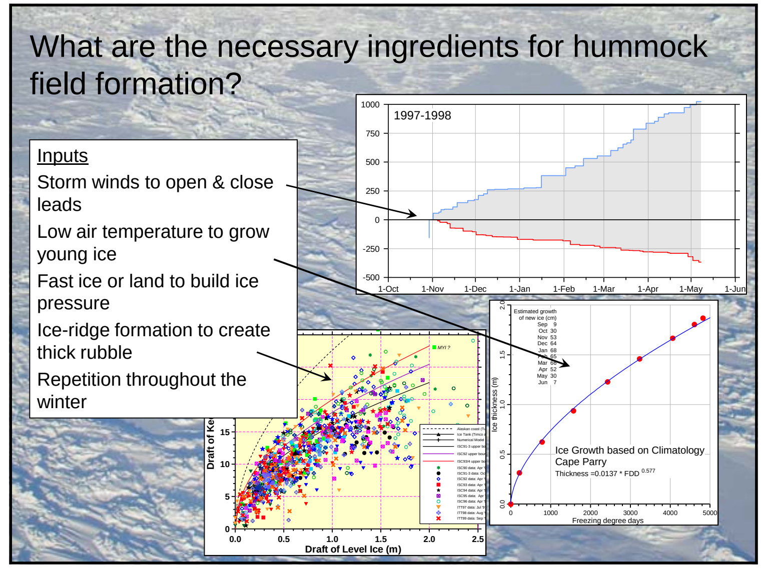
Radarsat

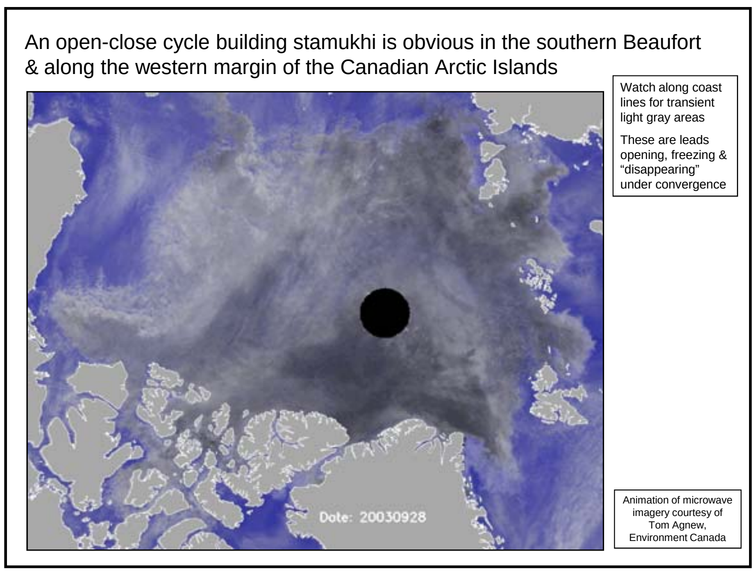


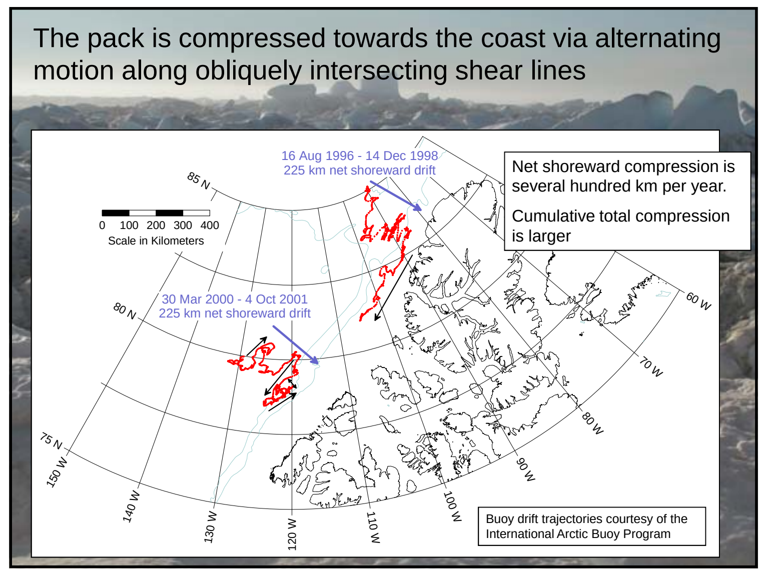
March 2005
Lois Harwood

Rubble remained grounded well into August

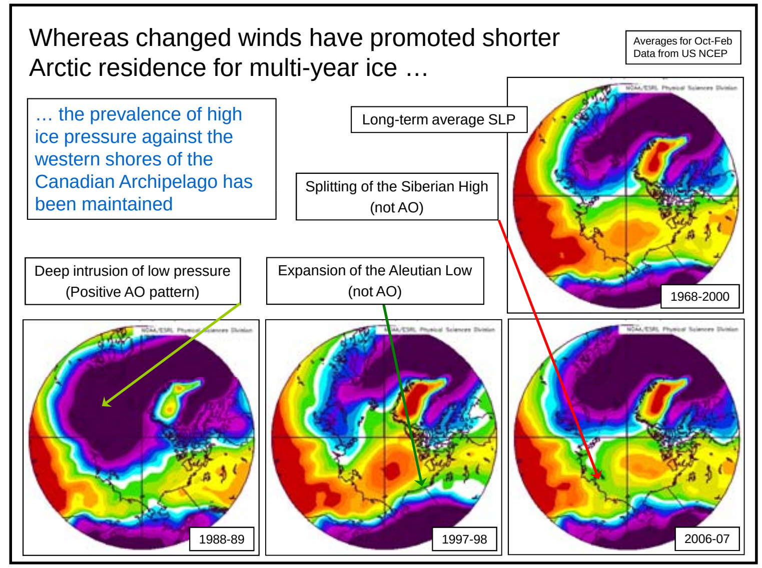

The expanse of ice consumed in ridge-building was an astounding 190 km in width
January 2005 Storm
Ice drift
Edge of fast ice
Start
80 km
55 km
55 km
80 km
Distance (north), km
Distance (east), km
Rubble generating events may be more common in a stormier future Arctic

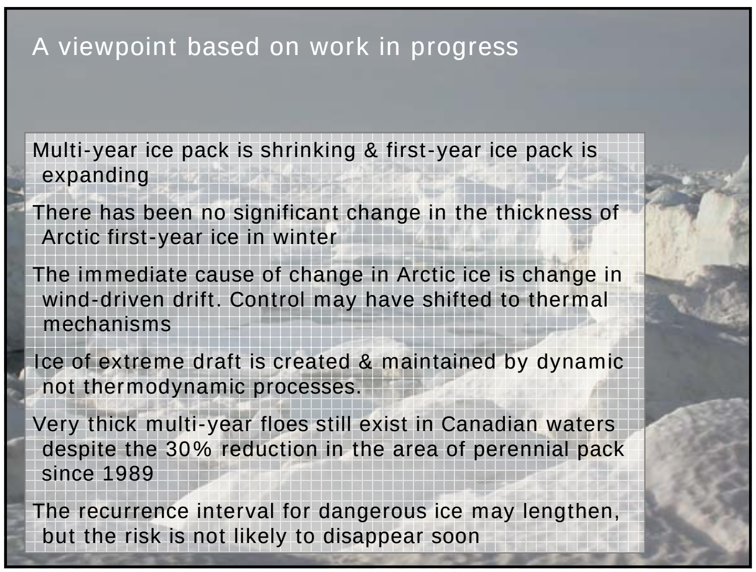

What are the necessary ingredients for hummock field formation?
Inputs
Storm winds to open & close leads
Low air temperature to grow young ice
Fast ice or land to build ice pressure
Ice-ridge formation to create thick rubble
Repetition throughout the winter
1997-1998
Draft of Level Ice (m)
Ice Growth based on Climatology
Cape Parry
Freezing degree days

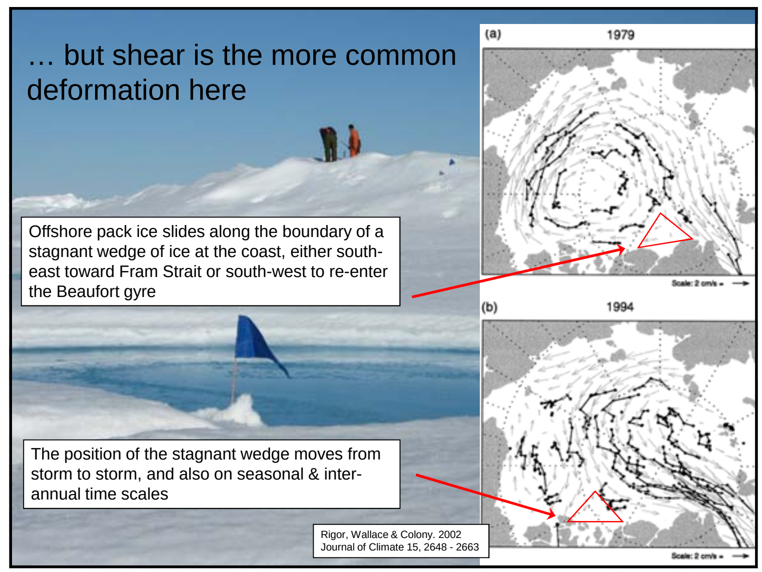

An open-close cycle building stamukhi is obvious in the southern Beaufort & along the western margin of the Canadian Arctic Islands
Watch along coast lines for transient light gray areas
These are leads opening, freezing & "disappearing" under convergence
Date: 20030928
Animation of microwave imagery courtesy of Tom Agnew, Environment Canada


The pack is compressed towards the coast via alternating motion along obliquely intersecting shear lines
16 Aug 1996 - 14 Dec 1998
225 km net shoreward drift
30 Mar 2000 - 4 Oct 2001
225 km net shoreward drift
Scale in Kilometers
Net shoreward compression is several hundred km per year.
Cumulative total compression is larger
Buoy drift trajectories courtesy of the International Arctic Buoy Program

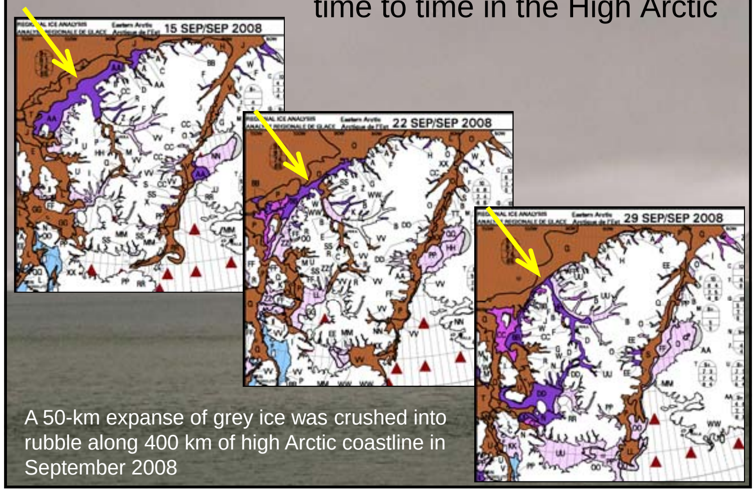

There is a future for thick multi-year ice in the Arctic if …
The Arctic continues to foster the creation of thick floes via persistent strong pressure & deformation at coastal boundaries
The circulation of pack ice in the Arctic continues to trap ice-rubble fields for more than one year, so that they may weather to become thick multi-year ice floes


Whereas changed winds have promoted shorter Arctic residence for multi-year ice …
Averages for Oct-Feb Data from US NCEP
… the prevalence of high ice pressure against the western shores of the Canadian Archipelago has been maintained
Long-term average SLP
Splitting of the Siberian High (not AO)
Deep intrusion of low pressure (Positive AO pattern)
Expansion of the Aleutian Low (not AO)
1968-2000
1988-89
1997-98
2006-07


A viewpoint based on work in progress
Multi-year ice pack is shrinking & first-year ice pack is expanding
There has been no significant change in the thickness of Arctic first-year ice in winter
The immediate cause of change in Arctic ice is change in wind-driven drift. Control may have shifted to thermal mechanisms
Ice of extreme draft is created & maintained by dynamic not thermodynamic processes.
Very thick multi-year floes still exist in Canadian waters despite the 30% reduction in the area of perennial pack since 1989
The recurrence interval for dangerous ice may lengthen, but the risk is not likely to disappear soon


… but shear is the more common deformation here
Offshore pack ice slides along the boundary of a stagnant wedge of ice at the coast, either south-east toward Fram Strait or south-west to re-enter the Beaufort gyre
The position of the stagnant wedge moves from storm to storm, and also on seasonal & inter-annual time scales
(a) 1979
(b) 1994
Rigor, Wallace & Colony. 2002
Journal of Climate 15, 2648 - 2663

Divergent/convergent deformations occur from time to time in the High Arctic



A 50-km expanse of grey ice was crushed into rubble along 400 km of high Arctic coastline in September 2008

5.2.5 Creation of Leads and Ridges: What is the Ice Behavior?,

Max Coon

Ph.D., Senior Scientist; NorthWest Research Associates. Email: max@nwra.com

The behavior of sea ice depends on the problem being solved. We are developing a model to explicitly model the creation and evolution of leads and ridges. The models and proprieties of sea ice needed for crushing ice on a structure are very different from those needed to calculate the location of the "ice edge", or for use in a large scale climate change calculation. The most striking features of the arctic ice as seen from ice level, over flying, or from satellite images are the leads and ridges. Within the Arctic sea-ice, stresses are formed from wind, ocean currents and other sources. These stresses are continuously changing and cause the opening and closing of cracks (leads) in the pack ice that may be thousands of kilometers in length. Leads are important for climate modeling because an open lead provides an avenue for heat transfer from the ocean to the atmosphere. The formation of new ice within leads upon refreezing is also noteworthy because of the large amounts of energy required to create ice and of brine injected into the ocean. Another obvious feature of the Arctic landscape is ridges formed when leads are forced to close, crushing new ice within the lead.

Existing constitutive equations used for modeling pack ice are primarily continuum based and, as such, do not incorporate specific information about leads such as orientation, length and width. Instead, such models generally give an indirect measure of lead opening through an integration of the divergence of velocity, and infer the direction of leads through plots of divergence over the spatial domain. However, these models provide a computationally efficient scheme to predict the motion of Arctic ice as well as an indication of the area of open water and the amount of new ice created over a winter season. For the original purpose, these models work admirably well. However, a more precise constitutive equation can bring significant improvements to detailed predictions of the formation of leads and new ice and, consequently, corresponding improvements in the prediction of ice motion and deformation.

The modeling was a joint effort by NorthWest Research Associates, University of New Mexico, Jet Propulsion Laboratory, and Technical University of Denmark. A first formulation of the model has been completed together with a solution procedure. We have developed a new metric for comparing simulated and measured lead orientation. Also, we have a new data simulation procedure. At this time the present project is complete and the final report is in preparation. Together we will examine results of model runs for the ice in the Beaufort and Chukchi Sea with comparison to leads measured with SAR. This model should be verified, validated and made operational.

This work was sponsored by MMS, NASA, ONR, and NSF.

Sea Ice Modeling for Nearshore Beaufort and Chukchi Seas

Max Coon, Senior Research Scientist, NorthWest Research Associates, Seattle, WA, max@nwra.com

NWRA
NorthWest Research Associates
Since 1984

United States and Canada Northern Oil and Gas Research Forum: Current Status and Future Directions in the Beaufort Sea, North Slope and Mackenzie Delta, October 28 to 30, 2008, Anchorage, Alaska

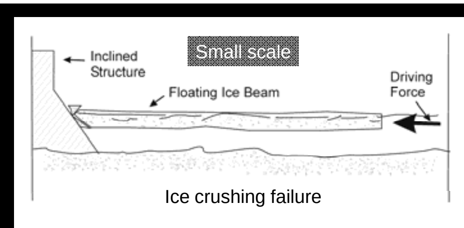
The Fram team…

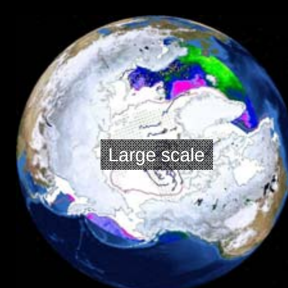
Research funded by:

MMS NASA NSF ONR

Creation of Leads and Ridges: What is the Ice Behavior?

a) The behavior of sea ice depends on the problem being solved.
b) Existing constitutive equations used for modeling pack ice are primarily continuum based and, as such, do not incorporate specific information about leads such as orientation, length and width.
c) A more precise constitutive equation can bring significant improvements to detailed predictions of the formation of leads and new ice and, consequently, corresponding improvements in the prediction of ice motion and deformation.





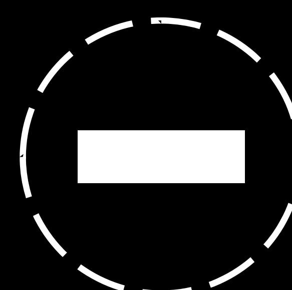


Image credit: NASA, NSIDC, Leif Toudal

Ice Model of Leads and Ridges Cross Cuts our 4 Themes

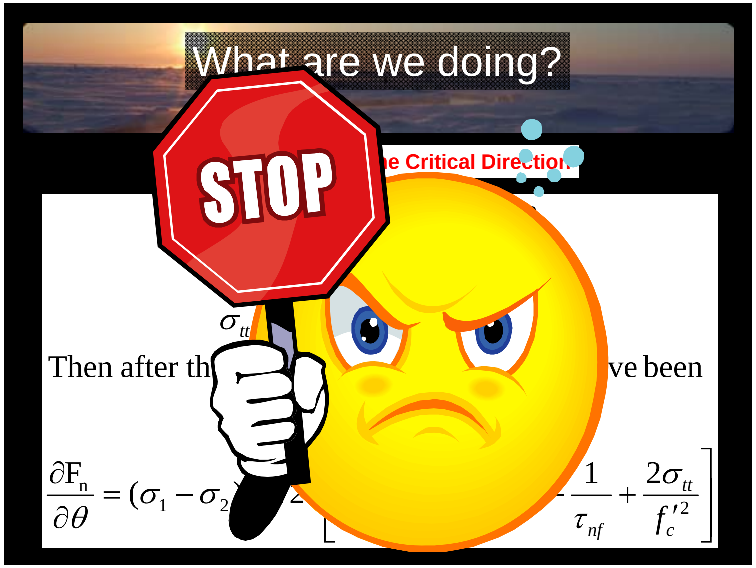
Technical – Engineering
- Ice engineering, ice loads, shipping
- Oil spill modeling
- Offshore pipelines, seabed gouging

Socio-Cultural / Socio-Economic
- Impact assessment—Where are the leads?
- Assessment management—Where will the leads be?

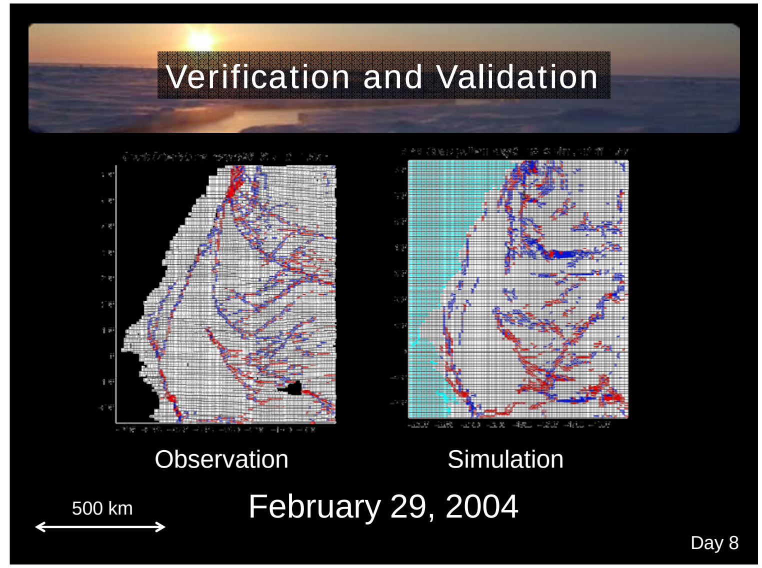
Ice Model of Leads and Ridges Cross Cuts our 4 Themes

Biological Sciences
- Feeding for whales, seals, fish in leads
- Whale migration

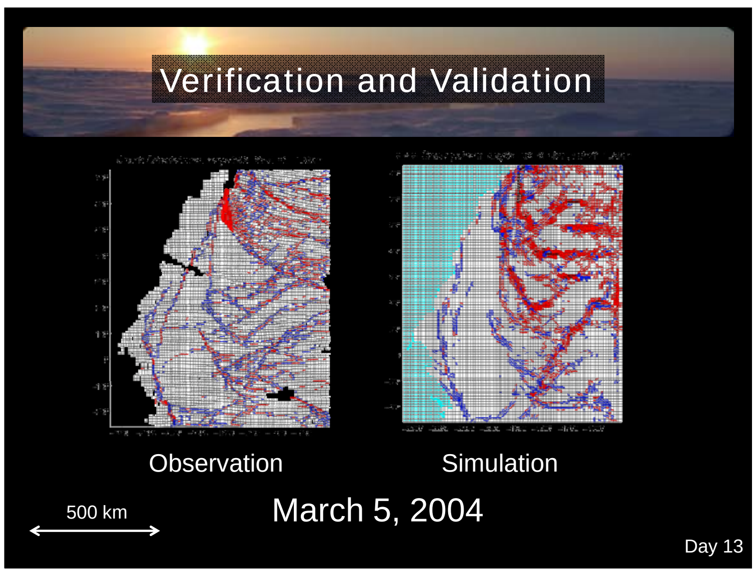
Physical Sciences
- Air-ice-sea interactions
- Seabed-ice interaction



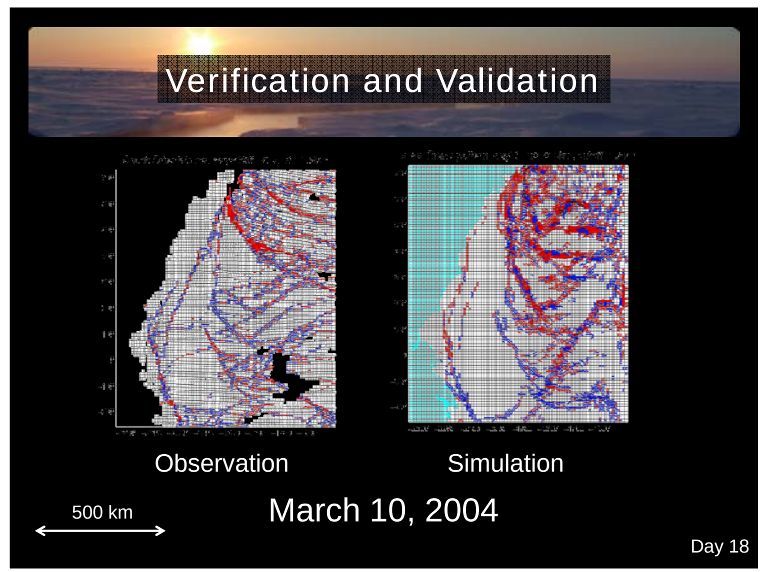
What are we doing?
STOP
e Critical Direction
Then after th
ve been



Verification and Validation
Observation
Simulation
500 km
February 29, 2004
Day 8

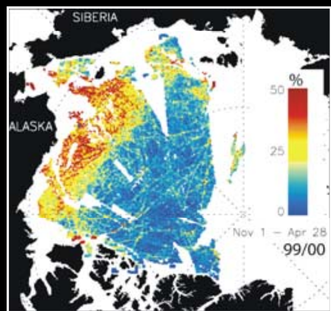


Verification and Validation
Observation
Simulation
500 km
March 5, 2004
Day 13



Verification and Validation
Observation
Simulation
500 km
March 10, 2004
Day 18

Future Sea Ice Modeling



- **Verification** – Does it work like we expect?
- **Validation** – Does it match the data?
- **Exercise** – More model runs under different conditions

Image credit: Ron Kwok, JPL

Future Funding

- **Joint Project with:**
  - U.S.A.
  - Canada
  - Government
  - Industry
- **Needs a champion.**

Needs $3 to $10 million distributed among researchers and developers.

$3 million to put into the hands of users.

$10 million to have a well validated model.

5.2.6 Using Technology to meet the Arctic Offshore Challenge, *Allan Reece*

Program Manager, Arctic R&D, Shell Exploration and Production. Email: Allan.Reece@shell.com

The Arctic presents one of the most demanding and challenging arenas for oil and gas operations. The challenges create sensitivities which include a technically difficult operating environment (remoteness, temperature, permafrost, winter darkness, and ice cover); indigenous peoples with strong dependence on, and cultural ties to, the environment; large geographical extent, relatively untouched by human activity; and most recently the added dimension of climate uncertainty and reduced sea ice cover.

The historic role of Arctic technology within the oil and gas industry has been overcoming the physical challenges to provide safe and realiable solutions. Key focus areas include: prediction of structural loads from sea ice features, interaction of ice features with on-bottom structures, such as pipelines, performance of marine vessels in and around ice, as well as conducting safe and reliable operations (e.g., drilling) in and around ice.

Successful entry and sustainability in the Arctic require addressing the social and environmental challenges in an equally comprehensive manner. This poster provides perspective on how Shell is applying technology to meet the technical and non-technical challenges of the Arctic offshore in a safe, responsible, and cost effective manner. Specific attention is given to a new dimension added to address the non-technical challenges. Examples are presented including sound mitigation, under ice surveys, and unmanned aircraft systems.

One example of this added dimension for technology application is sound mitigation. In the case of the Alaskan Beaufort Sea, there is concern that increased underwater sound levels will alter whale behaviors in ways that could interfere with feeding, migration patterns, or subsistence whale hunting. Sound mitigation, as a means of reducing impacts and protecting the environment, has therefore become a prominent component of Shell's Arctic technology program, which includes:

- Collecting baseline sound data from the drilling vessel Kulluk to quantify noise signatures and provide a basis for evaluating technical solutions for sound reduction.
- Investigating application of fabric curtain and air bubble technology for reducing drilling noise.
- Investigating quiet design specifications for new-build marine support vessels and platforms.

Another example of this expanding dimension for technology is under- ice surveys. A principal aim of this focus area is to reduce the intensity of activity during the short open water season and the concomitant risk of conflict with marine mammals.

The use of Autonomous Underwater Vehicles for seafloor surveys is well established. However for the Arctic the capability is still nascent, with the key challenge being able to autonomously navigate around ice keels in the survey path. Instrumentation being considered for under ice surveys includes multi-beam sonar for seafloor bathymetry, side scan sonar to investigate gouging, and sub-bottom profiler to characterize the sediment under the seafloor.

Meeting the Arctic technical and non-technical challenges requires a multidisciplinary approach to achieve balanced solutions; to create a future that strikes a balance between its economic, environmental and social aspects. Industry is at a unique crossroads. Opportunities abound for seeking holistic solutions that overcome the physical challenge, while meeting local and societal requirements and expectations.

5.2.7 Materials R&D for Northern Pipelines – Integrity, Safety, and Environmental Protection in the North,

R. W. Revie, J. T. Bowker, M. Elboujdaini, J. A. Gianetto, S. Papavinasam, W. R. Tyson & W. Zheng

[1]Ph.D., CANMET Materials Technology Laboratory, Natural Resources Canada, Ottawa, ON. Email: wrevie@NRCan.gc.ca

[2] Ph.D. Email:jbowker@NRCan.gc.ca

[3] Ph.D. Email:melboujd@nrcan-rncan.gc.ca

[4] Email: jgianett@nrcan-rncan.gc.ca

[5] Ph. D. Email: spapavin@nrcan-rncan.gc.ca

[6] Ph. D. Email: btyson@nrcan-rncan.gc.ca

[7] Ph.D. Email: wenyue@nrcan-rncan.gc.ca

In this presentation, an overview of materials R&D being carried out to help ensure reliability of northern pipelines will be presented, with emphasis on girth welding of high strength X80 and X100 pipe, engineering critical assessment, and corrosion protection.

Through a comprehensive evaluation of high-strength girth welds, a fundamental understanding is being developed of the welding variables that influence the attainment of the high strength and toughness that will ensure integrity and safety of pipelines in demanding applications in the North.

Guidelines are being drafted and recommended practices documented for weld metal tensile and fracture toughness testing of advanced, high-strength girth welds for strain-based design. A toughness test is being developed to measure toughness under low constraint, e.g., a defect in a girth weld under local tension as a result of bending or tensile deformation of the pipe. A standardized test is expected to be an output of this research, which will make it possible to avoid excessive conservatism in pipeline design.

In strain-based design pipelines, one of the challenges is to ensure the strength overmatching of girth welds with respect to the pipe body after both the pipe and the field welds have been coated. The girth weld coatings must be compatible with mainline coatings and with the cathodic protection system.

Research is in progress on the parameters that control stress-corrosion cracking of high-strength linepipe steels under pipeline operational conditions, including cathodic protection of the steel pipe.

Materials R&D for Northern Pipelines

Integrity, Safety, and Environmental Protection in the North

R. W. Revie, J. T. Bowker, M. Elboujdaini, J. A. Gianetto, S. Papavinasam, W. R. Tyson, and W. Zheng

CANMET Materials Technology Laboratory
Natural Resources Canada
Ottawa, Canada

Major Objectives

1. To meet the Government of Canada's needs for S&T information on federally regulated pipelines.
2. To develop innovative strategies to:
   a) Advance steel technology,
   b) Control fracture and corrosion,
   c) Enhance safety and reliability.
   } **Prevent Failures**
3. To reduce GHG emissions from pipelines by increasing efficiency of transportation.
4. To enhance competitiveness.

Challenges in the North

Northern Pipelines

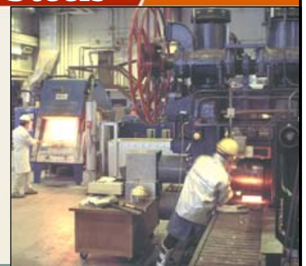
- Long distances
- Sensitive environments
- Higher Pressures
  - Higher-strength steels
  - Fracture control
  - Girth weld integrity
  - Corrosion control

Pipelines in the North

- **Development of High-Strength Steels**
- **Development of Technologies to Assess High-Strength Steels**

Development/Assessment of High Strength Steels

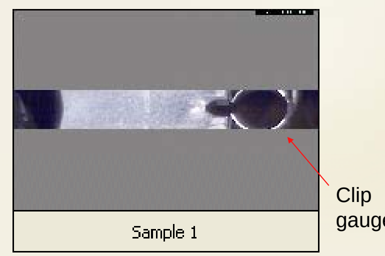
- Pilot-scale processing and evaluation of X80 to X120 line pipe steels



- Enhanced heat-affected zone toughness in modern line pipe steels

Toughness Testing for Strain-Based Design

Drop-weight tear tests on high-toughness steel, including use of a high-speed digital camera to monitor crack propagation



Girth Weld Integrity

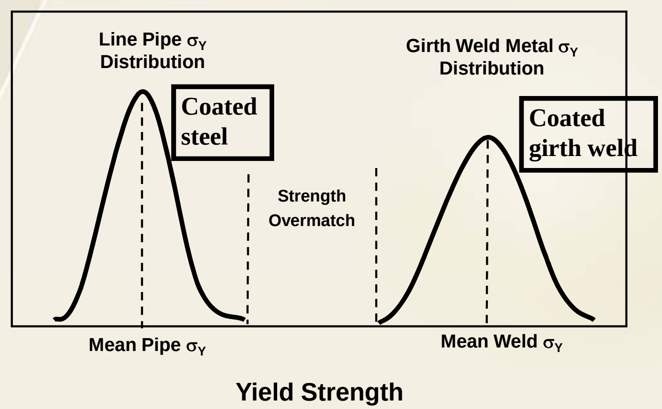
Develop and Evaluate Tensile Testing Protocol → **Establish Influence of Essential Welding Process/Procedure Variables on Properties**

Establish WM & HAZ Toughness Testing Procedures → **Establish Influence of Essential Welding Process/Procedure Variables on Properties**

Establish Influence of Essential Welding Process/Procedure Variables on Properties →

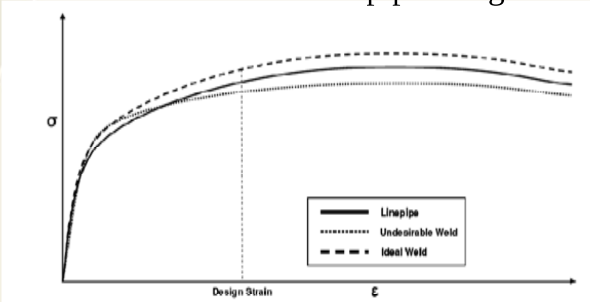
- Overmatching Strength
- Fracture Control

Girth Welds for Strain-Based Design



Strength Mismatch

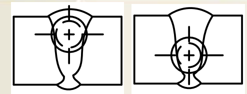
Stress-strain curves for linepipe and girth welds



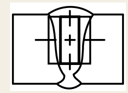
Undesirable weld overmatches the linepipe YS, but under matches linepipe at design strain.

Brian D. Newbury et al., Proceedings of the Sixteenth (2007) International Offshore and Polar Engineering Conference Lisbon, Portugal, July 1-6, 2007

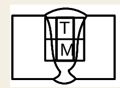
Tensile Testing Protocol



Standard round bar



Rectangular Strip Tensile



Split-Strip Tensile

How do we establish reliable measure of weld metal strength?

Issues

- **Clock location**
- **Through-thickness position**
- **Full weld testing – fill to root**
- **All-weld metal vs. cross weld**

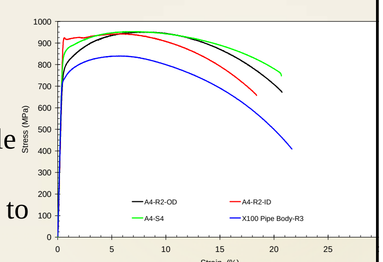
Natural Resources Canada Ressources naturelles Canada Canada

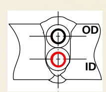
Weld Metal Qualification

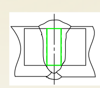
Recommended practice, guidelines and standards for assessing pipeline girth weld strength and toughness are being developed to:

- Provide consistent and reliable measurement;
- Allow overmatching strength to be quantified;
- Identify critical welding variables; and
- Enhance girth weld integrity.

Strengthening Codes and Standards through R&D







Natural Resources Canada Ressources naturelles Canada Canada

Stress Corrosion Cracking

Effects of operational variables and cathodic protection on cracking of high-strength steels

Strain-based design will allow high stress on pipe, creating more demanding SCC condition.

Pipeline Coatings

- Software for predicting coating performance
- Design criteria for external secondary pipeline coatings (e.g., girth-weld coatings, repair coatings)

Internal Corrosion

- **Internal Corrosion**
  - Development of methodologies/best practices for controlling internal corrosion of heavy oil and natural gas transmission pipelines
- **Microbiologically Influenced Corrosion**
  - Strategies to control microbiologically influenced corrosion
  - Biosensor

Strategic Outcomes

- Guidelines, recommended practices, standards, and regulations
- New high-strength steels used in northern pipelines successfully
- Enhanced integrity, reliability and security of federally regulated pipelines

5.3 OIL SPILLS

5.3.1 The Status of Current Technology for Oil Spill Cleanup in Ice,

Ian Buist

P. Eng., Director/Senior Engineer, SL Ross Environmental Research Ltd. Email: Ian@slross.com

Detection and Tracking

The presence of ice in conjunction with limited daylight greatly complicates the detection, mapping, monitoring and tracking of an oil spill in ice. The detection of oil on ice immediately following a spill is reasonably easy since the oil is generally thick and visible in sharp contrast to the snow. Airborne systems such as the laser fluorosensor and IR sensors have shown some potential for detecting and mapping oil among drift ice, but need to be proven. The latest generation of high-resolution radar satellites might be used to map large spills in drift ice conditions. The detection and mapping of oil spilled under ice is a difficult undertaking. Several techniques have been developed for detection and mapping of oil spilled under landfast ice: backlighting with powerful underwater lights, diver observations and coring. The use of traditional ground penetrating radar (GPR) has shown promise for thick spills and more powerful airborne GPR systems are being researched. The tracking of oil spills on, in or under ice generally involves techniques for tracking the ice.

Containment

Many spills in ice have the advantage of being contained by ice features. The main technique for containing spills on ice is to use surface barriers made of snow and/or ice. For containing oil under ice, techniques include slots cut in the ice, insulation to create underice cavities and the use of icebreakers to create refrozen rubble, but most are limited to landfast ice situations. For spills in drift ice, additional containment may be very difficult but some limited options are available or show promise.

Recovery

The techniques available to recover oil spilled on ice include direct pumping or skimming of thick pools of oil, mechanized and/or manual scraping and the use of sorbent. Oil spilled under solid ice is naturally contained within a small area and can be dealt with effectively when it surfaces in the spring; however, recovery also can commence earlier.

Oil spill recovery in drift and pack ice involves the use of skimmers (generally rope-mop and stiff-brush technologies) deployed in the water amongst floes from vessels, but the capacities of these skimmers would be greatly reduced.

In situ Burning

In situ burning is the countermeasure of choice to remove oil on ice or between ice floes. The efficiency of burning depends on the circumstances of the spill (e.g., film thickness, degree of emulsification). Burning of oiled snow can also be successful. The use of chemical herders to contract slicks among drift ice to thicken them for *in situ* burning shows considerable promise with minimal logistics.

Chemical Dispersants

Recent research on applying chemical dispersants to oil spilled in drift ice situations and then using azimuthal drive icebreakers to provide prop-wash mixing energy shows promise as an alternative response option. Research is also being conducted on applying dispersants to oil spilled in ice conditions and allowing the dispersant to soak into the oil for long periods until mixing energy is applied; and vessel-based dispersant application systems for targeting spills in drift ice.

5.3.2 Detection of Oil on and Under Ice: Phase III Evaluation of Airborne Radar System Capabilities in Selected Arctic Spill Scenarios, *David Dickins & John Bradford*

[1] P. Eng., DF Dickins Associates Ltd., La Jolla CA. Email: info@dfdickins.com

[2] Ph.D., Boise State University. Email: johnb@cgiss.boisestate.edu

The lack of any practical operational remote sensing system to detect oil in ice was identified as a priority research gap in Dickins (2004). The need for proven and reliable systems to detect oil trapped in a range of ice conditions remains at the forefront of continued efforts to advance Arctic spill response capabilities.

Under continued Minerals Management Service (MMS) sponsorship, the development of oil-in-ice detection systems based on ground penetrating radar (GPR) has made significant progress over the past four years through a series of related projects involving tank and basin trials, field tests and, most recently through this third study phase, model simulations of radar detection performance in a range of ice conditions. The Phase III study used the latest modeling software to carry out computer simulations of GPR performance for a variety of scenarios involving oil: under-ice, trapped-in-ice and on the ice surface buried under snow.

The overall results from this latest Phase demonstrate that currently commercially available GPR systems are capable of airborne detection and mapping of oil in ice over a broad operational time window from early to late winter, typically November to early April, in the Beaufort Sea. The most reliable months for detection are January and February with results in November, December and March depending on the internal brine volume of the ice (combination of salinity and temperature). Consistent imaging results in these months and earlier or later in the ice season will require the development of higher-powered airborne radar systems and/or a corresponding improvement in signal to noise ratios. For oil on the ice trapped beneath snow, existing GPR systems are capable of imaging the oil layer in an airborne mode through the entire ice season. The model results for oil –under-snow scenarios in this study indicated a positive mapping response in every situation considered. These findings were recently validated and confirmed in airborne tests over a spill on the ice at Svea, Svalbard in a joint program with SINTEF (April 2008).

GPR can now be considered as an operational tool to detect oil in a wide range of snow and ice conditions. The computer modeling tools developed in project produce realistic simulations of field conditions and could become part of an operational decision to use GPR in any given set of accidental spill circumstances.

Recent Progress

United States and Canada
Northern Oil and Gas Research Forum
October 28 2008

Detecting oil in ice and snow with Ground Penetrating Radar (GPR)

GPR Study Team 2006-08

John Bradford
Boise State University, Boise Idaho, USA
Center for Geophysical Investigation of the Shallow Subsurface

David Dickins
DF Dickins Associates Ltd., California, USA

Svalbard Experimental Spills Conducted by:

Per Johan Brandvik
SINTEF Materials and Chemistry, Trondheim, Norway

Liv-Guri Faksness
The University Centre at Svalbard (UNIS), Longyearbyen, Norway

Sponsoring Organizations

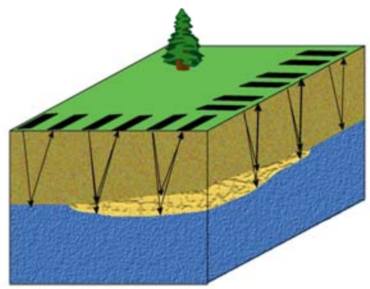
Funding & Support

- US Minerals Management Service
- Alaska Department of Environmental Conservation
- Alaska Clean Seas, Prudhoe Bay
- StatoilHydro ASA, Norway
- Shell Technology, Norway
- ExxonMobil
- ConocoPhillips Canada
- Store Norske Spitsbergen Kullkompani

Fundamentals of Ground Penetrating Radar

- GPR uses an electromagnetic wave operating at radio frequencies
  - 10 MHz – 1 GHz
- Sensitive to changes in electrical properties
  - Electric permittivity
  - Electric conductivity
    - Signal wont propagate through good conductors

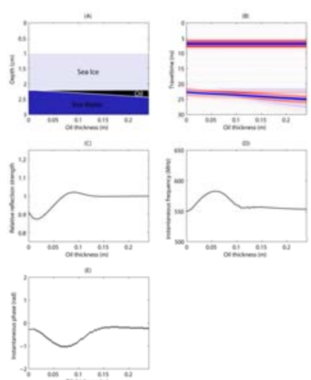
GPR Conceptual Model



Electrical Properties in the Arctic Marine Environment

Material	Relative Dielectric Permittivity	Conductivity (S/m)	Velocity m/ns	Wavelength @ 500 MHz
Air	1	0	0.3	60 cm
Sea Water	88	1-5	No propagation	
Sea Ice	4-8	.01 - .1	.134	27 cm
Oil	2	.0005	.212	42 cm

GPR response to oil



- The oil layer thickness is typically below the conventional resolution
- We can *detect* the presence of oil using detailed reflection analysis
  - Reflection strength
  - Wave spectrum
  - Wave shape

Topics

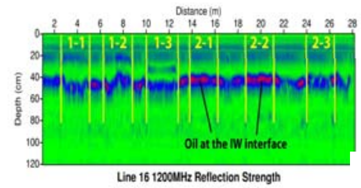
- GPR Test Phases
  - CRREL 2004 – Oil Under Ice
  - Svea 2006 – Oil Under Ice
  - Svea 2008 – Oil Under Snow
- **Model Simulations and Conclusions 2008**
- Future Possibilities
- Closing Points

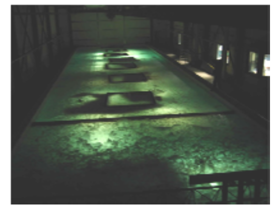
State of Knowledge – Detecting oil in Ice

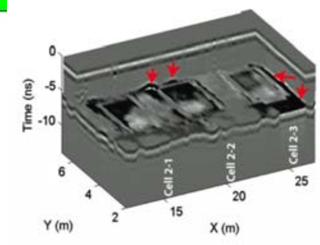
Kurdistan - searching in the fog for oil under ice floes

- Drilling and probing are traditional methods – very labor intensive and with serious safety issues
- Critical need for a reliable and safe operational remote sensing system for oil buried under snow and trapped in ice

GPR Breakthrough – CRREL 2004







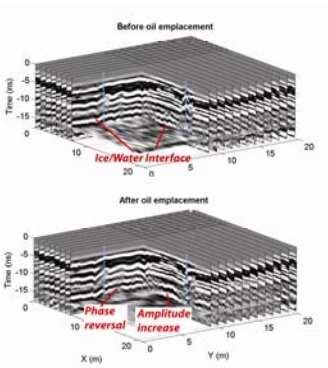
- Successfully detected presence of 2-3 cm oil films trapped in and under ice up to 40 cm
- GPR achieved positive detection and mapped extent of oiled areas trapped in and under ice

SINTEF JIP 2006 Under Ice Spill

Experimental release of oil under ice at Svea March 2006

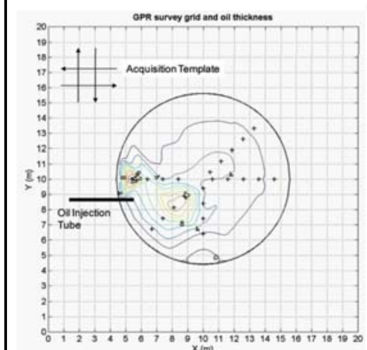
3400 litres of Statfjord crude pumped under 65 cm ice

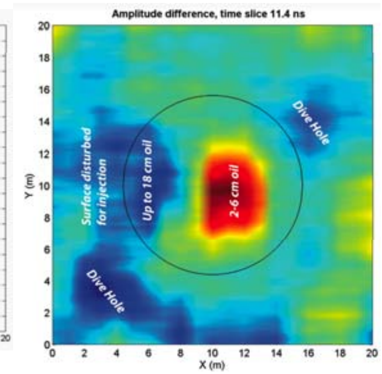
Successful Oil Detection Using 500 MHz GPR from the Surface



- GPR Reflection images before (top) and after (bottom) oil injection under the ice
  - Thick oil produces phase reversal
  - Thinner oil produces amplitude increase
- Response depends on ice conditions and oil thickness

Measured oil thickness vs. GPR response





Simulating field scenarios

- Controlled field spills are logistically difficult and expensive
- Task: Develop a numerical modeling approach to allow testing a broad range of ice conditions and spill scenarios
  - Define GPR applicability
  - Specify design parameters for future hardware development

The Problem – variable ice and snow properties and multiple interfaces

Oil Encapsulated in ice during an experimental spill In Alaska. Photo: A. Allen

Diesel spill under snow Photo: D. Dickins

Modeling GPR Capabilities

- Variable ice thickness, salinity, temperature
- Variable oil film thickness
- Variable geometry – trapped and free layers
- Variable roughness – macro and micro scale
- Effect of migrating oil
- Oil under snow

Work flow for modeling GPR data

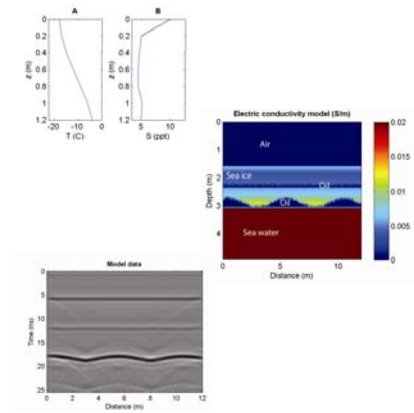
Input ice temperature and salinity

↓

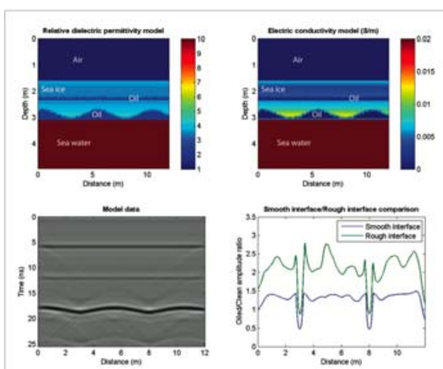
Estimate electrical property model

↓

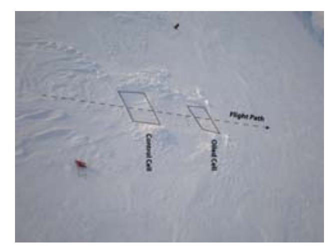
Simulate GPR data



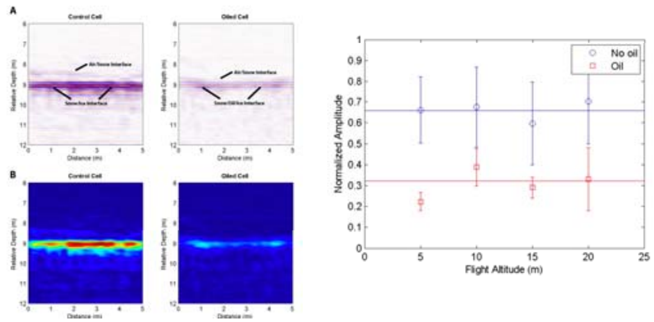
Rough Ice Simulation



2008 Oil Under Snow Tests



Successful Airborne Detection of Oil under Snow at Svea April 2008 (joint funding SINTEF JIP and MMS)

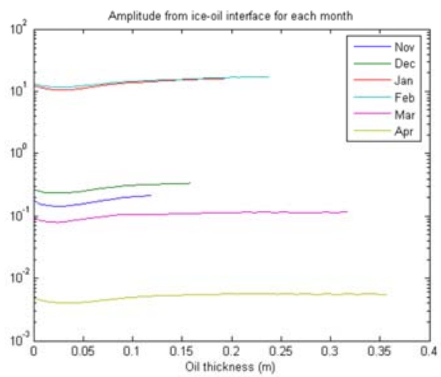


Significant reduction in reflection strength and signal amplitude – oil vs. no oil
Excellent agreement with numerical predictions.

Changing ice temperature

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Depth in)	Temperature								
AIR	-7	-13	-25	-25	-29	-30	-6	-3	3
2	-5	-7	-12	-17	-18	-19	-8.5	-3	-0.5
8	-3	-5	-10	-16	-17	-17	-8	-2	-0.8
16	-1.8	-4	-7	-13	-15	-14	-7.5	-2.5	-1
25	-1.8	-2.3	-3	-11	-12	-11	-6.5	-3	-1.5
32	-1.8	-1.8	-2.3	-7	-9	-8	-5.5	-3	-1.7
40	-1.8	-1.8	-1.8	-3	-6	-6	-4	-2.5	-1.5
48	-1.8	-1.8	-1.8	-1.8	-4	-4	-3.5	-2.2	-1
56	-1.8	-1.8	-1.8	-1.8	-1.8	-2	-3	-2	-0.5
64	-1.8	-1.8	-1.8	-1.8	-1.8	-2	-2	-2	-0.5
72	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8	-2	-2	-0.5
80	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8	-1.7	-1.6	-0.5

Strength of reflected signal from the ice/oil/water interface



Summary of GPR Operating Window

Range of Applicability for GPR Detection of Oil in Ice				
Ice Age	Ice Thickness (cm)	Oil Pool Depth (cm)	Oil Under Ice or as a Trapped Layer	
			Airborne Radar	Surface Radar
Early Winter Ice (October to December) - 30% of the ice season				
New or nilas	<10	N/A		
Young	10 – 30	2 - 3		
Thin First-year	30-70	3 - 7		
Winter Ice (January to February) - 25% of the ice season				
Medium First-year	70 – 120	7 - 12		
Thick First-year	120 – 200	12 - 21		
Late Winter Ice (March to April) - 25% of the ice season				
Thick First-year	120 - 200	12-21		
Spring and Summer Ice (May to June) - 20% of the ice season				
First-year ice	Highly variable	N/A		
Deformed Ice (any time of year)				
Rafted ice, rubble, ridges	*30 cm to 10 m+*	*Highly variable cm to m*		

	Detection considered highly unlikely due to warm, saline ice and lack of a defined oil layer. Ice too thin for surface operations.
	Detection possible in the future with higher-powered systems. Results uncertain, due to poorly defined oil layer in thin ice.
	Detection possible with existing systems but dependent on ice salinity and temperature. Consistent and reliable detection will require higher-powered radar systems or a significant improvement in signal to noise ratios.
	Consistent and reliable detection expected, based on knowledge gained at CRREL (2004) and Svalbard (2006 and 2008).

Suggested protocol for field responders

- Collect a sample of the spilled oil if available, and measure its dielectric permittivity. This can be done rapidly using a time-domain reflectometry probe or the GPR system itself.
- Acquire ice thickness, temperature and salinity profiles from the spill area.
- Run numerical model with varying oil thickness to verify applicability of GPR to particular spill conditions and predict expected response.

Key Findings from field tests and model simulations under different scenarios

- Ground penetrating radar at 500 MHz successfully detected and mapped the presence of oil films as thin as 1-3 cm under 65 cm of warm sea ice (worst case for radar)
- Airborne radar mounted on a helicopter clearly detected oil at the snow/ice interface from at altitudes up to 30 m and speeds to 20 kt. Results showed excellent agreement with numerical predictions.
- Recent modeling results indicate that existing GPR systems are capable of detecting oil trapped under or in solid ice under mid-winter Arctic conditions.
- Higher powered systems are proposed to expand capabilities into the shoulder seasons with high signal attenuation
- Overall, detection of oil in and under sea ice appears promising under a broad range of ice conditions through detailed measurements of reflected wave properties.

Airborne GPR for Detecting Oil in Ice and Snow

- Operational now for relatively smooth, cold ice sheets
- Existing off the shelf systems limited early and late in the season
- Potential to greatly expand the window of operation with dedicated new hardware

5.3.3 The Oil Spill Recovery Institute: Present and Future Work in the Arctic, *W. Scott Pegau*

Ph.D., Research Program Manager, Oil Spill Recovery Institute. Email: wspegau@pwssc.org

The Oil Spill Recovery Institute (OSRI) is a nonprofit organization that funds oil spill research, education, and demonstration projects applicable to Arctic and Subarctic marine waters. Our work in the Arctic has focused on technological demonstration projects and graduate student research through a variety of funding approaches. We cosponsored the workshop and publication on advancing oil spill response in ice-covered waters. We are presently contributing to a jointly funded project on oil transport within sea ice and the microbial response with the Coastal Response Research Center.

We are funding a student researching ways to combine traditional ecological knowledge and geophysical measurements to better understand sea ice services. We also sponsored a prize for solutions to breaking viscous shear of oil below the pour point in spill response barges.

OSRI is currently beginning to develop its next five-year research plan and is looking for input into the types of projects that it should consider funding during that period.

The Oil Spill Recovery Institute:
Present and Future Work in the Arctic

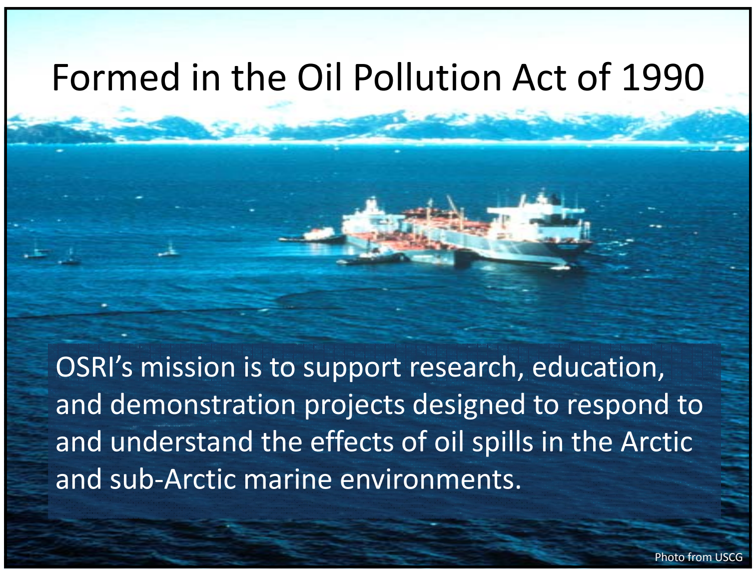
PRINCE WILLIAM SOUND
OIL SPILL RECOVERY INSTITUTE

Outline

- Introduction to OSRI
- Past and present efforts
- Request for the future

Photo from Cook Inlet Spill Prevention and Response Inc.

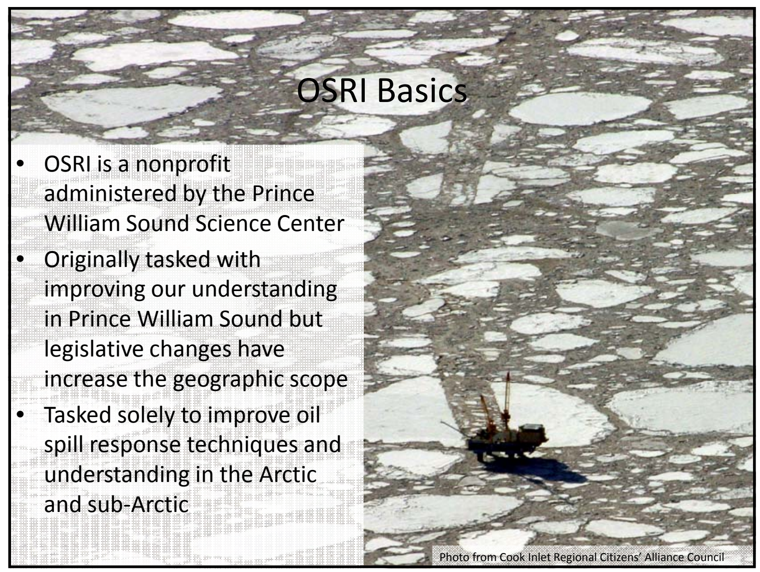
Formed in the Oil Pollution Act of 1990



OSRI's mission is to support research, education, and demonstration projects designed to respond to and understand the effects of oil spills in the Arctic and sub-Arctic marine environments.

Photo from USCG

OSRI Basics

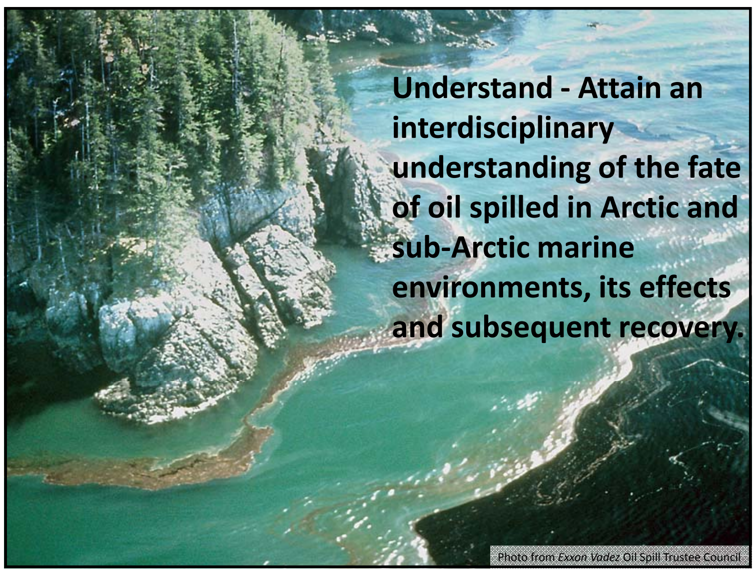


- OSRI is a nonprofit administered by the Prince William Sound Science Center
- Originally tasked with improving our understanding in Prince William Sound but legislative changes have increase the geographic scope
- Tasked solely to improve oil spill response techniques and understanding in the Arctic and sub-Arctic

Photo from Cook Inlet Regional Citizens' Alliance Council


• Funded by the interest on $22.5 million in the $3 billion oil spill liability trust fund
• Regular funding starting in 1998
• Scheduled to last as long as there is oil and gas development in Alaska
Photo from USCG


To achieve its mission OSRI has four goals
Understand
Respond
Inform
Partner
Image from NASA


Understand - Attain an interdisciplinary understanding of the fate of oil spilled in Arctic and sub-Arctic marine environments, its effects and subsequent recovery.
Photo from Exxon Vadez Oil Spill Trustee Council


Respond - Enhance the ability of oil spill responders to mitigate impacts of spills in Arctic and sub-Arctic marine environments.
Photo from Cook Inlet Spill Prevention and Response Inc.

Partner - Partner with other organizations to take advantage of shared funding, facilities, knowledge, and experience.

Past and Present Arctic Research

Graduate Research Fellowships

John Ash – The management of anthropogenic environmental risk associated with oil development in the Arctic littoral, Ph.D. Thesis, Scott Polar Research Institute

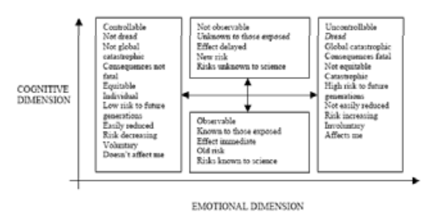
Jeremy Kasper - Modeling the effects of river discharge, windstress and sea ice on Arctic coastal circulation, Ph. D. student, University of Alaska Fairbanks

Matthew Druckenmiller – Promoting sustainable oil and gas development on Alaska's North Slope through local-scale integration of geophysical and traditional knowledge, Ph. D. student, University of Alaska Fairbanks

Ash

- Examines cognitive and management techniques for reducing anthropogenic environmental risk
- Focused on risk associated with roadless (ice road) oil development
- Perceived difference between risk management as outlined in regulation and the quality of decision making
- Proposed a new approach that fits within existing guidelines

Figure 4: Graphical Characterisation of Risk Perception on Cognitive and Emotional Dimensions [37]

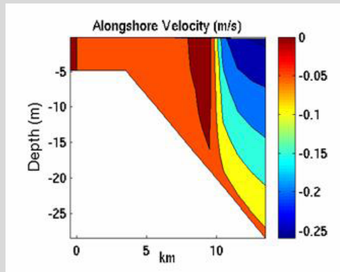


Kasper

• Modeled circulation under landfast ice

• Examined effect of freshwater input, wind stress, ice extent, and ice friction

• Ice blocks direct transfer of wind stress, which sets up a front near the ice edge that limits water exchange under the ice



Druckenmiller

• Work with local community to document ice conditions

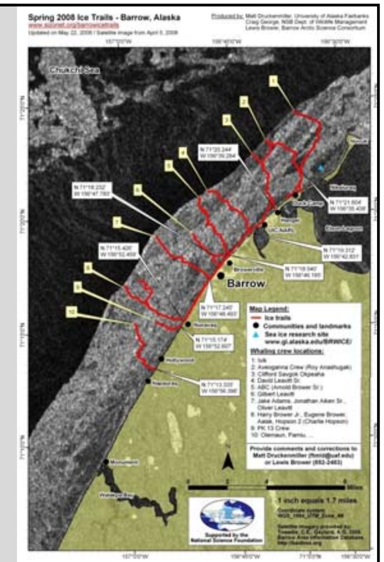
• Map landfast ice used by whalers

• Measure ice thickness along trails

• Interview community members about sea ice conditions

• Analyzing SAR satellite and ice radar data

•Barrow, Whales



Past and Present Arctic Research

Workshops and Reports

Oil-in-ice conferences – 2000, 2003, and 2007

Advancing oil spill response in ice covered waters*

The joint viscous oil pumping workshop*

Past and Present Arctic Research

Respond Projects

Morice

Skimmer testing

Prize program –
- Breaking viscous shear
- De-icing recovery equipment
- New ice boom system

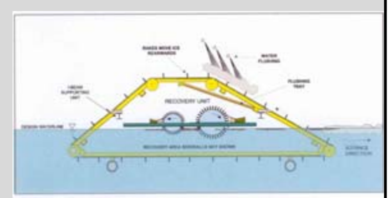
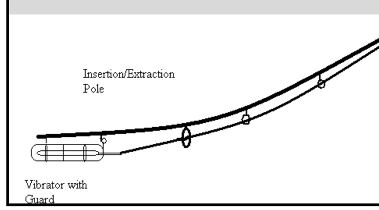


Figure 4.9 Lifting Grated Belt with flushing system and recovery unit.

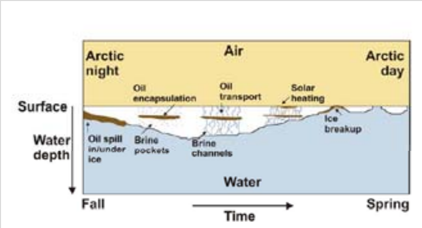


Past and Present Arctic Research

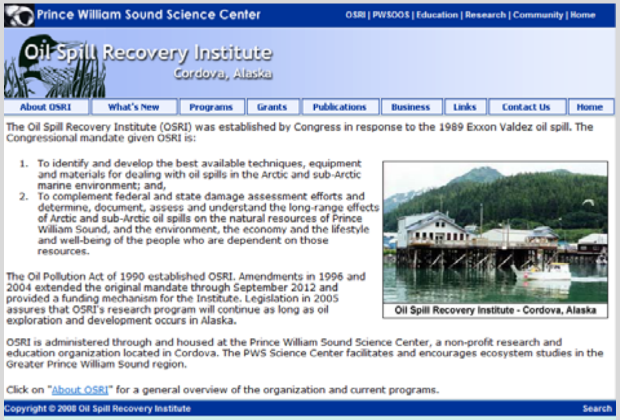
CRRC sponsored biological component to the JIP

Hajo Eicken and Chris Petrich – Oil in Ice: Transport, Fate, and Potential Exposure

- Simulate multiphase flow through ice
- Examine how ice boundary and growth conditions effect flow
- Work with SINTEF investigators to characterize ice used in laboratory experiments



For more information about OSRI and the projects it funds go to www.pws-osri.org



Prince William Sound Science Center

OSRI | PWSOOS | Education | Research | Community | Home

Oil Spill Recovery Institute

Cordova, Alaska

About OSRI | What's New | Programs | Grants | Publications | Business | Links | Contact Us | Home

The Oil Spill Recovery Institute (OSRI) was established by Congress in response to the 1989 Exxon Valdez oil spill. The Congressional mandate given OSRI is:

1. To identify and develop the best available techniques, equipment and materials for dealing with oil spills in the Arctic and sub-Arctic marine environment; and,
2. To complement federal and state damage assessment efforts and determine, document, assess and understand the long-range effects of Arctic and sub-Arctic oil spills on the natural resources of Prince William Sound, and the environment, the economy and the lifestyle and well-being of the people who are dependent on those resources.

Oil Spill Recovery Institute - Cordova, Alaska

The Oil Pollution Act of 1990 established OSRI. Amendments in 1996 and 2004 extended the original mandate through September 2012 and provided a funding mechanism for the Institute. Legislation in 2005 assures that OSRI's research program will continue as long as oil exploration and development occurs in Alaska.

OSRI is administered through and housed at the Prince William Sound Science Center, a non-profit research and education organization located in Cordova. The PWS Science Center facilitates and encourages ecosystem studies in the Greater Prince William Sound region.

Click on "About OSRI" for a general overview of the organization and current programs.

Search

Future Research

OSRI is in the process of developing a new 5-year research plan that will outline it's priorities in research, demonstration, and education projects.

I am looking for your input on what projects OSRI should have in that plan.

wspegau@pwssc.org

907-424-5800 x222

5.3.4 ERMA: A New High Resolution Environmental Data Display and Management System for Oil Spill Planning and Response,

Amy Merten & John Whitney

[1] Ph.D., NOAA Co-Director, Coastal Response Research Center. Email: Amy.Merten@noaa.gov

NOAA's Office of Response and Restoration (ORR) in a partnership with the University of New Hampshire Coastal Response Research Center (CRRC), is leading an effort to develop a data platform capable of interfacing diverse data sets with a map server and displaying real-time data in a web-based format accessible to a command post and to assets in the field. The system called ERMA (Environmental Response Management Application) is an integrated data management platform that integrates geospatial, regional-scale data and real-time (weather, currents, AIS data, etc.) and static data sets with suitable mapping capabilities, resulting in high-impact, high-resolution visualization output all in a web-based geographic information system. The platform, based on GIS, is able to collect, manipulate, analyze and display spatially referenced data for solving complex resource issues. The web-based nature of the platform is critical as it allows for the integration and synthesis of various types of information, provides a common operational picture for all individuals involved in an incident, improves communication and coordination among responders and stakeholders, and provides resource managers with the information necessary to make faster and better informed decisions. In terms of pre-planning and preparedness for oil spill response in the Arctic, this system is nearly as important as any oil spill detection or response technique, and NOAA is hoping to partner with other agencies and industry to develop an ERMA system for locations critical to Arctic development and transportation, like the Bering Straits and Unimak Pass.

ERMA™

Environmental Response Management Application

Amy Merten, Michele Jacobi, John Whitney and Nancy Kinner

October 28, 2008

US/Canadian Oil and Gas Research Forum

Acknowledgments

- Portsmouth Harbor area local and regional response community.
- Coastal Response Research Center (CRRC) facilitated and funded the development of ERMA.
- Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET) provided funding.
- Development by:
  - NOAA Office of Response and Restoration
  - UNH Earth Systems Data Collaborative
  - UNH-NOAA Joint Hydrographic Center
  - UNH Research Computing

Outline

- Overview background and design process
- Discuss of how web-based GIS technology can assist in a environmental response effort and operations
- Highlight examples of the ERMA's capabilities

Coastal Response Research Center

- Partnership between NOAA's Office of Response and Restoration (OR&R) and University of New Hampshire
- Mission:
  - Develop new approaches to spill response and restoration through research/synthesis of information
- ERMA Sites:
  - Operational in Portsmouth NH
  - Planned in Caribbean (EPA Region 2)
  - Discussions with Arctic Community

Continuum of "Response" for the OR&R

Response (24 hours)

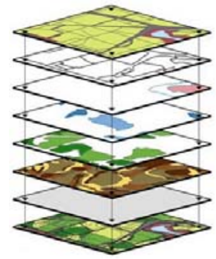
Restoration - Recovery

(Years to Decades)

Emergency Response Division (ERD)

Assessment and Restoration Division (ARD)

A Picture is Worth a Thousand Words…



- Diverse datasets can be interlaced on a single map to better visualize a the complex nature of an area

Why use a web based GIS platform during a Response?

- Integrate and synthesize various types of information
- Provide fast visualization of current information
- Improve communication and coordination among responders and stakeholders
- Provide resource managers with the information they need to make better informed decisions

Functional Web GIS Platform for Response

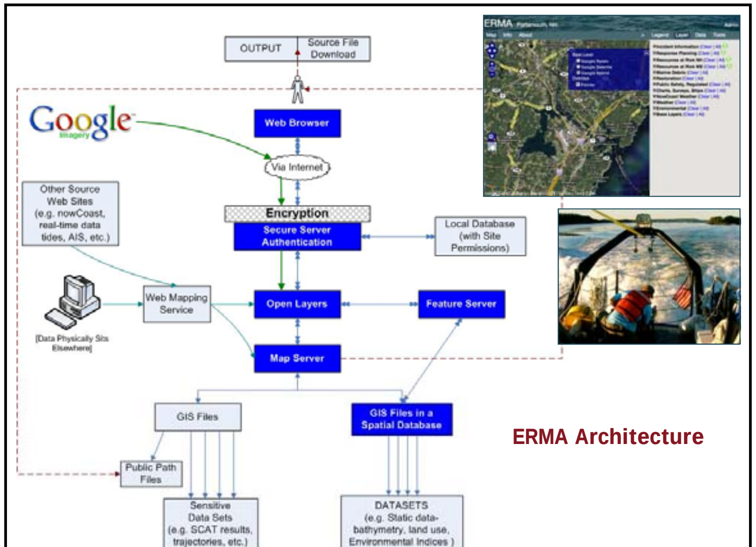
- Package data in a well-designed management, visualization, and analysis tool:
  - Easily accessible - field and command
  - User friendly
  - Quick to display
  - Capable of real-time data display
  - Simple to update/ download from
  - Secure

Project Partners: Technical Advisers

NOAA
- Office of Response and Restoration
- Coastal Services Center
- Office Coast Survey
- Weather Service
- Gulf of ME Ocean Observing System

UNH
- Joint Hydrographic Center
- Joint Center for Ocean Observing Technology
- Cooperative Institute for Coastal and Estuarine Environmental Technology
- Coastal Ocean Observing and Analysis
- Research Computing Center
- Earth Systems Data Collaborative

Additional Partners
- US Coast Guard
- US EPA
- NH Dept. Environmental Services
- ME Dept. Environmental Protection
- NH Fish and Game
- NH Coastal Manager
- NH Div. Emergency Services
- Piscataqua River Cooperative
- FL Fish & Wildlife



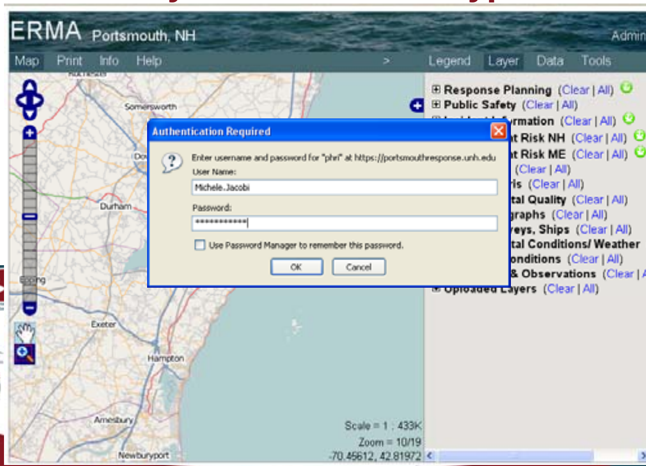
ERMA Architecture

Demo Highlights

Site basics
- Secure access
- Document & data links
  - ESI information
  - NOS/NOAA data
- Real-time feed for weather, ships
- Incident information
  - Trajectories
  - Resource Movements
  - Shoreline Assessment results

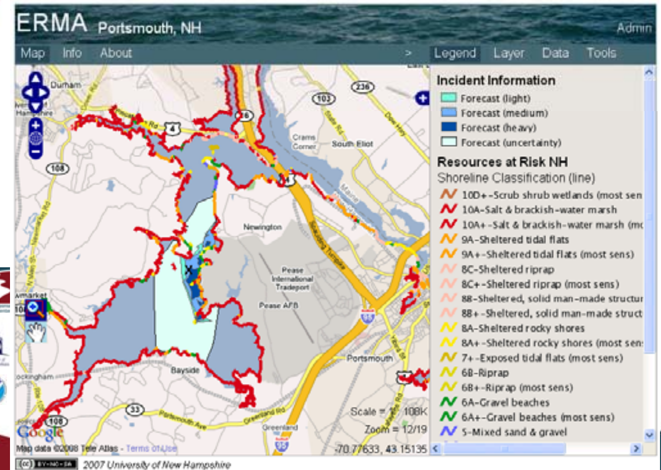
Interactive Tools
- Zoom to location
- Interactive drawing areas of interest
- Upload/ Download
- File and site access management

Easy to Access Data Types



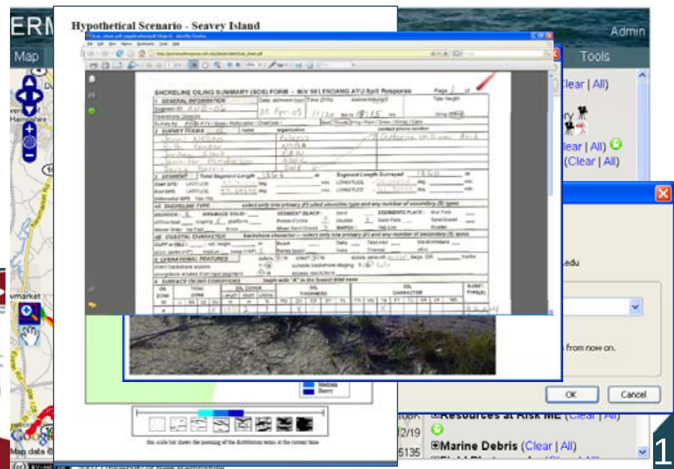
13

Critical Datasets for Environmental Response



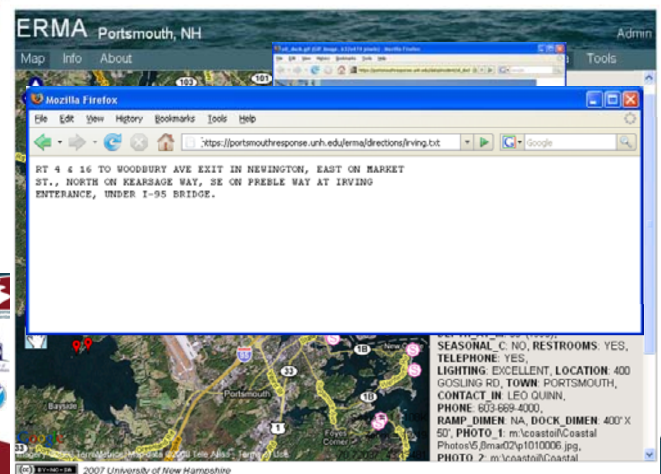
14

Link to documents and Download data



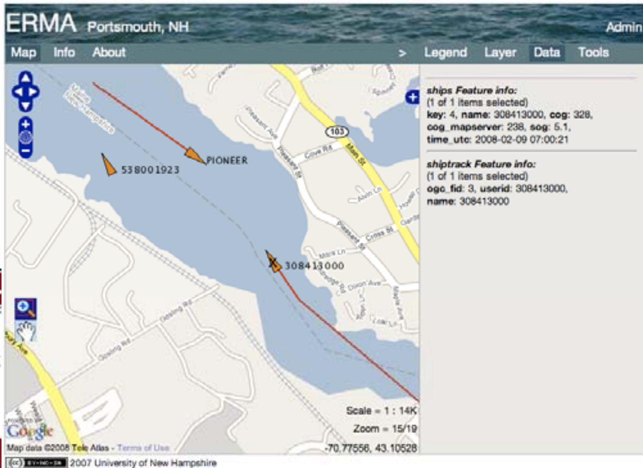
15

Data Table Access



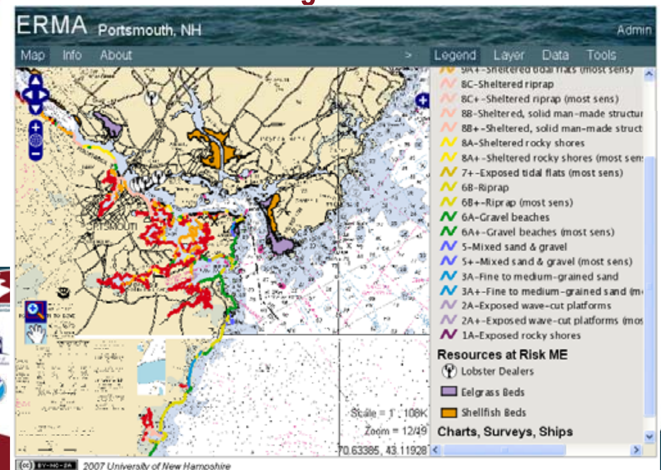
16

Real-time vessel traffic from AIS



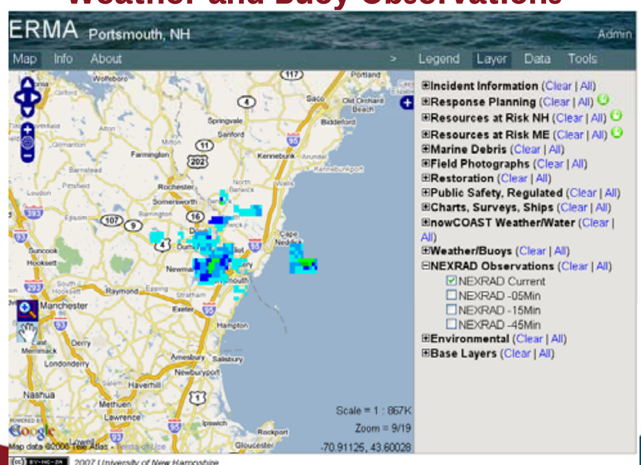
17

NOAA Navigational Charts



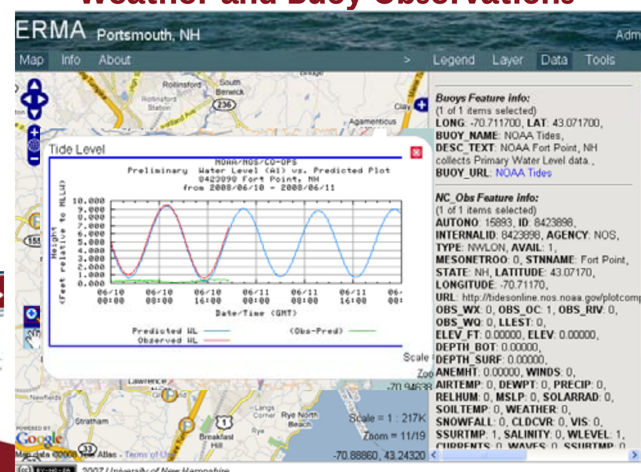
18

Weather and Buoy Observations



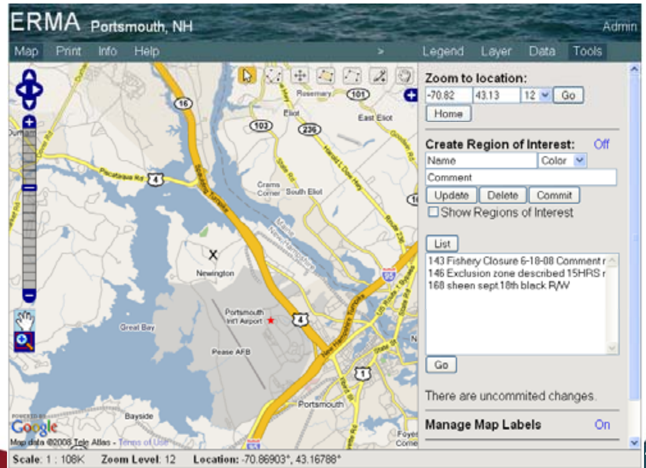
19

Weather and Buoy Observations



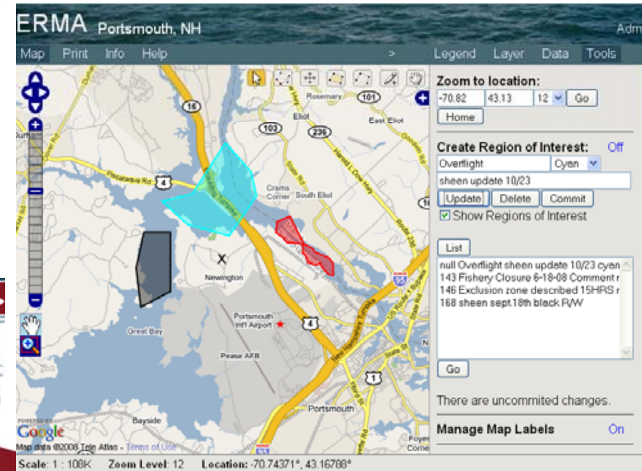
20

Interactive Tools



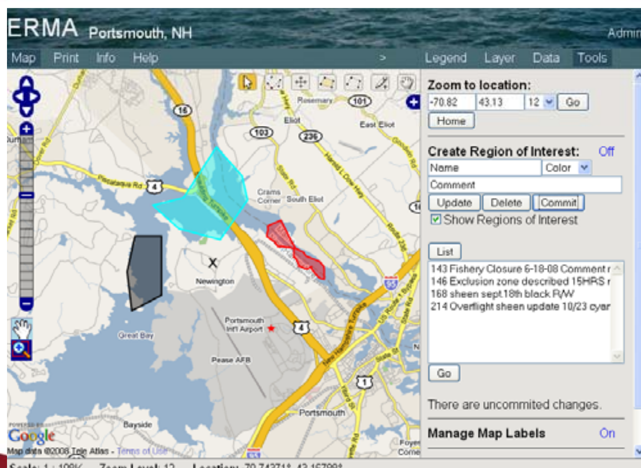
21

Interactive Tools



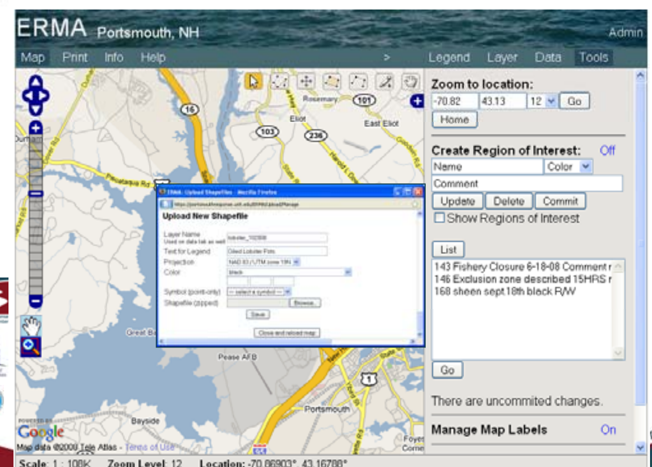
22

Interactive Tools



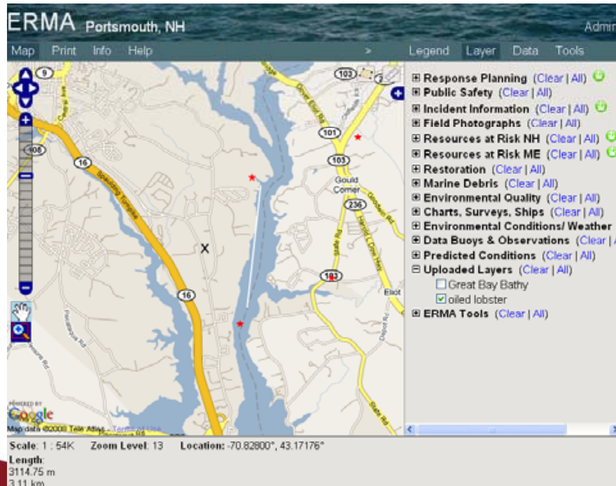
23

Interactive Tools

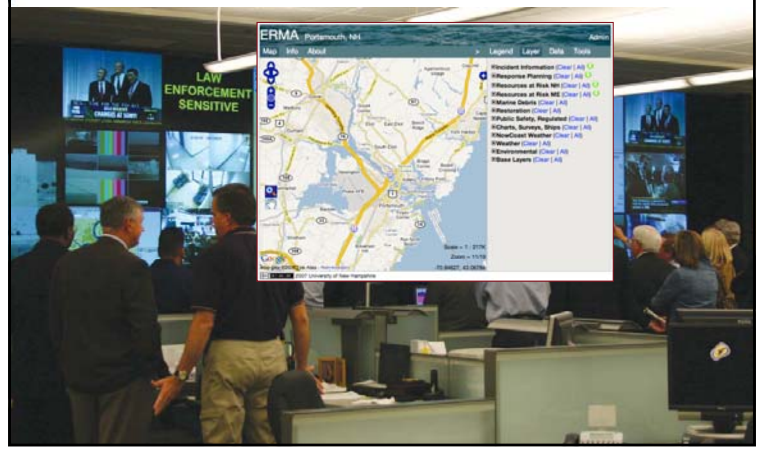


24

Interactive Tools



Environmental Response Management Application



ERMA™

Acknowledgement

Funding for this project was provided by the Coastal Response Research Center
www.crrc.unh.edu

University of New Hampshire

Coastal Response Research Center

Coastal Response Research Center

5.3.5 Oil Spill Preparedness, Response and Countermeasures Planning in the Canadian Arctic, *Steve Potter*

P. Eng. Director, Senior Engineer, SL Ross Environmental Research Limited. Email: Steve@slross.com

From 1958 to 1991, more than 200 wells were drilled in the Mackenzie-Beaufort Basin, including 83 in the Beaufort Sea. The drilling program activity confirmed the presence of significant quantities of both oil and gas in onshore and offshore locations.

In 1990, reacting to concerns raised in the environmental assessment of two offshore drilling proposals, the Canadian government formed the Beaufort Sea Steering Committee. The Committee was made up of representatives of the Inuvialuit community, the petroleum industry, and the federal and territorial governments and was given a mandate to examine a number of facets of oil spill response and environmental effects of hydrocarbon development. From the perspective of oil spill issues, the most prominent of these were: a review of the operating seasons for drilling in the context of relief well drilling; review and approval of industry contingency plans; and the development of credible worst-case spill scenarios.

Since the start of offshore drilling in the Beaufort Sea in 1976, it has been government policy that an operator not drill into a hydrocarbon-bearing zone without the ability to drill a same-season relief well. As new drilling systems were introduced, and as ice breaking capabilities were improved, the specific dates for “risk drilling” evolved, although the concept of “same-season” relief well capability has remained intact.

A contingency plan must be prepared and approved before a Drilling Program Approval is granted. There is no prescriptive formula for response capability or time standards, and no particular response techniques are explicitly ruled out. A process for plan review, approval, and subsequent testing and auditing is recommended.

The development and costing of a credible “worst-case” scenario was done to estimate the potential liability of an operator with regards to cost of well control, marine countermeasures, shoreline protection and cleanup, remediation, and compensation for lost wildlife. The process was also valuable in developing a consensus among the Committee on the appropriate countermeasures strategies and required levels of effort.

Since the Steering Committee’s work was completed there have been just a few drilling programs in the Canadian Beaufort region. Recognizing the potential for renewed activity in the near future, the Federal government launched the Beaufort Sea initiative in 2001 to ensure that all applicable government agencies were prepared for industry’s return to the offshore; the result was the Beaufort Offshore Guide, published in 2002, which summarizes all applicable regulations and approval processes for hydrocarbon exploitation in frontier areas.

Oil Spill Preparedness, Response and Countermeasures Planning in the Canadian Arctic

Steve Potter, P. Eng.
Director, Senior Engineer
SL Ross Environmental Research Limited
Steve@slross.com

Background

- More than 200 wells drilled in the Mackenzie-Beaufort Basin from 1958 to 1991
- Includes 83 in the Beaufort Sea
- Significant quantities of both oil and gas in onshore and offshore locations, but no production development to date

Drilling Program Approval (DPA)

- Environmental Assessment (under CEAA)
- National Energy Board (NEB) responsible for conducting Environmental Assessments
- Inuvialuit Final Agreement (IFA): Environmental impact screening and review

Regulatory background

- Following the Exxon Valdez spill, Inuvialuit Game Council requested that future drilling applications be subject to review, and consideration of a "Worst-case Scenario"
- Concept had been included in the Inuvialuit Final Agreement (IFA) in 1984
- Two subsequent drilling applications in 1989 and 1990: one rejected
- Led to Beaufort Sea Steering Committee work (1991)

Beaufort Sea Steering Committee

- Series of task forces that included government, industry, and Inuvialuit
- Reports published in 1991, including:
- Definition and Costing of a Worst-Case Scenario
- Remedial and Mitigative Measures
- Compensation and Financial Responsibility
- Operating Seasons
- Contingency Plan Testing and Inuvialuit Involvement

Oil and Gas Approvals in the Beaufort Sea (2002)

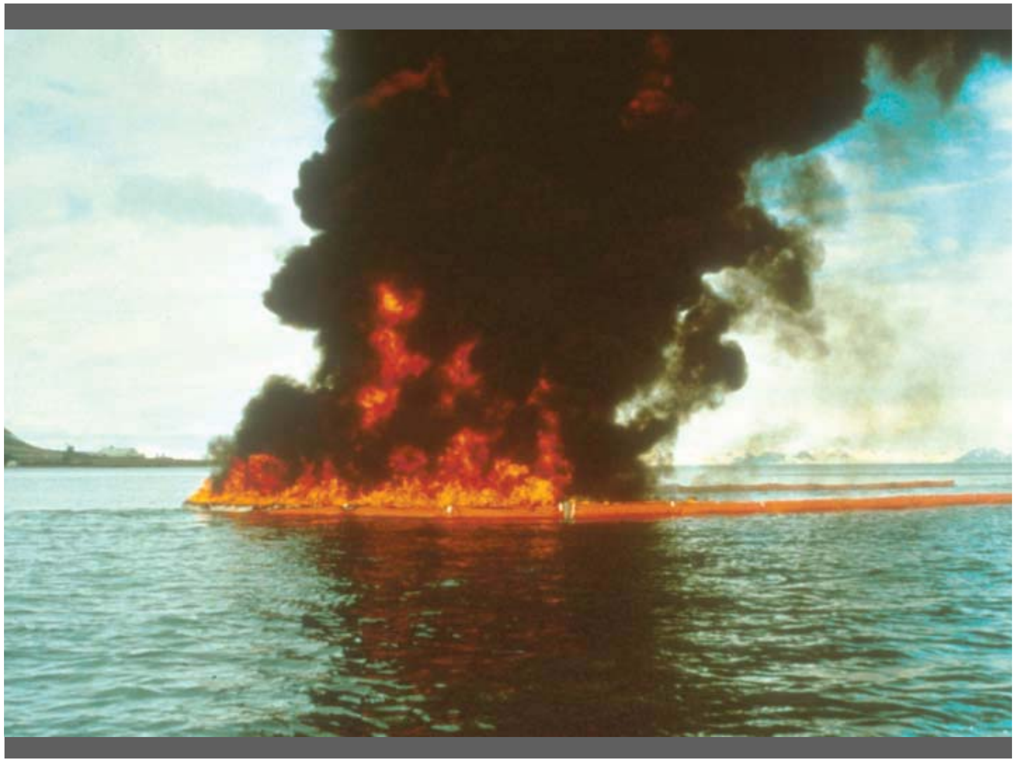
- http://www.oilandgasguides.com
- Funded by Indian Affairs and Northern Development Canada and the Canadian Association of Petroleum Producers
- Roadmap for approvals process for Beaufort Sea (as well as offshore Newfoundland and Nova Scotia)

Key Contingency Planning Issues

- Same season relief well drilling capability
- Response capability commensurate with associated spill probability and consequences
- No prescriptive standards

Key Contingency Planning Issues

- Lack of infrastructure
  - Equipment delivery
  - Personnel support
  - Waste handling
- Offshore locations remote from other responders: limited cascading or pooling of resources
- Arctic environment limits response options




Example Seasonal Ice Cycle for the Alaskan Beaufort

PREDOMINANT ICE ZONE	TYPICAL WATER DEPTHS (ft)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
		Average Daily Ice Drift (nautical miles per day)											
		10	7	6	4	3	2	3	5	5	4	6	7
Offshore Pack Ice	>100 ft												
Mixed Pack, Fast Ice	70 to 95												
Mixed Pack, Fast, Shear Zone	45 to 70												
Nearshore fast ice	15 to 45						FAST ICE						
Inshore Fast Ice	0 to 15												

	LEGEND AND NOTES
	Stable fast ice, variable roughness, bottomfast inshore 6 ft depth, severe ridging in 45-70 ft depths
	9 to 9+/10 very close pack and/or unstable fast ice
	7 to 8/10 close pack.
	1 to 6/10 drift ice (highly variable)
	<1/10 ice cover including period of ice overflood late May off major river deltas

Source: Dickins and Allen 1987

Broken Ice Conditions

- 0 to 3 tenths
  - Oil spread and movement not affected much by ice
  - Use open-water techniques (fire-resistant booms, etc.) in trace ice (<1/10th): at 1 to 3 tenths tend to accumulate brash ice and small floes rapidly
- 3 to 6-7 tenths
  - Oil spread slowed by ice pieces
  - Difficult to maneuver booms
  - Attempt uncontained burning of thick slicks
- 6-7 to 9+ tenths
  - Floes touching, oil contained, thick slicks easy to burn

Technology Gap

- Can burn thick slicks in pack ice (timely response)
- Need to address ISB for thin slicks in pack ice (Rules of Thumb, how to thicken without booms)

Steve Potter
SL Ross Environmental Research

Steve@slross.com
www.SLRoss.com

5.3.6 Empirical Weathering Properties of Oil in Ice and Snow,

Ian Buist, Randy Belore, David Dickins, Alan Guarino, Dan Hackenberg & Zhendi Wang

[1]P. Eng., Director/Senior Engineer, SL Ross Environmental Research Ltd. Email: Ian@slross.com

A considerable amount of field research was done in the 1970's and 1980's on first order processes of oil weathering in ice. Additional studies continued in the laboratory in the late 1980's and 1990's, but were generally limited to low-viscosity, low-pour point oils. It is now recognized that oil weathering is strongly dependent on the specific chemical composition and characteristics of individual crudes. The physical and chemical data required by modern state-of-the-art computer models are scarce, of poor quality, or nonexistent for oil-ice interaction. The objective of this study was to generate experimental data to validate and refine oil spill weathering algorithms for computerized models for spills in ice and snow.

The emphasis for the research was extensive laboratory testing with meso-scale verification to investigate the fate, behavior and interactions of fresh crude oil spilled with first-year, land-fast sea ice. Six series of experiments were conducted over a four-year study:

1. Spreading on Ice and in Snow
2. Evaporation in Ice and Snow
3. Slick Thickness on Cold Water
4. Migration Rates through Brine Channels
5. Formation of Water-in-Oil Emulsions
6. Full Spill-Related Characterization of Crude Oil Samples

These experiments were conducted at three facilities:

1. An outdoor test facility near Ottawa, ON constructed using insulated, IBC shipping containers as the test tanks each containing 1 m^3 of salt water.
2. An indoor, 11-m^3 wind/wave tank at SL Ross in Ottawa, ON specially modified: to incorporate a refrigerated cold air system to allow precise air temperature control to –30°C; to allow the growing of substantial thicknesses of sea ice; and, to generate under-ice water currents.
3. The 10,000-m^3 Ohmsett Facility in Leonardo, NJ, outfitted with large-capacity industrial water chillers to ensure freezing water temperatures.

Four crude oils from Alaska, representing a wide range of physical properties, were used in the research: Alaska North Slope, Northstar, Endicott, and Kuparuk.

Algorithms were recommended, based on the best fit of the experimental data from the experiments to various theoretical equations, for the following oil spill processes:

- The equilibrium thickness of oil on quiescent cold water.
- The spreading of oil on cold water.
- The equilibrium thickness of oil on ice.
- The spreading of oil on ice.
- The spreading of oil in snow.
- The stripping velocity for small oil forms under ice.
- The evaporation of oil on ice, under snow and among drift ice.

It was not possible to develop algorithms for emulsification or brine channel migration but significant new information was obtained through the experiments.

Empirical Weathering Properties of Oil in Snow & Ice

Ian Buist, Randy Belore, David Dickins, Dan Hackenberg, Alan Guarino and Zhendi Wang

Minerals Management Service
Alaska Outer Continental Shelf Region

Presented by Ian Buist, SL Ross Environmental Research

SL ROSS · MAR · DICKINS

Acknowledgements

SL ROSS · MAR · DICKINS

- MAR, Inc. (Project Management and Ohmsett)
- DF Dickins Associates (Ice and Snow Characteristics)
- Environment Canada (Chemical Analyses)
- Dr. Dick Prentki (MMS COTR)

Rationale

SL ROSS · MAR · DICKINS

- MMS Alaska uses oil spill weathering models for National Environmental Policy Act (NEPA) analysis, as well as for preparing oil spill response strategies for Oil Discharge Prevention and Contingency Plans (ODPCPs).
- The oil data required by modern state-of-the-art models (such as the one used by MMS in Alaska) are scarce, of poor quality, or nonexistent for oil-ice interactions.

Objective

SL ROSS · MAR · DICKINS

To generate experimental data that can be used to validate and refine weathering algorithms and computerized oil weathering models in the presence of ice and snow.

Scientific Approach

- Contract initiated in September 2004
- Emphasis was extensive laboratory testing with meso-scale verification to investigate the fate, behavior and interactions of fresh crude oil spilled with first-year, land-fast sea ice.
- Final report submitted October 2008

Scientific Approach

Six series of experiments were carried out over 3 years:

1. Spreading in Ice and Snow
2. Evaporation in Ice and Snow
3. Slick Thickness on Cold Water
4. Migration Rates through Brine Channels
5. Formation of Water-in-Oil Emulsions
6. Full Spill-Related Characterization of Crude Oil Samples

Experimental Facilities

The experiments were conducted at three facilities:

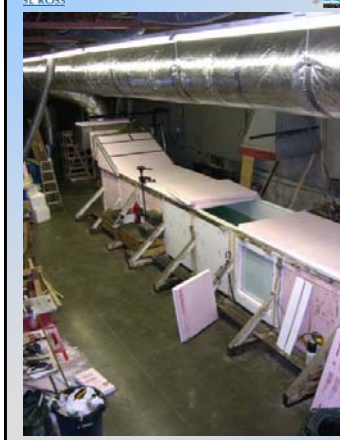
1. An specially-constructed outdoor test facility near Ottawa.
2. An indoor, 11-m^3 wind/wave tank at SL Ross in Ottawa specially modified to: incorporate a -30°C refrigerated air flow system to allow the growing of substantial thicknesses of sea ice: and, to generate under-ice water currents.
3. The 10,000-m^3 Ohmsett Facility in NJ, outfitted with large-capacity industrial water chillers to ensure freezing water temperatures.

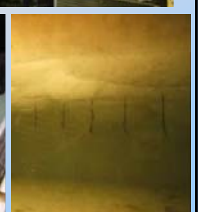
Experimental Facilities

Experimental Facilities

Experimental Facilities

Experimental Facilities





Experimental Facilities

Crude Oil Selection

- Crudes selected covered wide range of density, viscosity and pour point:
  - » Alaska North Slope crude from Pump Station 1 of TAPS
  - » Endicott sales crude
  - » Kuparuk sales crude
  - » Northstar sales crude
- All samples were collected in late October 2004 and shipped simultaneously to both SL Ross and Ohmsett to ensure consistency

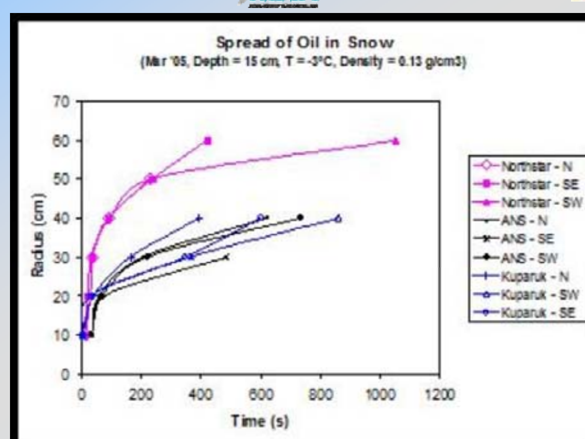
Full Characterization of Crudes

Property	Test Temperatures	Equipment	Procedure
Evaporation	To be specified	Calibrated Wind Tunnel Distillation Apparatus	ASTM D86-90
Boiling Point Distribution	N/A	GC SIMDIS	ASTM D5307-97
Density	To be specified	Anton Paar Densitometer	ASTM D4052-91
Viscosity (Oil and W/O Emulsions)	To be specified	Brookfield Viscometer DV III+	ASTM D2983-87
Interfacial Tension	To be specified	CSC DuNouy Ring Tensiometer	ASTM D971-82
Pour Point	N/A	Koehler Cloud and Pour Point Chamber	ASTM D97-87
Flash Point	N/A	Pensky-Martens Closed Cup Flash Tester	ASTM D93-90
Emulsification Tendency/Stability	To be specified	Rotating Flask Apparatus	(Hokstad and Daling 1993)
Hydrocarbon Groups (SARA)	N/A	Extraction /gravimetric and GC	Environment Canada, EST
Waxes	N/A	GC SIMDIS	Environment Canada, EST
N-alkanes	N/A	GC	Environment Canada, EST
Volatile Organic Compounds (VOCs)	N/A	GC/MS analysis for BTEX	Environment Canada, EST

Table 1. Test Procedures for Oil Characterization

Spreading in Snow - Methods

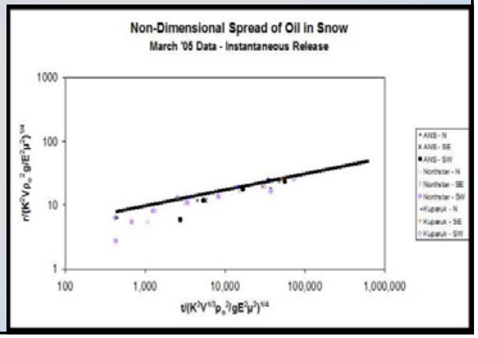
Spreading in Snow - Results



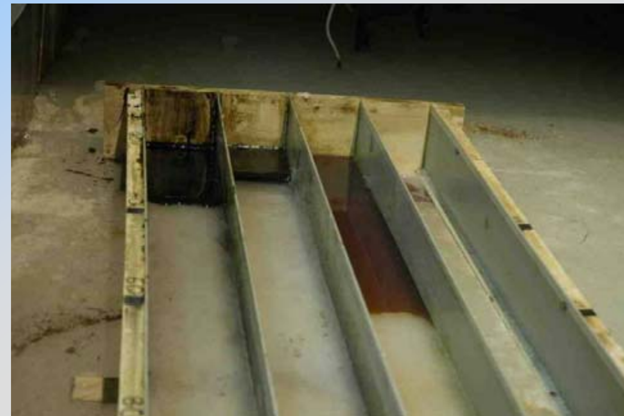
Spreading in Snow - Model

$$r = \left(\frac{2K\rho_o gV}{\pi E^2 \mu} \right)^{1/4} t^{1/4}$$

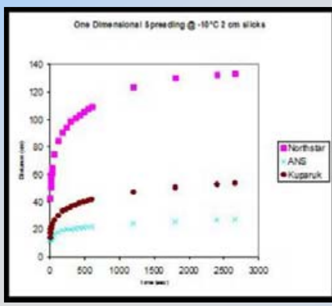
Where: $K \equiv$ specific permeability of snow [cm^2]
$= 7.7 \times 10^{-2} d_o^2 e^{(-7.8\rho_s/\rho_i)}$
$d_o \equiv$ mean snow grain size [cm]
$E \equiv$ porosity (void fraction) of snow
$= (1-\rho_s/\rho_i)$
$\rho_s \equiv$ snow density [g/cm^3]
$\rho_i \equiv$ ice density [g/cm^3]

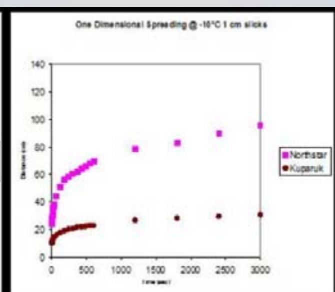


Spreading on Ice - Methods



Spreading on Ice - Results

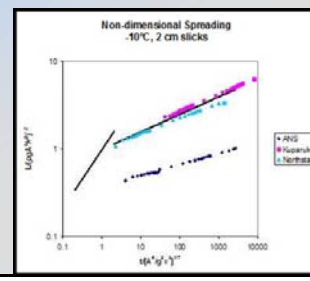


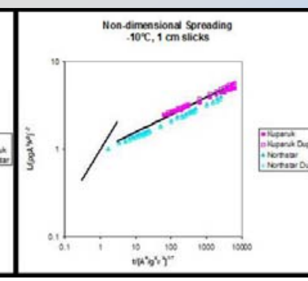


Spreading on Ice - Model

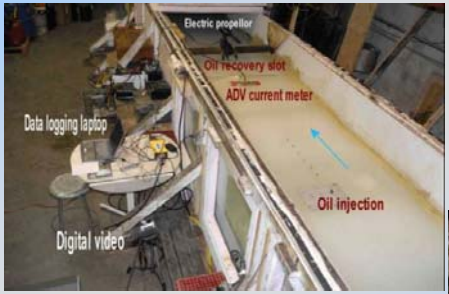
	One-dimensional	Axi-symmetric
Gravity-Inertia	$l = k(gA)^{1/3} t^{2/3}$	$r = k(gV)^{1/4} t^{1/2}$
Gravity-Viscous	$l = k\left(\frac{\rho_o g A^3}{\mu}\right)^{1/5} t^{1/5}$	$r = k\left(\frac{\rho_o g V^3}{\pi^3 \mu}\right)^{1/8} t^{1/8}$

$l \equiv$ the length of a 1-dimensional slick [cm]
$r \equiv$ the radius of a 2-dimensional slick [cm]
$k \equiv$ proportionality constants
$g \equiv$ acceleration of gravity [cm/s^2]
$A \equiv$ volume of oil per unit length normal to the direction of spread [mL]
$V \equiv$ volume of oil [mL]
$\mu \equiv$ dynamic viscosity of oil [g/cm s]
$\rho_o \equiv$ density of oil [g/cm^3]
$\sigma_i \equiv$ spreading coefficient, or net surface tension of oil on ice [g/cm s^2]

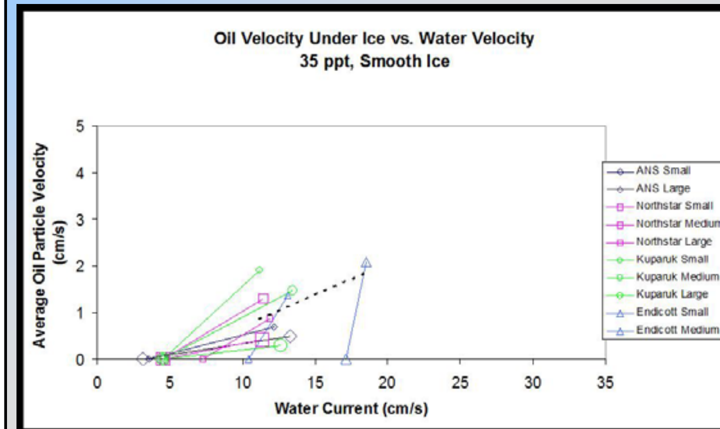




Movement of Oil Under Ice by Currents - Methods



Movement of Oil Under Ice by Currents - Results

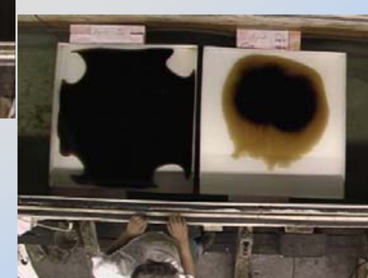


Movement of Oil Under Ice by Currents - Model

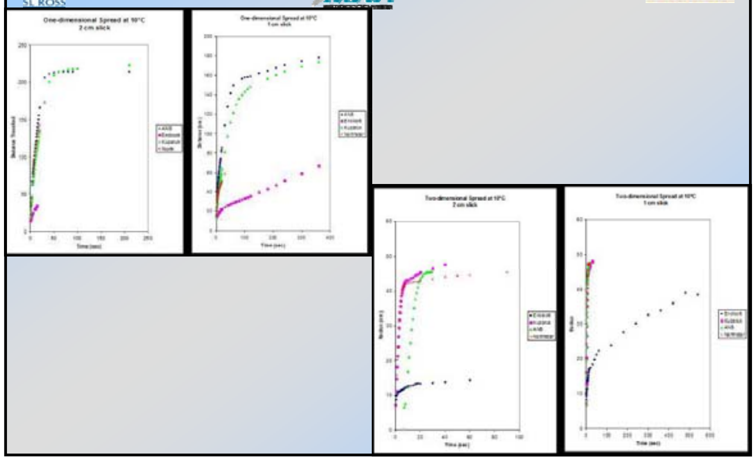
$$U_{th} = C_i \left(\frac{305.79}{88.68 - \mu_o} \right)$$

Where: $C_i \equiv$ under-ice roughness factor
= 2 for saline ice
= 3 for undulations under freshwater ice
= 4 for undulations under saline ice
= 6 for any refrozen rubble ice

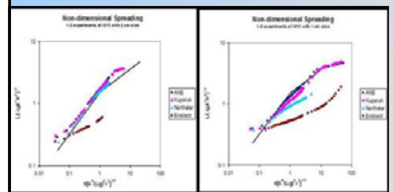
Spreading on Cold Water - Methods



Spreading on Cold Water - Results

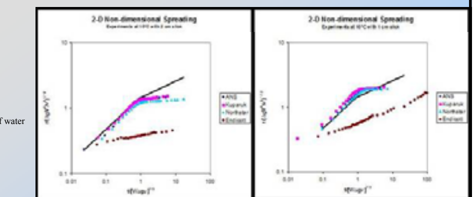


Spreading on Cold Water - Model



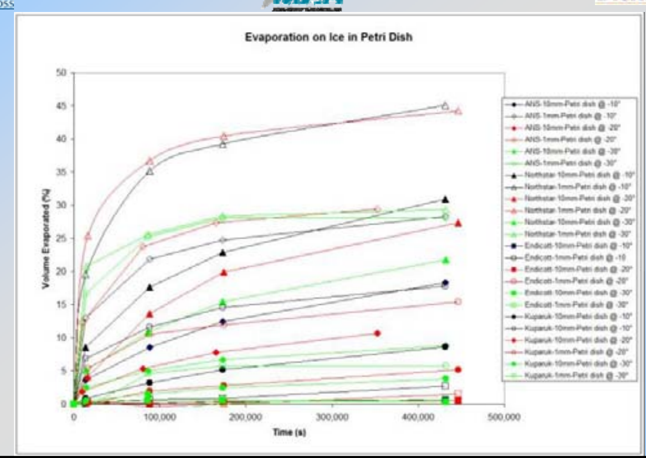
	One-dimensional	Axi-symmetric
Gravity-Inertia	$l = k_{1I}(\Delta g A)^{1/3} t^{2/3}$	$r = k_{2I}(\Delta g V)^{1/4} t^{1/2}$
Gravity-Viscous	$l = k_{1T}\left(\frac{\sigma^2}{\rho^2 \nu}\right)^{1/4} t^{3/4}$	$r = k_{2T}\left(\frac{\sigma^2}{\rho^2 \nu}\right)^{1/4} t^{3/4}$
Surface Tension-Viscous	$l = k_{1V}\left(\frac{\Delta g A^2}{\nu^{1/2}}\right)^{1/4} t^{3/8}$	$r = k_{2V}\left(\frac{\Delta g V^2}{\nu^{1/2}}\right)^{1/6} t^{1/4}$

$l \equiv$ the length of a 1-dimensional slick [cm]
$r \equiv$ the radius of a 2-dimensional slick [cm]
$k \equiv$ proportionality constants
$\Delta \equiv$ ratio of the density difference between water and oil to the density of water
$g \equiv$ acceleration of gravity [cm/s^2]
$A \equiv$ volume of oil per unit length normal to the direction of spread [mL]
$V \equiv$ volume of oil [mL]
$\nu \equiv$ kinematic viscosity of water [cm^2/s]
$\rho \equiv$ density of water [g/cm^3]
$\sigma \equiv$ spreading coefficient, or net surface tension [$g/cm\ s^2$]
$= \sigma_{w/a} - \sigma_{w/o} - \sigma_{o/a}$



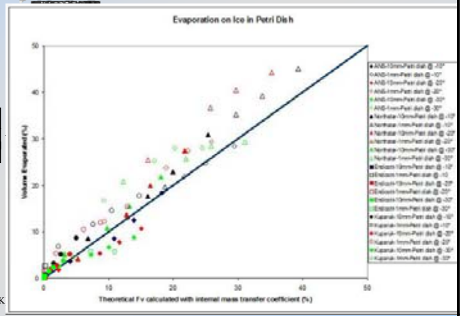
Evaporation on Ice - Methods

Evaporation on Ice - Results



Evaporation on Ice - Model

$$F_v = \ln\left[1 + \frac{BT_G}{T}\theta \exp\left(A - \frac{BT_0}{T}\right)\right]$$



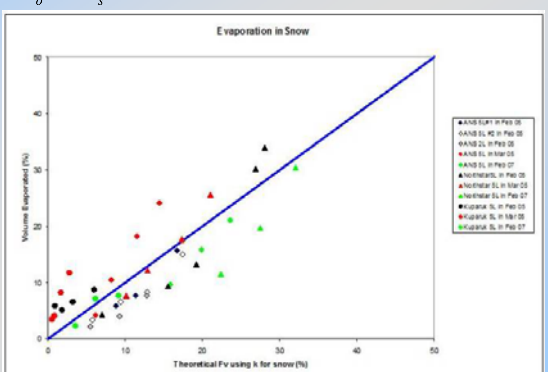
Where: F_v ≡ volume fraction of the oil evaporated
T_0, T_G ≡ the intercept and slope of the modified ASTM distillation [°K]
T ≡ environmental ambient temperature [°K]
B, A ≡ dimensionless, oil-specific constants equal to the least-squares slope and intercept of a plot of the natural logarithm of the Henry's Law constant vs. T_b/T
T_b ≡ boiling point of weathered crude oil at atmospheric pressure [°K]
P ≡ vapor pressure of the weathered crude oil [Pa]
v ≡ liquid's molar volume [m^3/mol]
R ≡ gas constant 8.314 [Pa m^3/mol °K]
θ ≡ dimensionless evaporative exposure = $kAt/V_0 = kt/x$
k ≡ mass transfer coefficient [m/s]
A ≡ area of slick [m^2]
t ≡ elapsed time since oil release [s]
V_0 ≡ initial volume of oil released [m^3]
x ≡ slick thickness [m]

Evaporation in Snow - Methods

Evaporation in Snow - Model

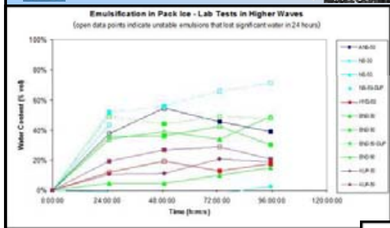
$$\frac{1}{k_T} = \frac{1}{k_a} + \frac{K_{oa}}{k_o} + \frac{x}{D_s}$$

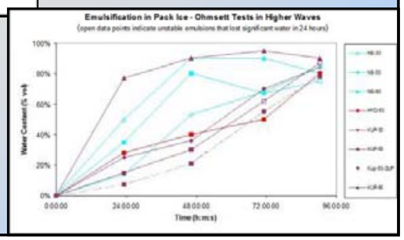
Where: D_s ≡ diffusivity of oil vapor in snow [m^2/s]
x ≡ thickness of snow [m]



Formation of Water-in-Oil Emulsions - Methods

Formation of Water-in-Oil Emulsions - Results





Formation of Water-in-Oil Emulsions - Model

At present no satisfactory algorithms predict emulsification of oil slicks at sea. There are two basic reasons for this:

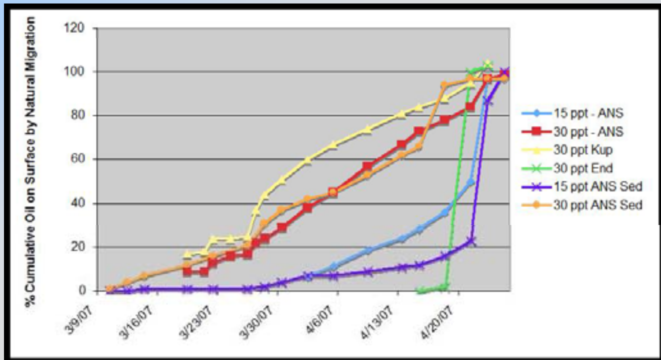
1. There is still a lack of understanding of the basic mechanisms by which emulsification occurs; and,
2. There is a basic lack of understanding how to measure and quantify the energy levels in various test tanks and the sea.

- State of the art is small-scale testing with evaporated oil samples to predict when it will be come susceptible to forming stable emulsions.
- There may be an effect of ice concentration and mixing energy on emulsification rate, but until emulsion formation in open water is better understood, it is not possible to model the effects of drift ice on the processes.

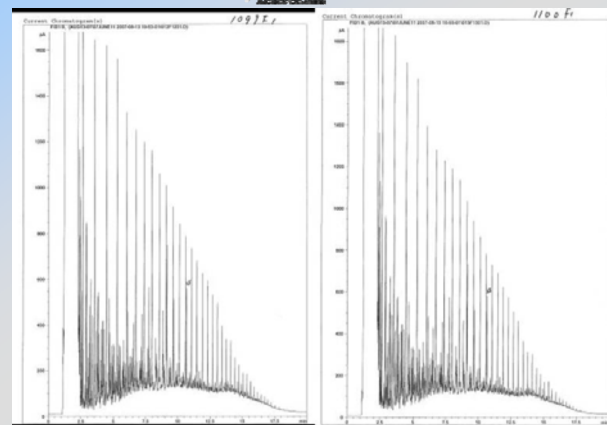
Migration Rates through Brine Channels - Methods

Migration Rates through Brine Channels - Methods

Migration Rates through Brine Channels - Results



Migration Rates through Brine Channels - Results



Migration Rates through Brine Channels - Model

It was not possible to develop algorithms for the rate of appearance of oil on the surface of ice in spring; however, the following key conclusions were made:

1. Oil viscosity/pour point/density played a major role in controlling the rate of oil migration in a given ice salinity.
2. Brackish ice provides fewer pathways for migration and slowed down the appearance rate.
3. The presence of sediment in the upper layer of the ice also slowed migration rates. It is not clear if this is related to the particle inclusions at the grain boundaries or the substantial cap of frazil ice in the upper layers of the sheet, providing no aligned brine channels.
4. Regardless of oil type, water salinity or the presence of sediments, the difference in timing when most of the oil was exposed (80% or better) amounted to less than ten days. Differences in migration rates due to these variables could be much more significant in the case of spills under much thicker ice.

5.3.7 Effectiveness of Chemical Dispersants on Alaskan Oils in Cold Water, *Randy Belore*

SL Ross Environmental Research Ltd., Ottawa, ON. www.slross.com

The U.S. Minerals Management Service (MMS) funded and conducted a series of large-scale dispersant experiments in very cold water at Ohmsett – The National Oil Spill Response Test Facility, located in Leonardo, New Jersey in 2003, 2006 and 2007. Alaska North Slope, Endicott, Northstar and Pt. McIntyre crude oils and Corexit 9500 and Corexit 9527 dispersants were used in the tests. The crude oils were tested both when fresh and after weathering. Results demonstrated that both Corexit 9500 and Corexit 9527 dispersants were very effective in dispersing the fresh and weathered crude oils tested at cold temperatures. The MMS expects that results from these test series will assist government regulators and responders in making science based decisions on the use of dispersants as a response tool for oil spills in the Arctic.

A poster presentation will be prepared to communicate the test methods and results from this research.

5.3.8 Oil-in-Ice: Transport, Fate, and Potential Exposure,

Whitney Blanchard, Odd Gunnar Brakstad, Hajo Eicken, Liv-Guri Faksness, Per Johan Brandvik, Øistein Johansen, Nancy E. Kinner, Amy Merten, Rainer Lohmann, Scott Pegau, Chris Petrich & Mark Reed

[1] Coastal Response Research Center, University of New Hampshire

[2] SINTEF Marine Environmental Technology

[3] National Oceanic and Atmospheric Administration

[4] Graduate School of Oceanography, University of Rhode Island

[5] Prince William Sound Oil Spill Recovery Institute

[6] Geophysical Institute, University of Alaska Fairbanks

Oil spilled in the arctic marine environment can be rapidly frozen into the ice sheet. The oil will in this way be to some extent preserved, in the sense that evaporation, dissolution, and degradation are expected to be reduced. This implies that the oil will retain much of its potential toxicity upon release from the ice, either via transport in brines channels and/or eventual breakup and melting of the ice sheet. Being able to estimate the pathways, release rates, and chemical characteristics of the remaining oil will provide the basis for eventual environmental risk and impact assessments. The purpose of this project is to provide a basis and methodology for estimating routes and magnitudes of potential environmental exposures and concentrations of oil components migrating through the ice regime as the oil is subjected to a freezing-thawing cycle. A transport/exposure laboratory study is suggested to determine how ice growth conditions affect the transport and fate of entrapped oil in ice. Quantitative data on the partitioning of oil (dissolved, particulate oil) components (bioavailable fractions) into brine inclusions and channels, and rates of vertical transport, will be collected. Since biodegradation of petroleum hydrocarbons at subzero temperatures in marine ice has not yet been shown, it will be essential to determine if crude oil biodegradation takes place in marine sea ice within a defined span of time and to what extent. If so, the contribution of biodegradation to the depletion of hydrocarbons in comparison to other depletion processes will be quantified. Targeted analytes will include polycyclic aromatic hydrocarbons (PAHs) and BTEX compounds, as well as decalines and phenols.

The study directly addresses the need for exposure and injury assessment tools for oil spills in cold climates. The use of passive samplers is a fast and cheap method to detect PAHs, one of the most toxic groups of compounds present in oil. In this proposal, we suggest advancing the use of two different passive samplers as a tool to detect PAHs from oil spills in ice cores. The two types of passives samplers being considered are polyethylene (PE), and solid-phase micro-extraction (SPME) fibers. They will be used to detect the transport and fate of oil-derived PAHs in ice cores. In a combination of laboratory and field studies, performance reference compounds will be included in the polyethylene matrix to enable their use as kinetic samplers and shorten deployment time in the field. In flow-through exposures using Narragansett Bay water, deployment will be undertaken to verify the use of the passives samplers to reflect dissolved concentrations as either equilibrium or kinetic samplers. Finally, in simulated oil spills in ice cores in the laboratory, dissolved concentrations of oil components will be detected using the passive samplers. The developed passive samplers will enable the oil spill community to deploy passive samplers to measure baseline conditions before a spill, as kinetic samplers during a spill and during the recovery phase of the natural ecosystem.

5.4 SOCIO-CULTURAL/ SOCIO-ECONOMIC

5.4.1 Variability in Cross Island (Arctic Alaska) Subsistence Whaling: An Examination of Natural and Anthropogenic Factors,

Michael Galginaitis

Applied Sociocultural Research. Email: msgalginaitis@alaska.net

Humans constitute an important and complex, but surprisingly often overlooked and neglected, element of Arctic ecosystems – except, perhaps, as the cause of perturbations in the more "natural" parts of the ecosystem. Monitoring changes in this human component of the ecosystem, whether such changes are due to natural or anthropogenic causes, presents substantial challenges, but can be successful when focused on especially significant socioeconomic aspects of local human activity. Contemporary subsistence (aboriginal) whaling constitutes one such nexus for Native communities in northern Alaska. One task of the ANIMIDA/cANIMIDA program gathered data and information to assess the potential effects of oil and gas (industry) activities, weather and ice conditions, and non-industry vessel and aircraft activities on subsistence whaling near Cross Island, Alaska. This presentation uses project data for 2001 to the present to discuss how year-to-year variability in subsistence whaling can be related to these factors, natural fluctuation, or other factors. Additional factors potentially accounting for changes in subsistence whaling such as changes in whale behavior, whaling technology, and climate change, will also be addressed using longer-term data. Weather and ice conditions, and the distance of whales from Cross Island, appear to be the most important factors affecting bowhead whale harvest near Cross Island. Anthropogenic factors are much more difficult to document, for a variety of reasons that will be discussed during the presentation.

A discussion of methods (GPS/GIS data combined with systematic observation and informal interviews with whalers) and a general overview of subsistence whaling at Cross Island will also be part of the presentation. Due to the limits of time, this portion of the presentation will necessarily be brief, but questions and discussion after the presentation are welcome.

NOAA Archive

Continuation of Impact Assessment for Cross Island Whaling Activities – Beaufort Sea (2001-2007)
Presented at the Northern Oil and Gas Research Forum '08, 29 October 2008
Contract Numbers 1435-01-04-CT-32149 and M04PC00032

Michael Galginaitis, Applied Sociocultural Research
msgalginaitis@alaska.net

NOAA Archive

Acknowledgments

Residents of Nuiqsut, especially the whalers and the Kittick (2001), Ahkiviana (2002, 2005, 2006, 2008), Oyagak (2003, 2007) and Napageak (2004) crews for serving as hosts

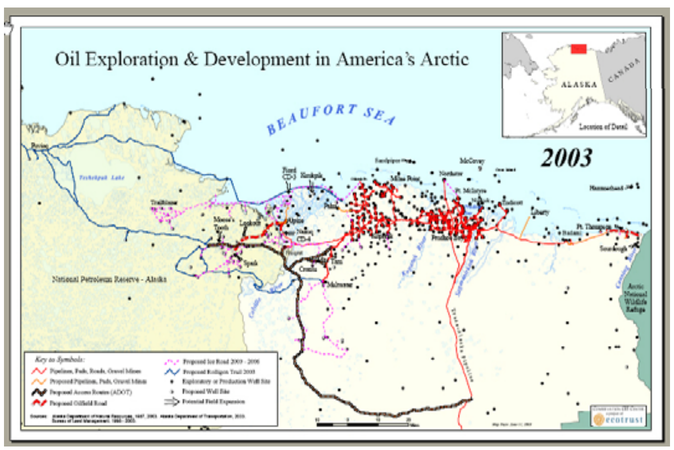
Alaska Eskimo Whaling Commission (AEWC)

Minerals Management Service for primary sponsorship and overall oversight (2001-2007, ANIMIDA and cANIMIDA)

Industry helped with logistics (2002-2008) and supplemental funding (2005-2008) for reports at the NMFS/MMS Open Water meetings in 2006-2008.

Oil and Gas Infrastructure and Exploration on the North Slope, 2003 (with focus on Nuiqsut)

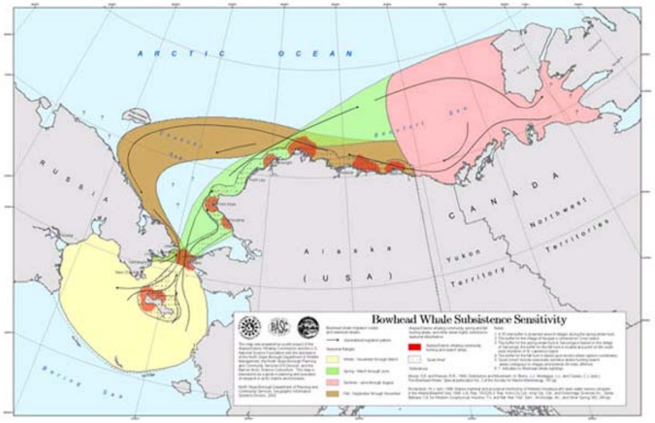
Source - Ecotrust Website



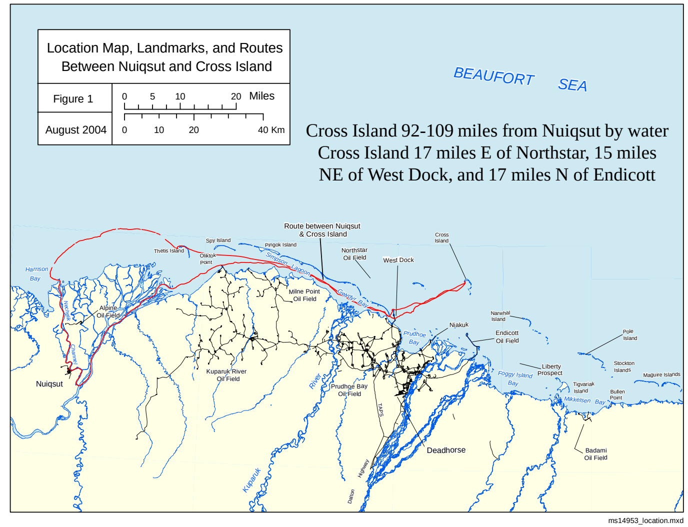
Recent North Slope Oil and Gas Activity

Source - Department of Natural Resources, State of Alaska

Bowhead Migration Route and Subsistence Harvest Areas -- Western Arctic Stock

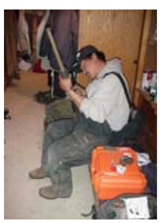


Alaska Eskimo Whaling Commission and the U.S. National Science Foundation; with the assistance of the NSB Department of Wildlife Management, the NSB Planning Department GIS Division, and the Barrow Arctic Science Consortium



Typical Cross Island Whaling Equipment and Crew

Float, Shoulder Gun, and Darting Gun



FIELD METHODS (2001-2007)

GPS units carried by all whaling vessels to document:

- Complete track while whaling
- Locations of whale sightings and whaling events

Conversations with and reports from whalers during each season

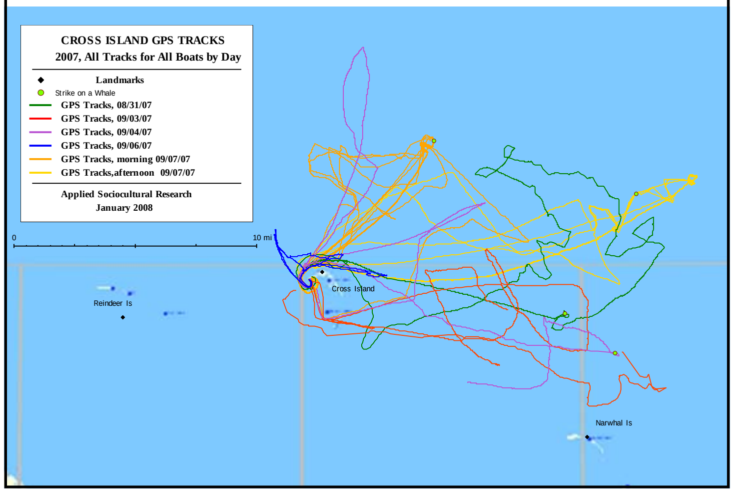
Researcher observations while on Cross Island during each season (present for majority of each season)

Weather station to collect systematic time series data

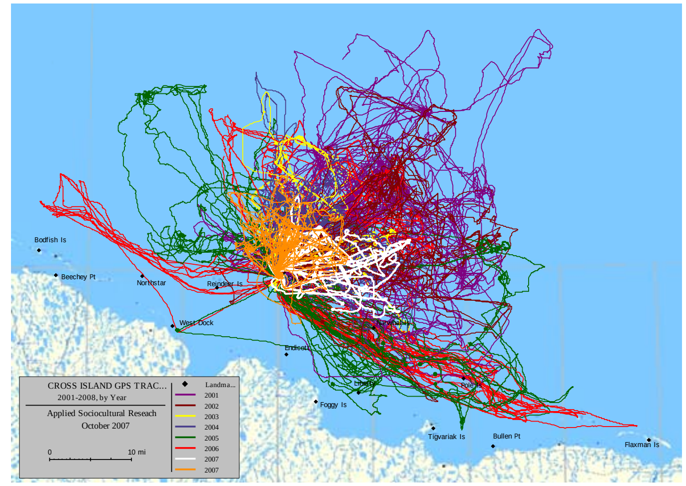
Review of draft reports and presentations by NWCA

Periodic meetings and visits to Nuiqsut

All GPS Tracks, Coded by Day, Cross Island Whaling 2007



All GPS Tracks, Coded by Year, Cross Island Whaling 2001-2008



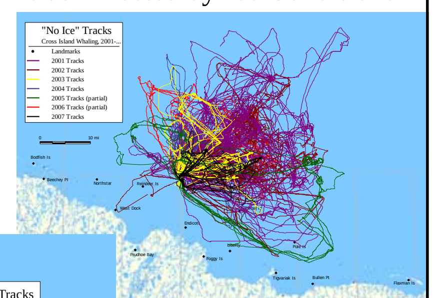
Selected Measures of Cross Island Whaling, 2001-2007

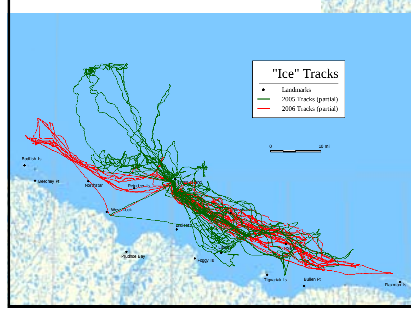
Metric		Season						
Measure	Type	2001	2002	2003	2004[7]	2005[7]	2006	2007
Whales Taken/Whales Struck and Lost	count	3/0	4/1	4/0	3/0	1/0	4/0	3/1
Active Crews on CI (maximum)	count	4	3	4	4	5	4	5
Scouting Boats on CI (maximum)	count	7	9	10	8	8	7	9
Cross Island Population	average	27.7	26.6	20.4	18.9	29.8	29.2	26
Length of Season[1]	count	24	23	19	30	27	21	13
Weather Days	count	8-9	4	8	10	11-15	4	3
# days scouting[2]	count	12[8]	15[8]	7	12[8]	8[9]	10	5
# days whales seen[3]	count	9	9	7	6	7	8	4
# boat days[4]	count	57	65	33	41	34	45	16
Boats scouting/day	average	4.8	4.3	4.7	3.4	4.1	4.5	3.6
Length of trip (miles)	average	85.6	65.1	36.4	47.8	64.7	61.0	30.1
Duration of trip (hours:minutes)	average	9:55	8:04	4:28	7:24	7:32	8:12	6:02
Furthest point from CI (miles)	average	23.9	19.8	11.5	12.5	20.1	22.4	10.4
Strike distance from CI (miles)	average	19.5	13.4	9.3	9.7	25.9	17.0	12
Strike Direction from CI –degrees[5]	average	64°	67°	56°	36°	82°	59°	80°
Total Effort (Boat-Hours)[6]	sum	575.3	532.5	156.4	299.4	338.9	418.2	126.6

[1]Number of days with at least one crew on Cross Island - includes day of arrival at and departure from Cross Island.
[2]Number of days when at least one boat went out scouting for whales
[3]Number of days when at least one crew saw whales while scouting from a boat. Blows were seen from Cross Island on a few non-scouting days, but are not included in these totals.
[4]Each boat scouting for whales on any given day counts as one "boat day" – regardless of the duration of the trip or if whales are seen or not. Thus if 2 boats scout on one day and 4 boats scout on the next, the total for the two days would be 6 boat days.
[5]Due north is 0 degrees, due east is 90 degrees – includes struck and lost as well as landed strikes
[6]Yearly total equals aggregate sum of duration of all whaling trips by all boats. Includes estimates for missing information.
[7]One crew went to Cross Island well before other crews, so total season measures may be somewhat misleading. See 2004 and 2005 Annual Reports.
[8]On one of these days, only one crew with one boat went scouting.
[9]On two of these days, only one crew (one boat) went scouting. On another day, this same boat went out sealing (no whale gear).

Whale Searching Patterns as Affected by Ice Conditions

GPS Tracks when significant pack ice was present, compared to GPS Tracks when significant pack ice was absent



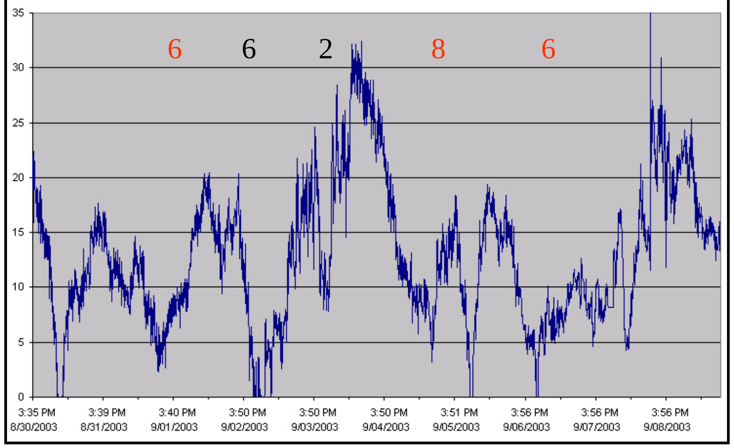


Ice packed against barrier islands most of 2005 season and the first half of the 2006 season. Only one whale landed in 2005, 3 or 4 in all other years

Wind Speed, 2003 (mph)

3 boats out scouting 8/25, 3 boats out scouting 8/37

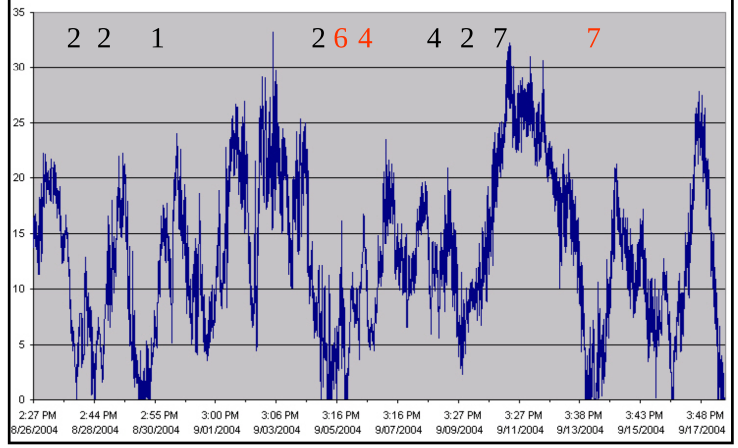
Numbers reflect # of boats out hunting. Red indicates a strike.



Wind Speed, 2004 (mph)

1 boat went out scouting 8/17

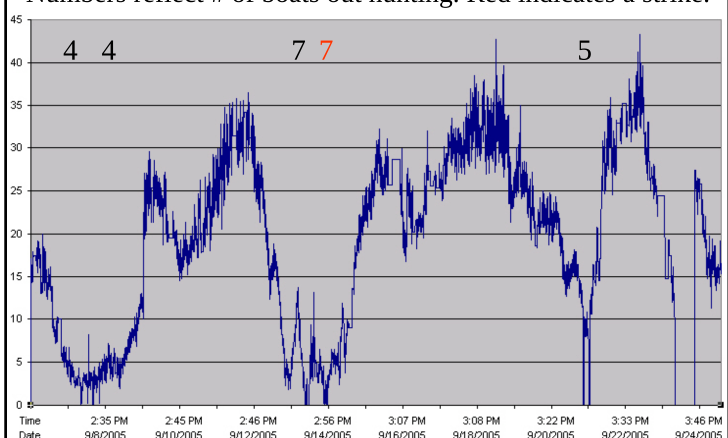
Numbers reflect # of boats out hunting. Red indicates a strike.



Wind Speed, 2005 (mph)

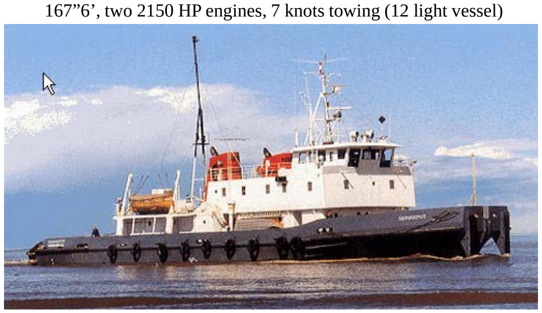
1 boat scouted 9/02, 1 boat scouted 9/03, 4 boats scouted 9/05

Numbers reflect # of boats out hunting. Red indicates a strike.



Commercial Vessel Traffic - Canadian Tug "Nunakput"

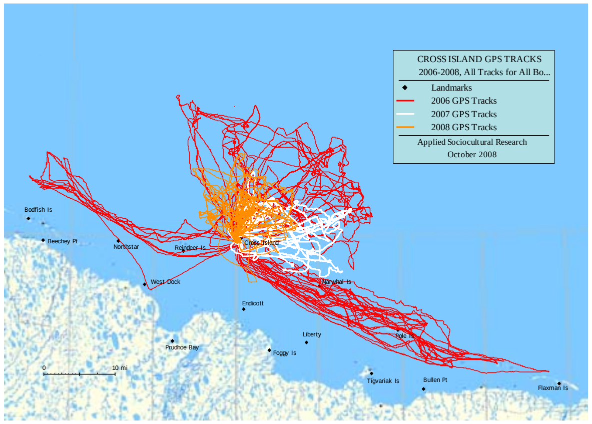
167"6', two 2150 HP engines, 7 knots towing (12 light vessel)



Unidentified Canadian Tug (NTC) with Barges

Source: Northern Transportation Company (owner of Nukakput) Website

Brief discussion -What do whalers say about whale migration and behavior in terms of ice, wind, noise, and industrial/commercial activities?



Summary of Factors Affecting 2001-2007 Cross Island Whaling Seasons

Weather and ice conditions greatly affect fall subsistence whaling as well as other maritime activities, and limiting conditions increase the probabilities of commercial maritime activities adversely affecting subsistence whaling.

Whales may migrate closer to shore in the fall in ice-free conditions, and thus may be more sensitive to disruption in such conditions.

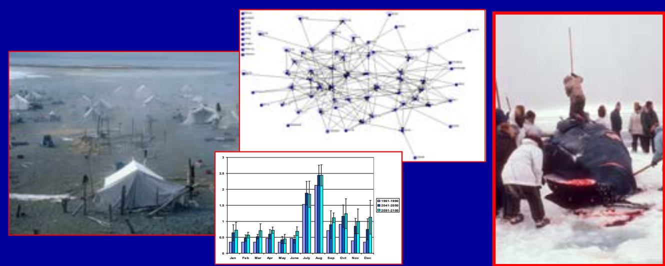
5.4.2 The Study of Ecosystem Services and Sharing Networks to Assess the Vulnerabilities of Communities to Oil and Gas, Development and Climate Change in Arctic Alaska,

Gary Kofinas

Associate Professor, School of Natural Resources & Agricultural Sciences and Institute of Arctic Biology, University of Alaska Fairbanks. Email: ffgpk@uaf.edu

Rapid change in the Arctic raises many questions about how research can improve our understanding of the dynamics social-ecological systems and inform decision making at local, regional, and national scales. What is the capacity of local communities which are highly dependent on harvesting wild food resources to cope with change? What are the implications of oil development with climate change to indigenous communities of the North? What information is needed to represent the subsistence economies of small villages and understand future changes? How do local residents perceive their future in a rapidly changing world? This presentation outlines two in-progress research projects that are together examining the resilience and vulnerabilities of communities of northern Alaska to the combined effects off- and on-shore oil and gas development and climate change. The project involves one interior and two North Slope partner communities and an interdisciplinary team of researchers. We are projecting change in ecosystem services using spatial models, analyzing social networks of subsistence sharing, and documenting local perceptions of resilience and vulnerability to change. Projections of changing ecosystem services are undertaken by the Scenarios Network for Alaska Planning and based on downscaled GCM models of the IPCC, as well as the best available knowledge on resource ecology. Social network analysis examines the structure and flows of household exchanges in foods, cash, and information to provide insight into social processes that are typically absent from studies focused only on harvesting levels. A participatory approach involving community residents and drawing on local knowledge helps to integrate findings and facilitate an exchange between researchers and community residents. Although the ecosystem services approach is a useful in the study of changing availability of subsistence resources, a social network approach captures social conditions that reflect cultural constructs and are important for understanding human adaptation. The two approaches used together serve our project as the basis for the integrated understanding of a highly coupled social-ecological system.

Ecosystem Services & Social Networks: Assessing Assess the Vulnerabilities of Communities to Oil and Gas Development with Climate Change in Arctic Alaska



Gary Kofinas
University of Alaska Fairbanks

Competing or Complementary?

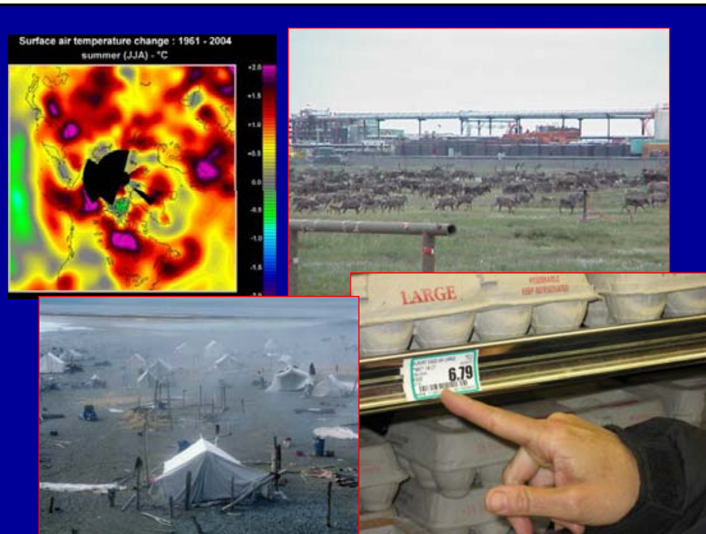
Ecosystem Services Approach

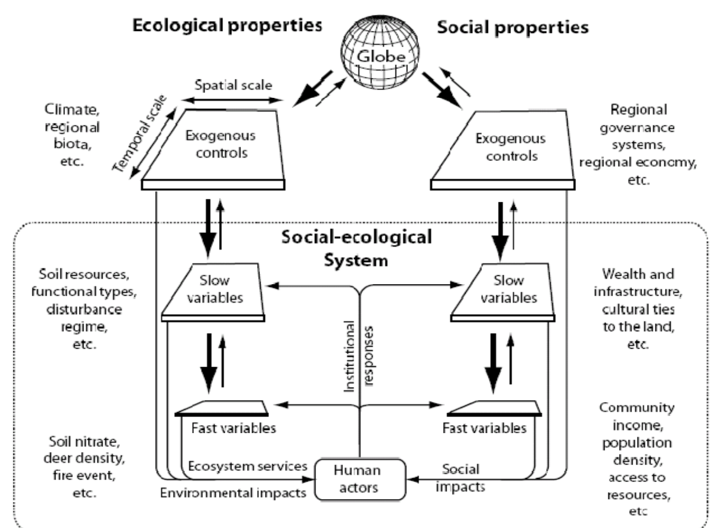
- Material orientation
- Quantified projections
- Spatially explicit
- *Neglects social process and feedback*

↕

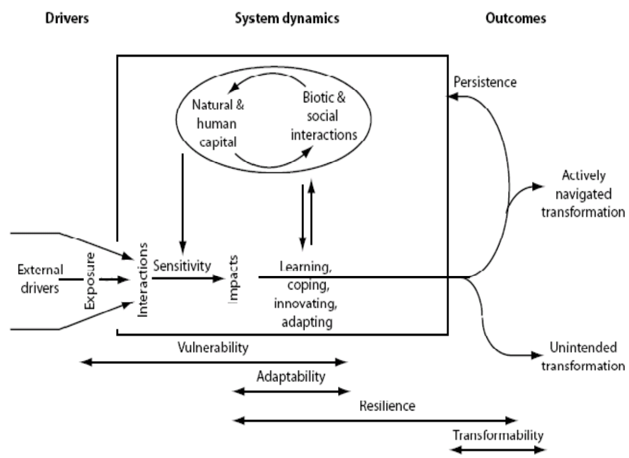
Social Networks Approach

- Specifies social structure (roles/types) and process
- Captures aspects of social capital
- Emic approach
- *Neglects ecosystem process and feedback*





Chapin et al 2007



Chapin, Kofinas, Folke (in press)

Towards meaningful partnerships with communities

Two Projects/Funding Sources

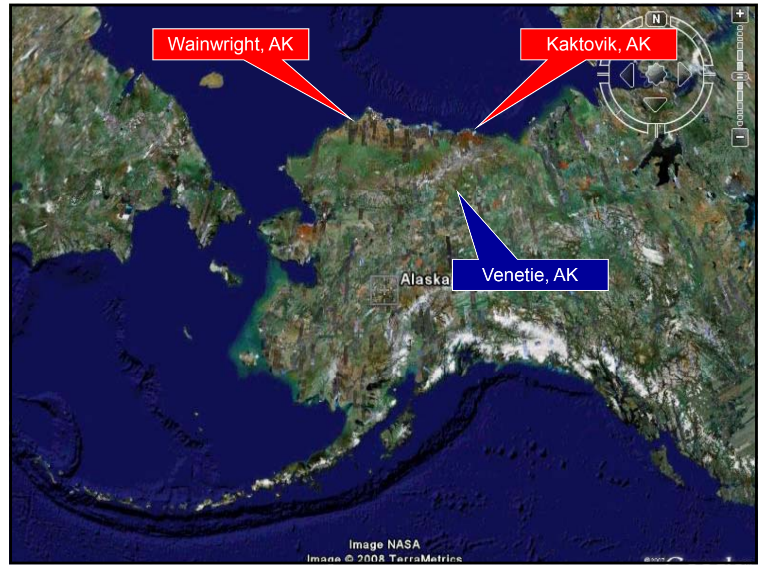
- "IPY: Impacts of High-Latitude Climate Change on Ecosystem Services and Society"
  - National Science Foundation (NSF)
  - 3 years
- "The Study of Sharing Networks to Assess the Vulnerability of Coastal Communities to Oil and Gas Development in Arctic Alaska"
  - Mineral Management Services (MMS)
  - 3 years

Project Questions

Ecosystem Services and Society
How may community ecosystem services change in the future? (climate change)

Study of Sharing
What is the structure and dynamics of social networks (subsistence and oil and gas)?

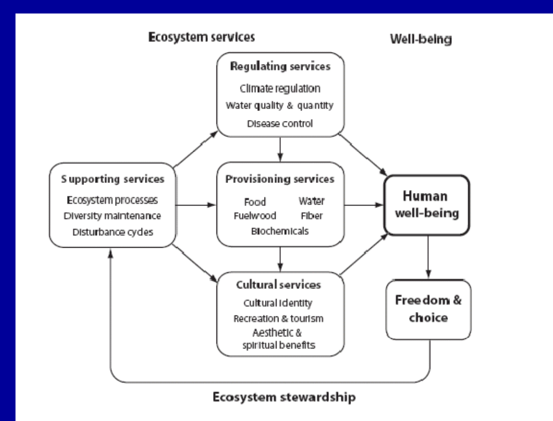
Analysis of Vulnerability & Resilience
What are communities' vulnerabilities to change? What are your sources of resilience? (cumulative effects)



Methods

- •Regional leader Co-PI
- •Formal MOUs with communities
- •Local liaison
- •Local Steering Committee
- •Document local observations of change
- •Focus groups
- •Census of HHs
  - •SNA; mixed economy
- •Model social-ecological responses
- •Quantitative; qualitative; narratives, models

Ecosystem Services Approach

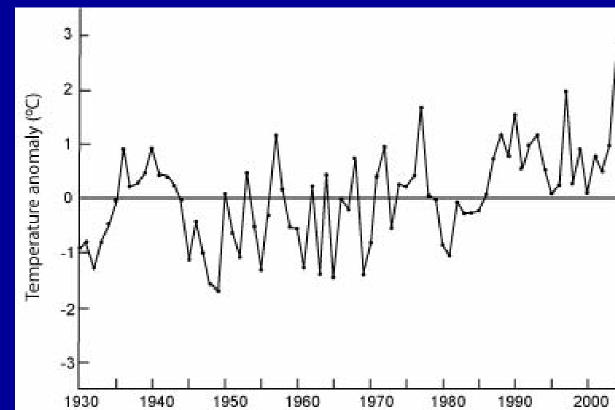


Local ecological knowledge of change / concerns

Venetie interviews:

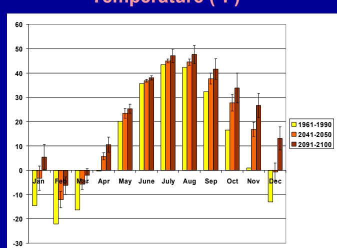
- Winter Temps ↑
- Moose ↓
- Grizzly bears ↑
- Fire ↑
- Water levels ↓
- Kind Salmon ↑
- Porcupine ↓
- Non-local hunters ↑
- Access to game and wood fuel ↓
- Youth's interest in hunting ↓

Alaska is warming

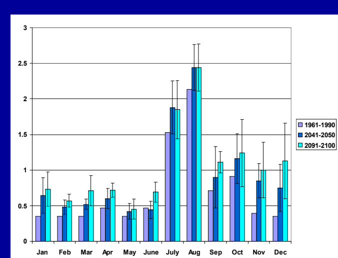


Wainwright Projections

Temperature (°F)



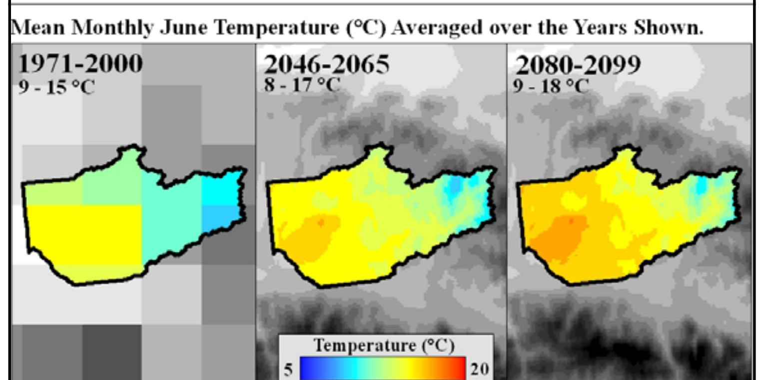
Perceptions (°F)

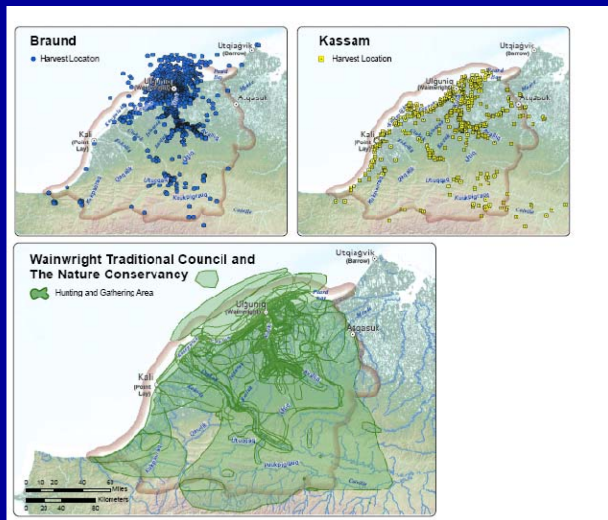


Error bars represent standard deviation between 5 IPCC models used

Mapping past, present, and future climate conditions

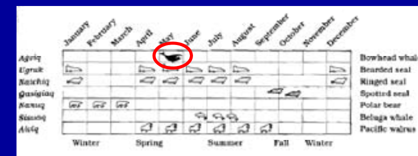
(Map of Fairbanks area: making maps of village homelands



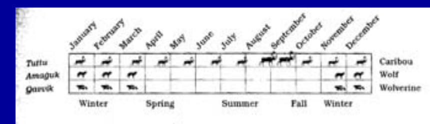


Seasonal round &
Δ in seasonality

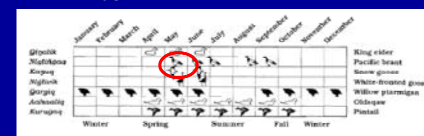
Marine mammals



Land animals



Birds



From Kassam

Our ecosystem services assessment

Global Climate Models

↓

Down-scaled spatial climate projections

↓

Community direction on which resources to examine → **Researchers' understanding of ecological response**

↓

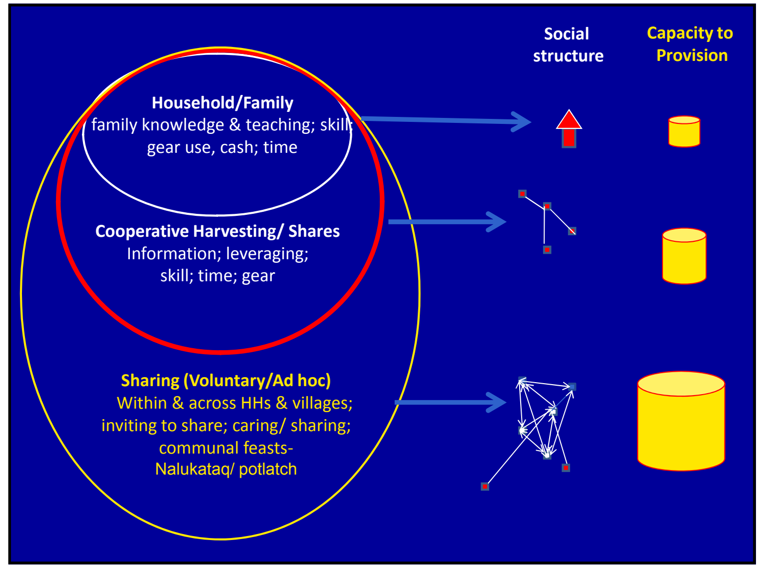
Local knowledge based model of social-ecological response

Social Network Approach

Wild food, gear, time, information, money.

Roles of sharing

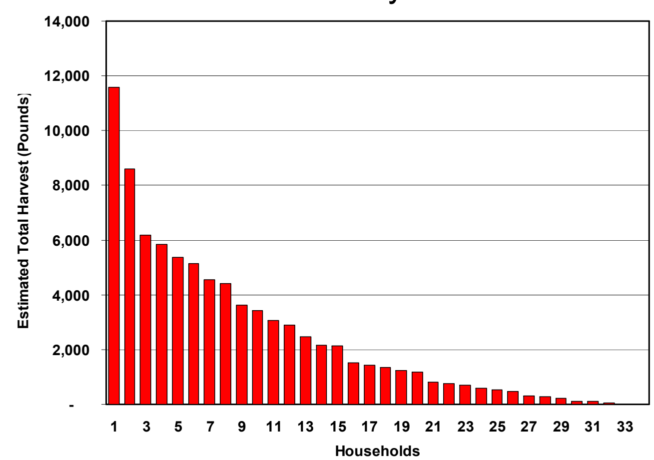
- Defines ethic of human-environment and human-human relations
- Buffers in times of resource scarcity
- Welfare function / institutionalizes equity
- Source of community and intercommunity cohesion
- Sources of identity, pride, cultural continuity
- Self presentation to outsiders
- Distinguishing marker from the urban harvester

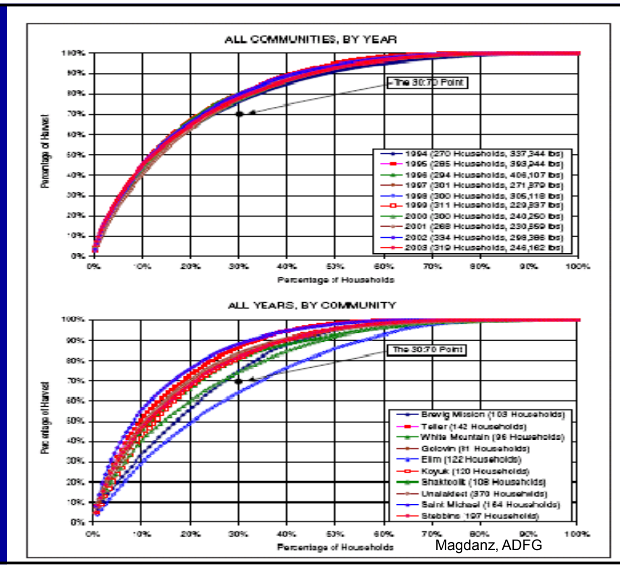


Ranked percentage of total harvest (pounds)

Wainwright (1988, 1989)		**Kaktovik** (1985, 1986, 1992)	
Bowhead	35%	Bowhead	48%
Walrus	27%	Caribou	22%
Caribou	23%	Arctic Char	9%
Bearded Seal	5%	Bearded Seal	3%
Least Cisco	2%	Dall Sheep	3%
Polar Bear	2%	Ringed Seal	3%
Rainbow Smelt	1%	Bering Cisco	2%
Ringed Seal	1%	Muskox	2%
White-Fronted Geese	1%	Moose	1%
Grayling	1%	Cisco	1%
Cumulative total	*98%*	*Cumulative total*	*95%*

Pounds Harvested by Household





Sharing Network patterns x resource

Marine mammals

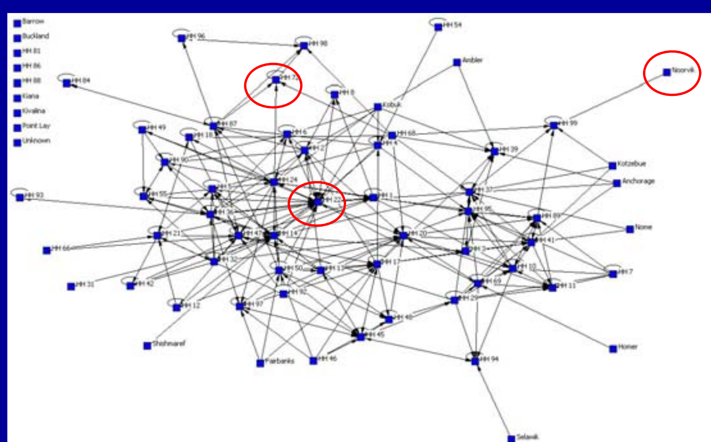
Harvest information

Land mammals

Birds and Eggs

Cash

Jim Magdanz, ADFG



Relate sharing to diet and nutrition and well being

Exogenous drivers	**Venetie**	**Kaktovik**	**Wainwright**
Climate	**drying ↑; water levels ↓;** **warming ↑; seasonality Δ**	**drying ↑; water levels ↓; coastal erosion ↑; seasonality Δ; snow Δ**	**drying ↑; water levels ↓;** **↑; seasonality Δ; snow Δ;**
Industrial activities	**proposed oil and gas in region**	**Local oil and gas; off and on shore active and proposed**	**Local oil and gas; off and on shore active and proposed**
Energy cost / COL	**fuel ↑ ↑ ; food ↑;** **air travel ↑**	**fuel ↑ ; food ↑ ↑; air travel ↑ ↑**	**fuel ↑ ; food ↑ ↑; air travel ↑ ↑ ↑**

Exposure-Sensitivity	Venetie	Kaktovik	Wainwright
Pop/HHs	202/80	274/90	546/179
Wild food dependence	moose; fish; caribou; berries	bowheads; caribou; seal; fish; berries	Bowhead; walrus; caribou; seal; fish; berries
Median HH income / % ↓ PL	$21, 000 / 42.8%	$55,000 / 7%	$54,700 / 12%
Human capital	Very low	Low to med	Low to med
Language	Med ↓	Med ↓	Med ↓
Local control - homelands	High (Fee simple)	Med to low (Home rule/ANCSA)	Med to low (Home rule/ANCSA)
Social capital	?	?	?

Coping strategies	Venetie	Kaktovik	Wainwright
Land resources	Fee simple	ANCSA/Home Rule	ANCSA/Home Rule
Access restrictions	Change mode and location of hunting	Change timing and location of hunting	?
Access to cash	Gas sharing?	Corporate ownership	Corporate ownership
Safety perceived /risk		More cautious of marine	More cautious of marine
Oil and gas Development proposals	On-shore: public advocacy; selective engagement	Off and on shore: lawsuits selective engagement	Off and on shore: lawsuits
Efforts at local control	Fire co-management	Subsistence oversight liaison	?

Speculative propositions

- The greater the degrees of separation from a super HH, the lower the consumption of wild foods; the lower the nutrition if low income.
- The lower the community's average income, the greater the sharing of $.
- The higher the community's diversity of harvested resources, the lower the effects in times of scarcity
- The fewer the super HHs, the lower the community's total consumption of wild food.
- The greater # of ties with external agents, the greater the awareness of change.
- The stronger the ties to formal leaders, the greater the sense of efficacy.

Oil and gas development scenarios???

Different approaches; Different opportunities

Ecosystem Services

- Material orientation
- Quantified projections
- Spatially explicit
- *Neglects social process and feedback*

Study of Networks

- Emic in approach
- Specifies social structure (roles/types) and process
- Captures social capital
- *Disconnect with ecosystem*

Integrated Approach

- Basis for study of the social-ecological system
- Basis for knowledge co-production
- Possible contribution to problem solving
- *Has its own risks!*

5.4.3 Inuvialuit Community Perspective: Mackenzie Gas Project - Impacts, Planning and Mitigation, *Amanda Cliff*

M.A., Planning and Policy Coordinator; Inuvialuit Regional Corporation. Email: acliff@inuvialuit.com

The Mackenzie Gas Project proposes large scale oil and gas development within the Inuvialuit region, NWT, Canada. If the project proceeds, both gathering and processing plants as well as the gas pipeline would take place on Inuvialuit lands. Extensive research and planning efforts are underway in the region in order to plan for both positive and negative impacts and to design mitigation strategies to both enhance benefits to the region and offset potential negative results from the project.

This presentation will outline the social, cultural and economic planning processes that have taken place in the Inuvialuit region to date to obtain the federally approved five hundred million dollar ($500 million) Mackenzie Gas Project (Social) Impact Fund. The Inuvialuit community perspectives will be presented as well as data on social conditions and from the community consultation process. Descriptions on some of the larger mitigation projects that are planned will be presented. The planning for the Mackenzie Project Social Impact Fund will be situated in the broader context of other policy initiatives in the region and ongoing challenges for effective implementation of mitigation measures will be identified.

Mackenzie Gas Project Impact Fund

Inuvialuit Perspectives and Planning Process

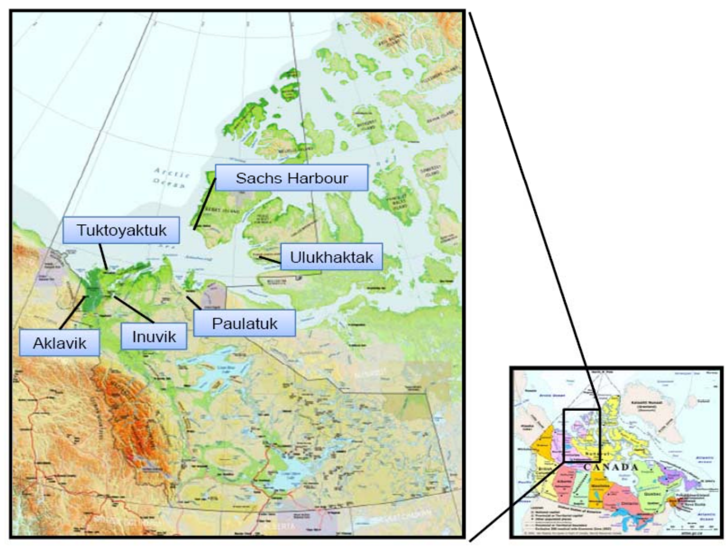
Amanda Cliff
Inuvialuit Regional Corporation
Nov 29, 2008.

Presentation Outline

- Introduction to the MGPIF
- Planning process IRC has undertaken
- Inuvialuit priorities for the fund
- Sample projects
- Future directions and gaps that need filling
- Questions

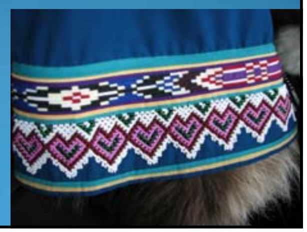
Mackenzie Gas Project

- Pipeline idea first explored in 1970's
- Current project proposal includes:
  - Pipeline that will run 1,300km from Inuvik NWT to Alberta
  - 3 natural gas production fields in the Inuvialuit region
  - Gathering pipeline for these systems
  - Gas processing facility
- Potential for induced development of both on-shore and off-shore oil fields



Inuvialuit perspective

- Inuvialuit continue to seek a balance between wage-based economy and a traditional, land-based lifestyle
- This involves managing and mitigating social and cultural impacts associated with development in the region
- Managing the pace and scale of the development is critical



MGP Impact Fund

- Access and benefits negotiations between project proponents and Inuvialuit halted in part due to the issue of social impacts
- Government of Canada announced $500 million impact fund in July of 2005
- Inuvialuit share of this is $150 million over 10 years

Successful Mitigation

1. Appropriate mitigation measures combined with sufficient resources to implement them
2. Careful monitoring of socio-cultural and economic impacts, combined with responsive, adaptive management structures
3. Effective regional coordination between various stakeholders and levels of government
4. Comprehensive and timely planning process that sets out actions well enough in advance to be effective

Planning Process

1. Review of documents and literature on resource development impacts
2. Community consultation process
3. Identification of predicted impacts
4. Development of priority areas for mitigation
5. Specific mitigation projects
6. Indicators for monitoring and assessment

Document Review

- Internal documents, academic and government literature
- Focus on:
  - evaluation of resource development impacts in other regions
  - existing/ baseline conditions in the region and how the would interact or be exacerbated by the MGP
  - Inuvialuit priorities for their region

Community Consultation

- Planning workshops in each communities
- Household surveys
- Ongoing consultation with key stakeholder groups

Identification of Predicted Impacts

Social

- Decline in graduation rates
- Additional strain on health care resources in the region
- Increased rates of infectious diseases (esp STIs)
- Increased rates of substance abuse
- Increased rates of crime and violence, accident and injury, family stress, community instability – boom town effects
- Declining physical fitness due to decreased participation in traditional activities
- Decreased consumption of country foods

Predicted Impacts (cont'd)

Economic

- Reduced capacity within community institutions
- Loss of skilled workers in non-resource development sectors
- Lack of capacity of regional residents for uptake on employment opportunities
- Lack of retention of economic benefits within the region

Predicted Impacts (cont'd)

Cultural

- Decreased participation in the traditional economy
- Parents engaging in work away from the community resulting in less time spent with family teaching Inuvialuit values, skills, and traditions
- Decreased sense of community and participation in social networks

Mitigation Strategies

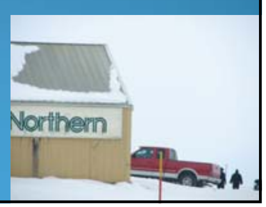
Social

- Strong starts in early childhood
- Success in core education for all Inuvialuit youth
- Increased quality of education experience
- Strong and connected families
- Improved physical fitness among regional residents
- Enhanced levels of community wellness and mental health
- Good access to good health care services
- Enhanced support for community policing initiatives
- Regional health promotion strategy – 'be your best'

Mitigation Strategies (cont'd)

Economic

- Increased job readiness and education levels
- Increased employment capacity among regional residents
- Strong and enhanced local governance



Mitigation Strategies (cont'd)

Cultural

- Young people learning traditional skills
- Use of country foods
- Enhanced traditional economy

Priority Areas

- Education and Learning
- Health and Wellness
- Culture, Language and Heritage
- Fostering Economic Growth
- Safe Communities and Crime Prevention

Education and Learning

Our goal:

To ensure our children are born healthy and receive education that allows them to reach their full potential and to provide adults with opportunities for lifelong learning through continued education and training.

Success means:

Every child receives the best opportunity to learn and grow, youth leave school with skills to allow them to achieve in post-secondary education or the workplace, and adult learners are able to upgrade their skills and compete effectively for jobs.

Project Title: Community Education Infrastructure (Trade Shops Labs and Libraries, and Internet Access)

Goal: Establish basic infrastructure in communities so community educators can provide for more diverse education opportunities and experiences for students.

PRODUCT	ACTIONS	TIMETABLE
Establish basic infrastructure in communities so community educators can provide for more diverse education opportunities and experiences for students, such as: • Trades and technology; • Environment and science; • Internet and distance learning.	Beaufort Delta Education Council (BDEC) and District Education Authority develop inventory of all equipment, facilities and resource material.	Fall 2009
	BDEC develop budget and implementation plan to enhance community education infrastructure	Winter 2009
	Regional Organization enter into contribution agreement with BDEC.	Spring 2010
	BDEC implements program	Summer 2010

Health and Wellness

Our goal:

To promote healthy lifestyles, facilitate productive and healthy lifestyle choices, ensuring all residents are meaningful participants in society.

Success means:

Residents of the region will have high levels of physical, mental and social well-being, are part of strong and connected family systems, and are achieving excellence in all areas of their lives.

Project Title: Strong and connected families

Goal: To provide additional support to families and parents through culturally relevant programming in all Inuvialuit communities. The programs will focus on parenting skills, residential school legacy and its impact on parenting, pre-and post-natal fitness and nutrition, enhanced family recreation and other programs to support family connectedness.

PRODUCTS	ACTIONS	TIMETABLE
• enhance support for families • enhance pre-natal and post-natal education programs • parenting programs aimed at addressing the residential school legacy • substance abuse prevention programs for parents	1. Develop RFP, post and hire project coordinator	Fall 2008
	2. Conduct needs assessment	Winter 2009
	3. Design and develop program	Spring 2009
	4. Implement program	Summer 2010

Project Title: Health promotion strategy

Goal: The goal of this project is to increase levels of fitness and physical health of residents. In particular, rates of obesity, diabetes, and cardiovascular disease are of concern and can be positively influenced through healthy living initiatives with a focus on addictions prevention and sexual health

PRODUCTS	ACTIONS	TIMETABLE
• to produce health promotion packages for each household • to produce posters and outreach materials for businesses and organizations • to develop high school presentations and outreach strategy • to design, market and run a fund to promote small scale recreation and traditional activity projects, leagues and activities • to develop an active living contest	1. Develop RFP, post and hire project coordinator	Fall 2009
	2. Develop household, business and school materials. Develop website and contest. Design fund guidelines and requirements.	Winter 2009
	3. Implement Program	Spring 2010
	4. Evaluate and update program based on evaluation	Summer 2010

Culture, Language and Heritage

Our goal: To strengthen Inuvialuit culture, language, and heritage within a changing northern environment

Success means:

Beaufort Delta residents knowing the history and cultural heritage and having a strong sense of identity and pride, using Inuvialuktun, eating country foods, and having the knowledge and skills of traditional practices.

Project Title: Inuvialuit History Project

Goal: To document the Inuvialuit History and develop teaching material to promote an understanding of the Inuvialuit history, lifestyle and their ability to adapt to change.

PRODUCT	ACTIONS	TIME TABLE
• Document Inuvialuit history and archive all relevant material • Produce a Inuvialuit history manuscript • Produce teacher handbook and teaching material	Establish Inuvialuit History Project Steering Committee and review timeline and provide on-going advice	Fall 2009
	Document all relevant history material and establish archive/data base of the material	Winter 2009
	Review historical material and produce draft manuscript for Steering Committee review and direction	Spring 2010 to 2011
	Develop Terms of Reference and hire Education Curriculum Consultant to produce Teachers Handbook and Teaching Material	Summer 2011 to 2014

Fostering Economic Growth

Our goal:

To enable Inuvialuit to be equal and meaningful participants in the northern and national economy and society.

Success means:

A diverse economy in the Beaufort Delta region that allows people to find employment and business opportunities that reflect the full range of peoples' talents and interests while providing good employment, working conditions, and income.

Project Title: Enhanced Traditional Economy and Community Infrastructure

Goal: The goal of this project is to provide additional support to local business that compliment the traditional economy, such as: tourism, small business, arts and crafts and develop and enhance infrastructure to support local economic development and local employment.

PRODUCTS	ACTIONS	TIMETABLE
Create integrated and coordinated economic support services	Transfer of ITI positions and recruit.	Spring 2009
Develop Community Infrastructure	Develop Business Plans for Community Infrastructure Projects	Spring 2009 to 2011
Deliver On-the Land Programs [see Educating our Children and Culture and Language]	Develop and Deliver Training and Mentoring Program	Winter 2009 - ongoing
		Summer 2009

Indicators

- Important to measure both impacts and results of mitigation
- IRC is collecting beyond the needs for MGP for other processes and objectives
- Set up in partnership with Statistics Canada and GNWT

d. Health and Social Well-being			
i. Family and community stress			
Women & children admitted to shelters (#)	R	A	-
People with somewhat or high stress (%)	N	A	Y
People with strong sense of belonging to local community (%)	N	A	Y
People with very good or perfect functional health (%)	N	A	Y
ii. family structure			
Single parent families (%)	C	5	Y
Single parent families (%)	N	A	-
iii. Children receiving services			
Child welfare apprehensions (#)	R	A	Y
Children receiving services (#)	R	A	Y
iv. Substance use, addictions and impacts			
Heavy alcohol use (%)	N	A	Y
Marijuana Use (%)	N	2	Y
Smoking rates (%)	N	A	Y
Gambling (%)	N	2	Y
v. Spending patterns			
Amount spent on shelter and food (%)	N	2	- Taxfilers
making RRSP contributions (%)	C	A	-
vi. Crime and justice			
Violent Crime Rates (per 1,000 persons)	C	A	-
Property Crime Rates (per 1,000 persons)	C	A	-
Other Crimes Rates (per 1,000 persons)	C	A	-
Charges for Violent & Property Crimes	C	A	-
Youths Charged (per 1,000 persons)	C	A	-
vii. Communicable diseases			
Cases of STIs (#)	C	A	-
Cases of TB (#)	N	A	-
viii. Non-communicable diseases			
Crude cancer rate	N	A	Y
Diabetes prevalence	N	A	Y
ix. premature deaths			
Injury Death Rate	C	A	-
Premature Death Rate	C	A	-

Next Steps and Gaps

- Further work on indicators – not enough info is available
- Collaboration to further develop project descriptions and work plans

Questions?

acliff@irc.inuvialuit.com

5.4.4 The Environmental Stewardship Framework in the NWT, *David Livingstone*

Director, Renewable Resources and Environment, Department of Indian Affairs and Northern Development, Government of Canada, Yellowknife, NT. Email: livingstoned@inac.gc.ca

The need for a common framework to help developers, regulatory agencies and others to understand and manage the effects of development projects on the environment and communities of the NWT has been recognized for years. The potential cumulative effects of development have become a central issue in environmental management; this has catalyzed the development and implementation of a broad environmental stewardship framework that establishes a context for responsible economic development in the NWT.

The framework is a product of legislation, policy and programs and has five broad components: an overarching vision; planning and environmental programs; assessment, regulation and enforcement; administration; and, audit and reporting. Most components and sub-component programs are entrenched in legislation, notably the Mackenzie Valley Resource Management Act and the Inuvialuit Final Agreement. The remaining programs and activities are largely policy and mandate-based.

Central to the effective implementation of the framework is the realization that environmental stewardship is a shared responsibility: no one agency in the NWT with an environmental mandate has sole responsibility and no agency is without responsibility. Coordination among agencies is essential to ensure that responsible economic development proceeds within the context of sound environmental stewardship.

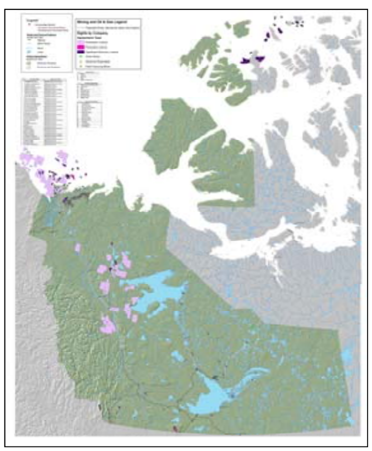
The Environmental Stewardship Framework in the Northwest Territories, Canada

responsible economic development in the context of a sound environmental management framework

US-Canada Northern Oil and Gas Research Forum
Anchorage, Alaska
October 28-20, 2009

Northwest Territories - Jurisdictions

Northwest Territories – Development



Context

- wide diversity of ecoregions, jurisdictions and cultures in the NWT
- largely undisturbed natural landscapes and habitats
- considerable interest in development – mining, oil and gas, related infrastructure
- cumulative effects now of major concern

Key Questions:

- is the water safe to drink; is country food safe to eat?
- are wildlife populations healthy?
- are developments proceeding with minimal impact?   are northern benefits maximized?
- what are the environmental trends?

Roles & Responsibilities for Environmental Stewardship

- proponents responsible for baseline studies, monitoring and adaptive management of project related cumulative effects
- governments responsible for setting the context for development
- governments also responsible for regional environmental management plans, programs and processes

Environmental Stewardship Framework

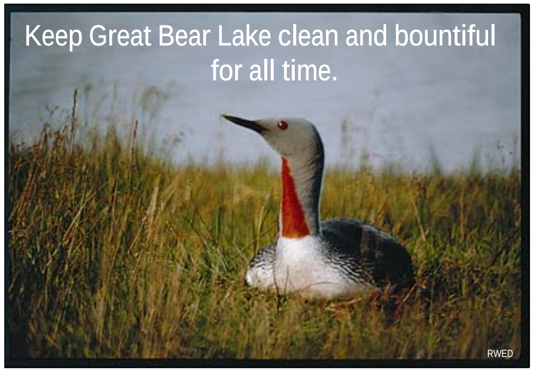
- need recognized during diamond mine review
- steering committee of federal, territorial and aboriginal governments, industry, ENGOs and resource management boards
- strategy, framework and blueprint
- regional plans of action where increased development is expected

Environmental Stewardship in the NWT

- inter-related plans, programs & processes to set the context for responsible economic development
- approach widely endorsed in NWT

Vision - GBLWMP

VISION & OBJECTIVES



Planning and Environmental Programs

LAND USE & CONSERVATION PLANNING

BASELINE STUDIES & LONG TERM MONITORING

RESEARCH

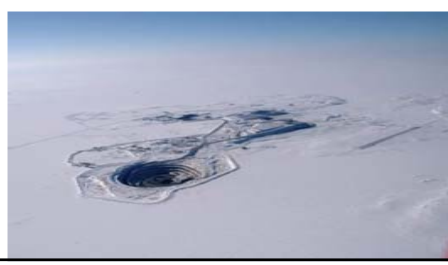
- NWT Protected Areas Strategy
- land use planning
- NWT Cumulative Impact Monitoring Program
- data collection standards and protocols
- thresholds
- regional plans of action (e.g., Beaufort Delta)
- baseline studies, research and monitoring
- scenario modelling

Assessment, Regulation & Enforcement

ENVIRONMENTAL ASSESSMENT

REGULATION & ENFORCEMENT

- environmental screenings, assessments and impact reviews
- compliance with terms and conditions set out in authorizations issued by regulators
- project-specific effects monitoring programs
- regulatory improvements and guidelines to enhance industry best practice



Information Management, Capacity Building & Coordination

INFORMATION MANAGEMENT

CAPACITY - BUILDING

COORDINATION

- monitoring portal
- spatial data warehouse
- stream crossing database
- capacity-building programs and projects
- monitoring program website

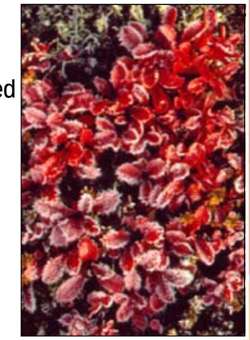
Audit and Reporting

AUDIT & REPORTING

- environmental audit required every 5 years under *MVRMA* to examine the:
  - state of the environment and trends;
  - effectiveness of the monitoring program;
  - effectiveness of environmental management;
  - response to previous audits.
- annual state of knowledge report
- Mackenzie River Basin Board State of the Aquatic Ecosystem Report
- Auditor General, Nation Round Table on the Environment and Economy reports, etc

Key Challenges and Gaps

- capacity needs across the board
- insufficient community involvement
- research (cause and effect)
- baseline studies
- incomplete network of protected areas and land use plans
- comprehensive monitoring
- Information management
- coordination
- vision



Opportunities

- improved regional programs and guidelines, e.g.,
  - effects monitoring programs
  - water quality standards
  - environmental thresholds
  - common monitoring protocols
  - common database protocols
  - river basin approach

More opportunities

- improved environmental monitoring network
- improved cumulative effects assessment processes
- effective transboundary agreements
- fully implemented NWT Cumulative Impact Monitoring Program
- completed NWT protected areas network
- enhanced community capacity and involvement
- improved research capacity, coordination and infrastructure

Conclusions

- we have the opportunity to do it right
- we know what we need to do to do it right
- we know it's a collective responsibility

- with the establishment and implementation of a sound regional environmental stewqrdship framework and with appropriate mitigation, monitoring, follow up and adaptive management taking place in that context, we can do it right

- but are we prepared to do it right?
- much work has been done, considerable work remains

5.4.5 Caribou Harvest Monitoring in the National Petroleum Reserve-Alaska: Developing Effective Future Mitigation,

Stacie McIntosh, Sverre Pedersen & Tina Kaleak

[1] MA, Anthropologist, Bureau of Land Management. Email: stacie_mcintosh@blm.gov

[2] MA, Subsistence Resource Specialist III, Alaska Department of Fish and Game

[3] Iñupiat Community of the Arctic Slope

Since 2003, ADF&G, BLM and ICAS have worked cooperatively to collect annual community caribou harvest information in Nuiqsut, Barrow and Atqasuk to be used to develop a quantitative, temporal and spatial baseline of community subsistence caribou harvest patterns. For five years surveys have been administered in the three communities by ICAS staff regarding the quantity of caribou harvested, the location of both successful and failed hunts, and a variety of other pertinent information such as health of the resource, modes of transportation utilized, and intensive periods of use. In addition, in-depth Local Knowledge (LK) has been collected about caribou movements, distribution and abundance in the Barrow area. Results from these efforts are meant to 1) provide managers with robust, time-series information on where, when and to what extent land and biotic resources of the NPR-A are used by local communities; 2) provide planners and policy makers descriptive, quantitative and spatial baseline subsistence land and resource use information to be used to evaluate current protective stipulations and the potential effects of exploration and development on subsistence land and resource use activities; and 3) assist in planning for additional oil/gas developments and future additional leasing within the NPR-A in a manner which would minimize conflicts with land and resource use by subsistence hunters.

Caribou Harvest Monitoring in the National Petroleum Reserve-Alaska: Developing Effective Future Mitigation

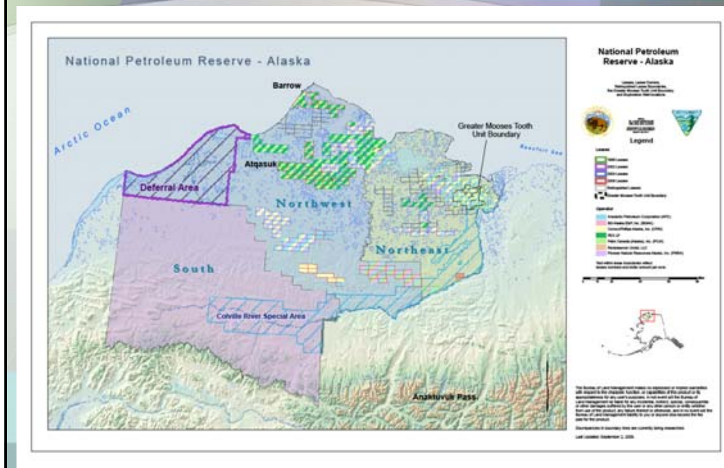
Stacie McIntosh, Anthropologist
Bureau of Land Management, Arctic Field Office

Sverre Pedersen, Subsistence Resource Specialist III
Alaska Department of Fish and Game, Division of Subsistence

Tina Kaleak, Project Coordinator
Iñupiat Community of the Arctic Slope

United States and Canada Northern Oil and Gas Research Forum
October 28-30, 2008 Anchorage, Alaska

Background



Project Description

Cooperative project between BLM, ADF&G, and the Iñupiat Community of the Arctic Slope.

Objectives:

- Estimate annual community caribou harvests in Atqasuk, Barrow and Nuiqsut based on systematic community household surveys.
- Develop a quantitative, temporal and spatial baseline of community subsistence caribou harvest patterns.
- Develop a Local Knowledge (LK) (descriptive) collection of caribou movements, distribution and abundance in the Barrow area.
- Establish internal subsistence resource harvest monitoring and LK data collection analysis and reporting capacity in ICAS.

To date, five 12-month periods of harvest data (June 2002 through May 2007) have been collected.

Study Area

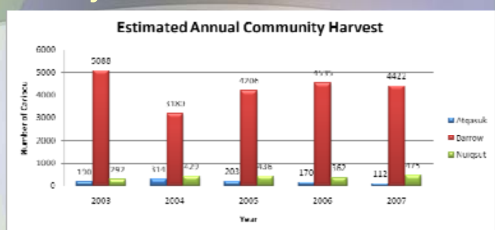
Methods: Harvest Data

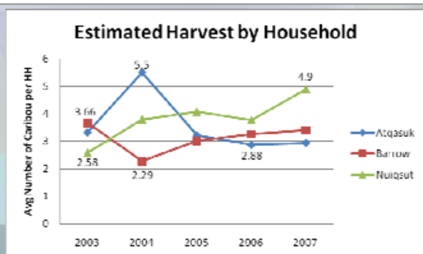
- Harvest data collected for 12-month period
- Standardized survey instrument
- Face-to-face household interviews
- Random sample in Barrow (due to large number of households; over 1,400)
- Census used in Atqasuk and Nuiqsut (small communities less than 100 households)
- Survey information collected included:
  - Number of caribou harvested by month
  - Sex of caribou harvested
  - Location of each reported harvest
  - Health condition of harvested caribou
  - Unsuccessful trips
  - Transportation utilized
  - Giving and receiving of harvested caribou

Methods: LK Data

- LK collected annually through semi-directed, recorded, interviews with a sample of acknowledged caribou experts in the Barrow area
- Standardized set of interview topics
  - Traditional and contemporary harvest methods.
  - Distribution, movements and abundance of caribou over time.
  - Observations on different caribou types and their behavior in the Barrow area.
  - Reindeer and caribou interactions.
  - Traditional stories, legends, and beliefs.

Preliminary Results: Caribou Harvest Numbers

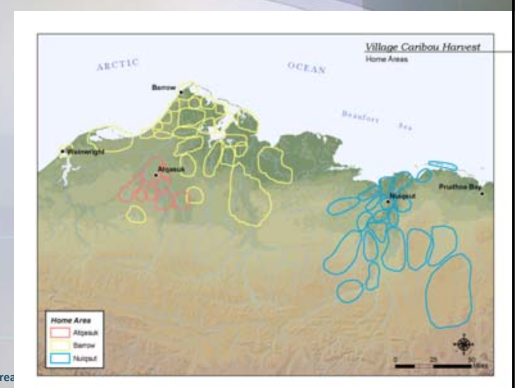




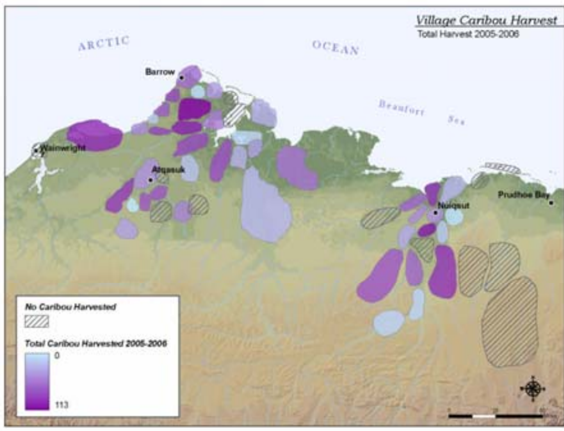
Spatial Data

Table 1. Nuiqsut Subsistence Caribou Harvest Location (Polygon) Number and Place Name

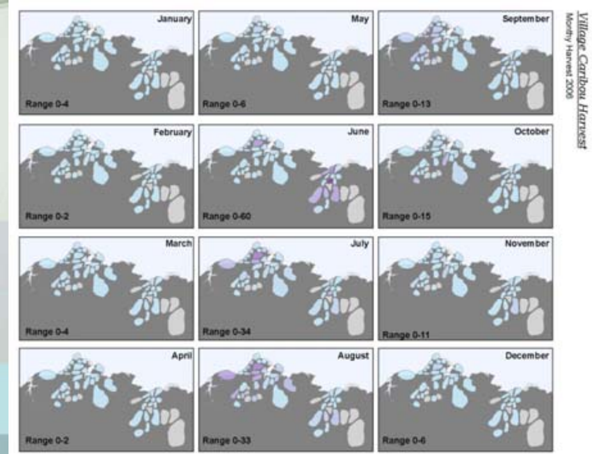
Polygon #	Polygon/Place Name
100	Itkillikpaa
101	Nigliq
102	Fish Creek
103	Ocean Point
104	Pingok Island
105	Kittiks's Camp
106	South
107	Harrison Bay
108	Nuiqsut Area
109	Umaruq
110	E. Colville R. Delta
111	Umiat Area
112	Sentinel Hill
113	White Hills
114	Kuparuk Area
115	Oliktok
116	Tingmiasiruk
117	Colville/Itkillik River Area
118	Tiragroak-Kayuktusilik
119	Lower Judy Creek
120	Anaktuvuk/Chandler R. Area
121	Mid-Itkillik River Area
122	Itkillik/Kuparuk River Area
123	Area E. of Putu



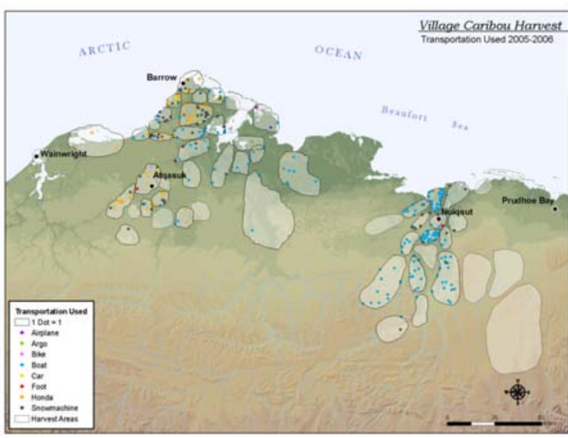
Examples of Use of Spatial Data



Examples of Use of Spatial Data

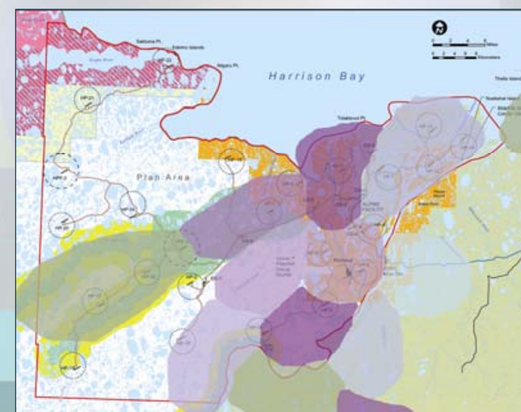


Examples of Use of Spatial Data



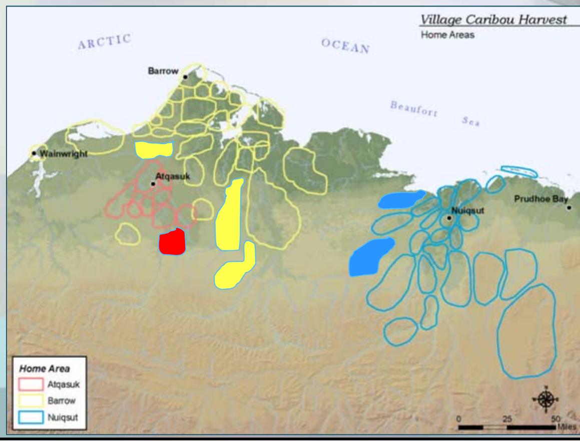
Developing Future Mitigation

1. Using spatial information to create models to assist in locating production pads, pipelines, and other infrastructure to cause the least impact to the harvest of caribou.



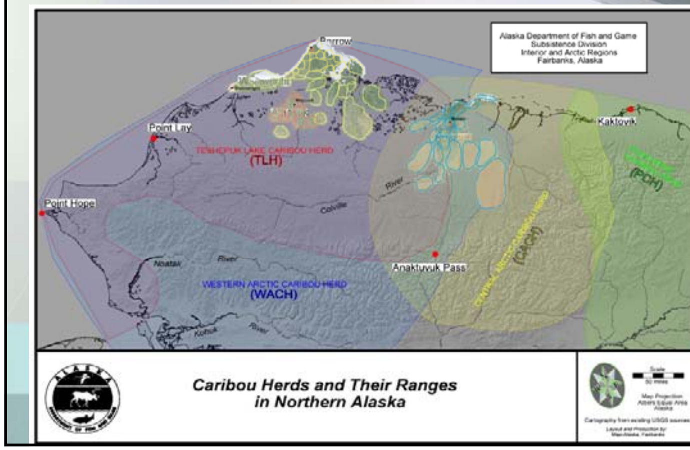
Developing Future Mitigation

2. Using spatial information to monitor change in harvest locations through time in response to exploration activity, construction, and production.



Developing Future Mitigation

3. Using spatial information to estimate harvest from individual herds by correlating collar data with harvest info.



Developing Future Mitigation

Requires:

- Commitment to monitoring
- Cooperation among stakeholders
- Stakeholders understanding benefits
- Communication!

For further information...

Stacie McIntosh
Bureau of Land Management
1150 University Ave.
Fairbanks, AK 99709
stacie_mcintosh@blm.gov
(907) 474-2310

Sverre Pedersen
ADF&G Division of Subsistence
1300 College Rd.
Fairbanks, AK 99701
sverre.pedersen@alaska.gov
(907) 459-7318

5.4.6 Social and Economic Effects in Canada's Mackenzie Delta Region from the Return of Oil and Gas Activity 2000-2004, *Thomas Stubbs*

Integrated Environments, Canada; www.integrated-environments.com

This presentation focuses on the social and economic effects of the renewal of industry activity on the community of Inuvik over the period from 2000 to 2004.

The oil and gas exploration industry returned to Canada's Mackenzie Delta in 1999 when federal government Calls for Nominations for exploration rights attracted work bid commitments from two companies totaling over $180 million; after years of lackluster interest in the area. Work commitments of this magnitude signaled industry's return to serious activity in the North; they promised the drilling of 14 new wells in the Delta region over the life of the licenses. By the following year interest had grown—calls for bids resulted in nine exploration licenses on over 900,000 hectares. Work bids topped $722 million. Then in 2001 the Inuvialuit also held a sale of oil and gas rights on their own lands and garnered $75 million in bonuses in addition to the work commitment bids.

The results of 30 years of northern exploration had demonstrated to the Inuvialuit both the rich potential of hydrocarbon reserves in their region and the booms and busts from exploration-led activity. Lessons learned from the renewal of activity, social and economic effects of activity and the renewal of increased investment in a region after a decade of inactivity are all covered in this presentation.

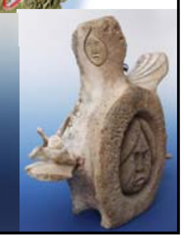
Social and Economic Effects in Canada's Mackenzie Delta Region from the Return of Oil and Gas

Activity 2000-2004

Thomas Stubbs

Presentation Overview

- Regional Setting
- Development Context
- Social and Economic Change
- Local Lessons & Approaches

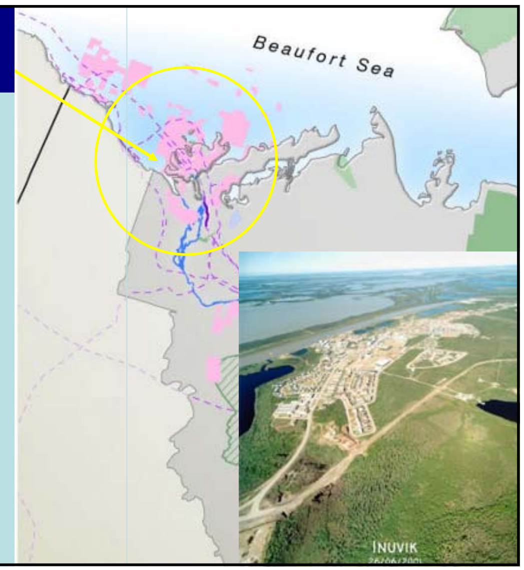


Regional Setting

Regional Setting

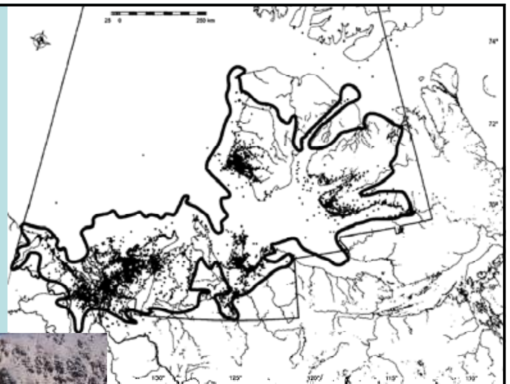
Inuvik

- Built in 1950's
- Regional Centre
- Fluctuating Population



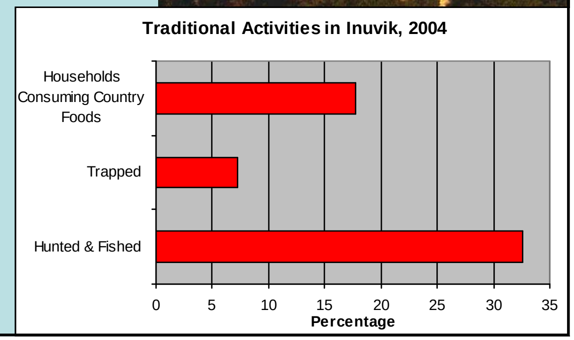
Regional Setting

❖Inuvialuit Use of the Beaufort Sea area, 1960,s, 1990's



Regional Setting

❖Traditional activities in Inuvik continuing



Development Context

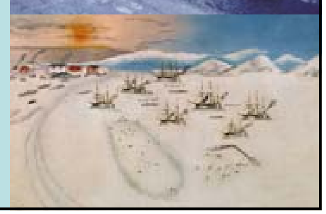
Waves of Development:

❖1700 + Fur trade& whaling

❖1920 + Missionaries, Miners and Military

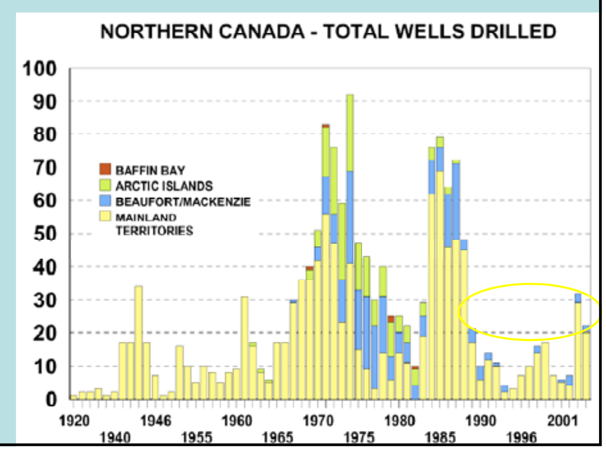
❖1960 + Continental Shelf Exploration search

❖1975 + Aboriginal rights & regional governance



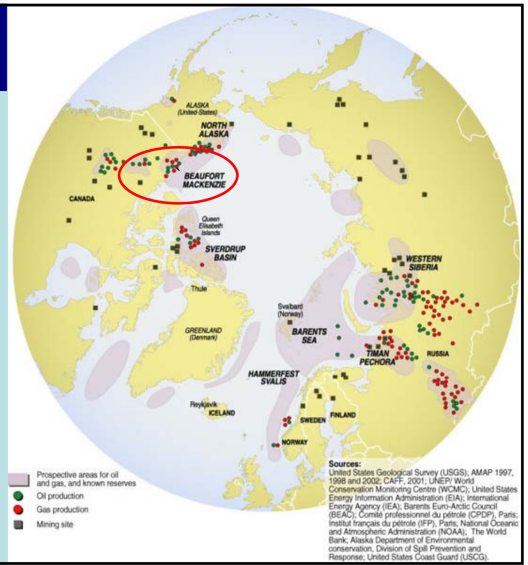
Development Context

❖Large variation in industry activity



Development Context

❖Beaufort Sea
❖Mackenzie River Delta



Development Context

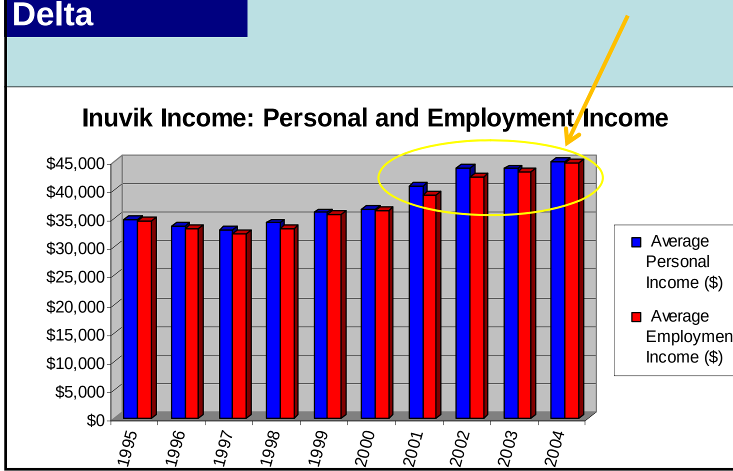
- ❖ 8% +/- GDP growth/yr 1999 - 2006
- ❖ 3 + major diamond mines in 10 years
- ❖ $325 M annual exploration forecast
- ❖Proposal for a 1,200km 1.9 bcf pipeline

Return to the Mackenzie Delta

2000 – 2004 Activity:

❖11 Wells
❖26 Seismic Programs
❖ Primarily winter exploration activity

Return to the Mackenzie Delta



Return to the Mackenzie Delta

❖Local employment grew slightly

Year	Total Person Days	% Inuvialuit	% Gwich'in	% Other Northern	% Southern
2000/2001	7,511	23.4	n/a	7.7	68.9
2001/2002	197,855	25.1	n/a	19.0	55.9
2002/2003	94,066	34.0	6.0	17.0	43.0
2003/2004	42,983	36.0	5.0	8.0	51.0

Return to the Mackenzie Delta

❖Significant local economic participation

Year	Value ($ millions)	% Inuvialuit Participation
2000/2001	78.30	58.0
2001/2002	310.50	62.4
2002/2003	101.50	42.0
2003/2004	88.30	75.0

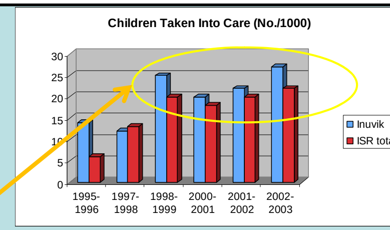
Return to the Mackenzie Delta

Education -

❖Presence of work turned around declining interest in education

❖Increased post-secondary training interest 75 to 175 participants

Return to the Mackenzie Delta



Family changes -

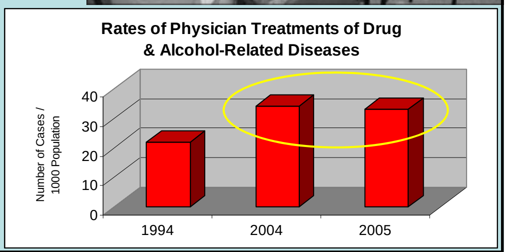
❖Increased children taken into care

❖Reduced need for income support payments

Return to the Mackenzie Delta

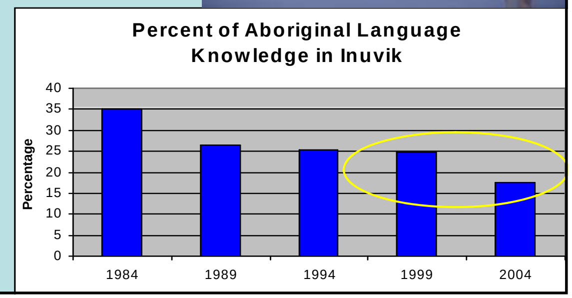
Stress indicators at times of change:

- Increased substance abuse
- Increased crimes against people



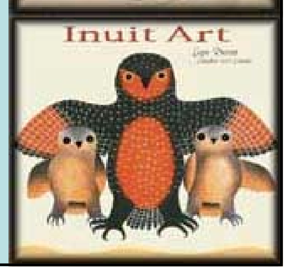
Return to the Mackenzie Delta

- Declining language use



Summary

- New institutions, local control
- Rapid changes in economy
- Changing social &economic conditions
- Changing family dynamics
- Capacity challenges



Thank You

Thomas Stubbs
www.integrated-environments.com

5.4.7 Archaeological Potential of Buried Terrestrial Landforms in the Beaufort Sea: a Review of Existing Geological and Geophysical Data,

Nancy J. Darigo, Owen K. Mason, Peter M. Bowers & Luke Boggess

[1] Principal Geologist, URS Corporation, Anchorage, AK. Email: nancy_darigo@urscorp.com

[2] Ph.D., Geoarcheologist, GeoArch Alaska, Anchorage, AK. Email: geoarch@ptialaska.net

[3] R.P.A.,Principal Archeologist/Vice President, Northern Land Use Research, Fairbanks, AK. Email: pmb@northernlanduse.com

[4] GISP, Senior GIS Specialist, URS Corporation, Anchorage, AK. Email: luke_boggess@urscorp.com

This project assessed the archaeological potential of submerged and buried terrestrial paleolandforms beneath the Alaskan Beaufort Sea based on existing core analyses and geoarchaeological/geophysical data. Past research suggested that relict terrestrial landforms such as stream terraces and coastal features dating from the last glacial advance and low sea level stands of late Pleistocene - early Holocene age were locations where preserved archaeological deposits could occur. Geophysical data from OCS lease areas in the Beaufort Sea indicated the potential presence of these types of relict landforms beneath the seafloor shoreward of approximately 20 m water depth, where shorefast winter ice tends to protect the seafloor from ice gouging. There have been insufficient data, however, to determine whether these landforms date from the last periods of low sea level, or from an earlier Pleistocene low sea level. New radiocarbon dates from this study were added to a compilation of all existing dates for the Beaufort Sea shelf, and interpreted in the context of regional data from the Chuckchi, Laptev, and Canadian Beaufort Seas. Our 14C dates ranged from 8,600 to 1,600 years B.P., confirming the Holocene age of sediment mapped from seismic data in these areas. Beaufort Sea dates from the late Pleistocene and early-mid Holocene range were generally considered unreliable due to recycling of organics. Dates from the later Holocene were considered more reliable due to the presence of potentially in situ peats. The results of our study indicate the following general Holocene paleo sea levels and rates of sea level rise for the Alaskan Beaufort Sea shelf: 1) at the beginning of the Holocene, about 11,000 years ago, sea level was at or below about 50 m below modern sea level (bsl), 2) after 10,500 years B.P., sea level had risen to at least 50 m bsl and flooded the Bering Strait, 3) between 9,000 and 7,500 years B.P., sea level rose rapidly from about 44 to 18/16 m bsl, a rate of about 1.8 cm/yr., 4) sea level was about 12 m bsl by 6,000 years B.P. and reached near modern levels (within 2 m bsl) by 5,000 years B.P., and 5) the rates of sea level rise between 7,500 and 4,500 years B.P., at 0.3 to 0.6 cm/yr, were more than 10 times the present rate of 0.3 mm/yr. Many Beaufort Sea coastal and shelf depositional processes complicate the interpretation of the radiocarbon data, such as river-eroded tundra redeposited at delta fronts, collapsed thaw lake banks recycled as lagoon peat, storm surges, and migrating barrier islands. Areas for future research could focus on paleolandforms that are relatively distinct based on seismic data, are preserved beneath a protective sediment cover, may be of terrestrial origin, and are likely to be early Holocene in age. These areas include buried channels with possible channel-edge features, the landward side of buried paleo-shorelines, terraced sides of buried peat-bogs or lagoons, and buried relict islands of coastal ridges containing terrestrial material. This project was funded by the U.S. Minerals Management Service, Anchorage, Alaska.

5.5 BIOLOGICAL SCIENCES

5.5.1 Assessing the Potential Effects of Near Shore Hydrocarbon Exploration on Ringed Seals in the Beaufort Sea Region 2003-2006,

Lois Harwood, Thomas G. Smith & Humfrey Melling

[1] Dept. of Fisheries and Oceans, Arctic Aquatic Research Division, Yellowknife, NT, Canada. Email: lois.harwood@dfo-mpo.gc.ca

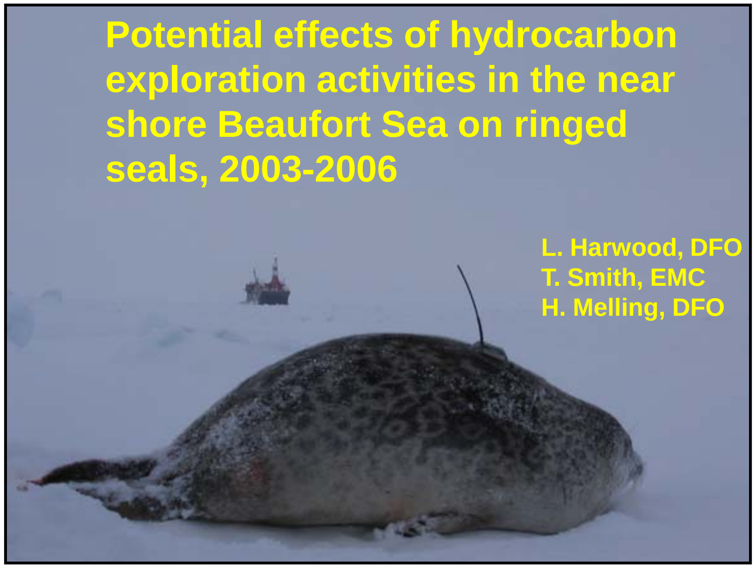
[2] EMC Eco Marine Corporation, Garthby, Quebec, Canada. Email: emccorp@sympatico.ca and Drakeheath Kennels, www.wildlifedetectiondogs.com

[3] Dept. of Fisheries and Oceans, Institute of Ocean Sciences, Sidney, BC. Canada Email: humfrey.melling@dfo-mpo.gc.ca

The objectives of this study were to identify and evaluate any potential impacts of offshore industrial activities on the resident seal populations, with a view to providing advice on any mitigating measures and monitoring studies which might be employed effectively in the future. The study area was on the land fast sea ice around Devon Canada's Paktoa test drilling site in EL420 in the SE Beaufort Sea. We did not conduct any studies related to the possible effects of the initial seismic surveys.

The first three years of our study (2003, 2004 and 2005) were conducted prior to industry activity at Paktoa, while our fourth year of study (2006) was conducted during the latter part of a single exploratory drilling season when they constructed and utilized an ice road and landing strip then tested, abandoned and demobilized the rig. Our study methods included ice surveys using trained detection dogs to find the subnivean seal lairs and breathing holes, plus the capture and, satellite tagging and tracking of 20 individual ringed seals in their breeding habitat. During the four seasons we also did aerial surveys during the seal's basking period, and collected 62 specimens to examine their body condition and reproductive status. Over the four years of the study, the work was greatly enhanced by the involvement of 19 Inuvialuit field technicians.

The distribution of subnivean seal lairs and breathing holes, and the behaviour and distribution of tagged seals, were not significantly different among the non-industry (2003, 2004, 2005) and industry (2006) years. Natural abandonment of seal structures ranged from 21 to 26% in 2003, 2004 and 2005, with a lower rate (10%) in 2006 being attributed to the significantly later date of freeze up in that year. The collected specimens showed the ringed seals in this area to be in good body condition with ample fat stores. They were in normal reproductive status and most (40/54 stomachs = 74%) were found with prey in their stomachs. Analyses of tissues from these seals showed none or negligible levels of PAH's. Aerial surveys indicated a significant increase in the densities of basking seals near the floe edge compared to farther from it, but showed no detectable relationship between the distribution of basking seals and the Paktoa site in any year. Overall, the study provided important baseline information on the use of the near shore Beaufort Sea by ringed seals during spring, and is a benchmark for any future studies involving multiple or longer term drilling operations. The results suggest that one-season of drilling by industry at the Paktoa site had no detectable effect on ringed seals in the study area. The effects of longer exposures to industrial activity, or exposure to multiple industrial sources, remain unknown.

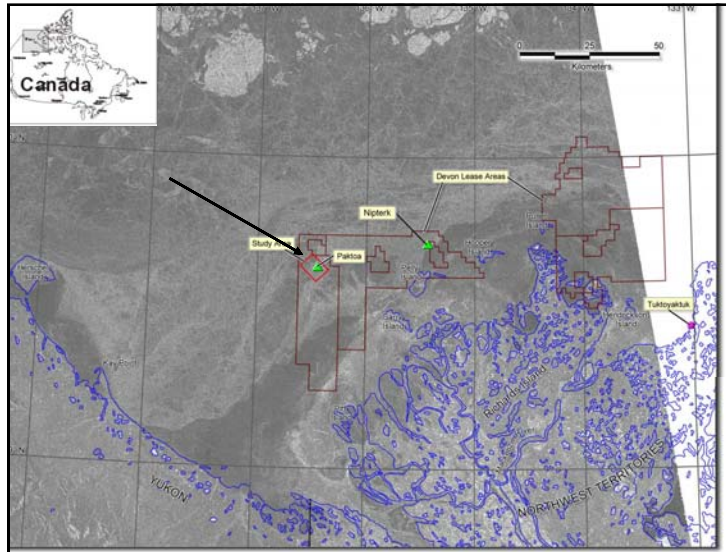

Potential effects of hydrocarbon exploration activities in the near shore Beaufort Sea on ringed seals, 2003-2006
L. Harwood, DFO
T. Smith, EMC
H. Melling, DFO


Tom Smith
& Humfrey Melling


John Moran and Brendan Kelly
University of Alaska (left)
Ruth McKechnie (above)
Dept. of Indian and Northern Affairs Canada

Study Objectives

1. Baseline data on seal distribution, movements, behaviour, body condition and reproduction
2. Estimate the impact/zone of influence of exploration activity on seals
3. Recommend mitigative measures, terms and conditions to reduce/eliminate effects on seals
4. Incorporate local knowledge and experience of the Inuvialuit in project delivery & interpretation



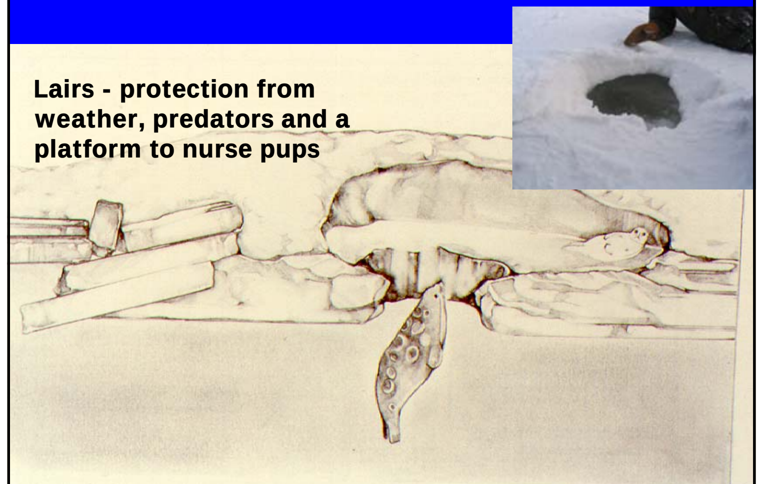
Industry activity during project – Feb-Apr 2006

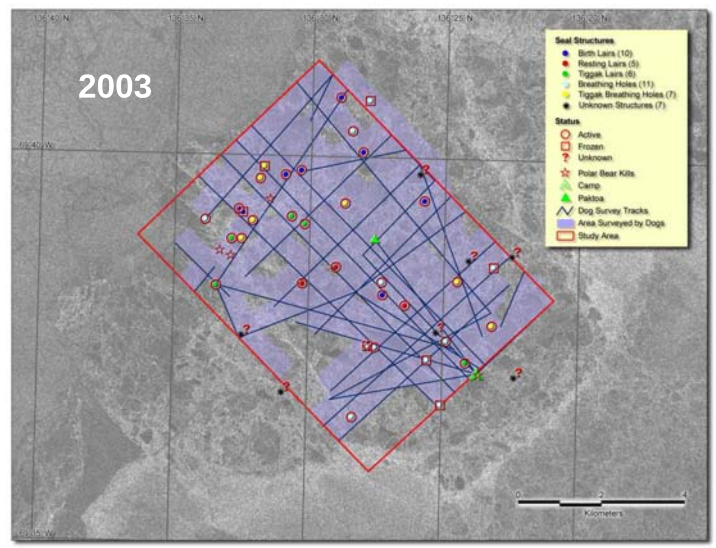
- Paktoa- well testing, abandonment, demobilization
- Helicopter traffic (3-4 per week)
- Runway and twin otter traffic (42 trips)
- Ice road with semi trucks (31 loads) and light trucks daily
- Research camp (9 man, 4 weeks)

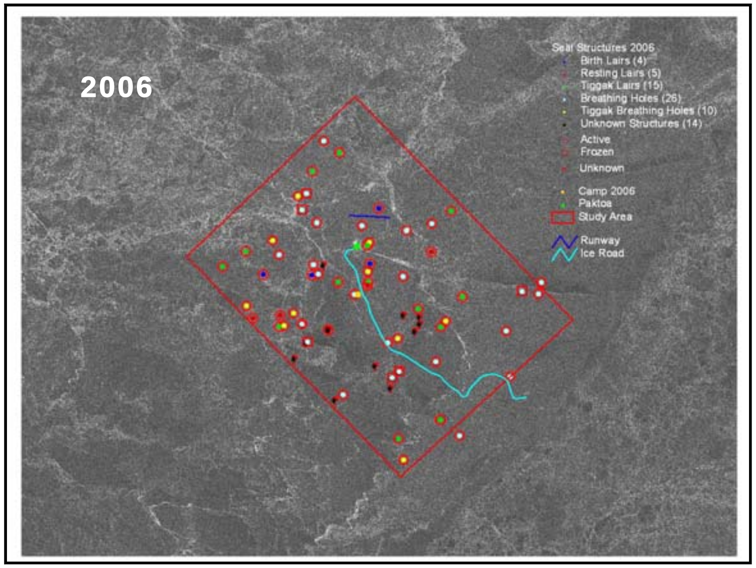
Methods

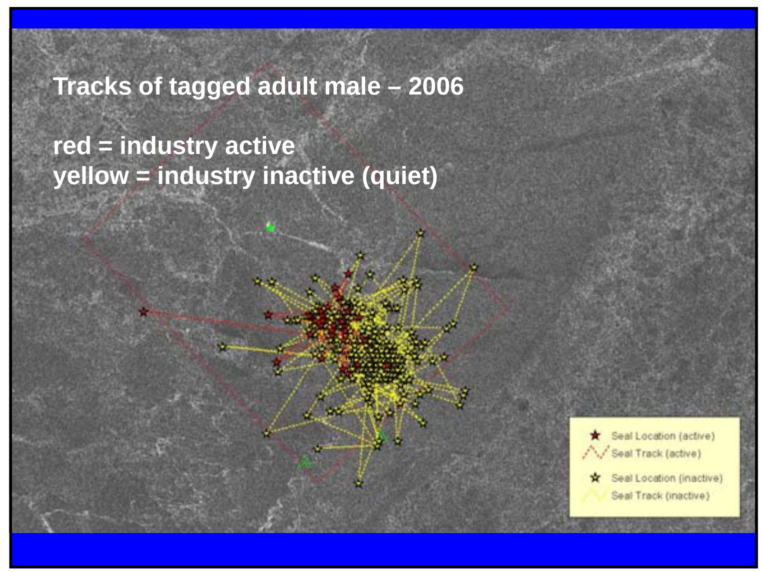
- Sea ice surveys – using dogs 30-40 km2 per year
- Live capture and satellite tagging and tracking – using traps deployed in seal holes n=20
- Seal collection n= 63
- Aerial surveys – 4 seasons

Lairs - protection from weather, predators and a platform to nurse pups



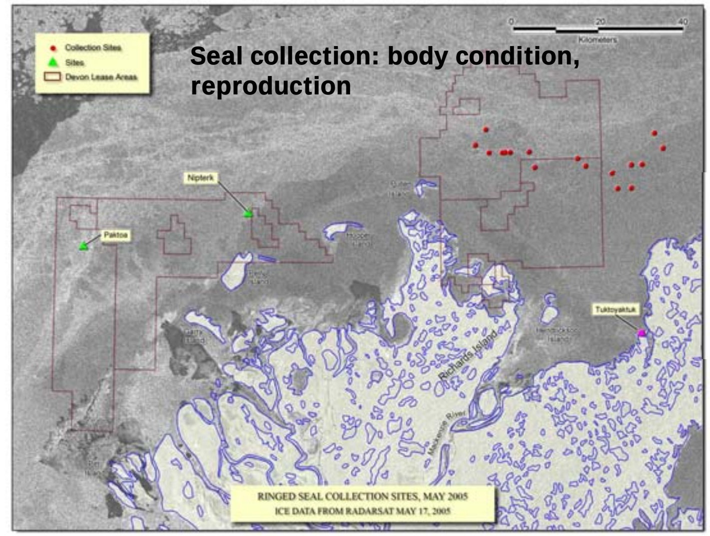



2006
Seal Structures 2006
Birth Lairs (4)
Resting Lairs (5)
Tiggak Lairs (15)
Breathing Holes (26)
Tiggak Breathing Holes (10)
Unknown Structures (14)
Active
Frozen
Unknown
Camp 2006
Paktoa
Study Area
Runway
Ice Road


Tracks of tagged adult male – 2006
red = industry active
yellow = industry inactive (quiet)
Seal Location (active)
Seal Track (active)
Seal Location (inactive)
Seal Track (inactive)

Results - seal structure density, distance from Paktoa and size of territories

Density	
density of structures adult females	ns
density of structures adult males	>in 2006
density of breathing holes	ns
rate of natural abandonment	ns; 2006 lowest
Distances	
active vs inactive from paktoa	ns
males vs females from paktoa	ns
males from ice road, seal camp, airstrip	ns
females from ice road, seal camp, airstrip	ns
Size of territories	
males vs females	ns
males between 2005 and 2006	ns
females between 2005 and 2006	ns
males 19 d active vs 19 d inactive 2006	ns
females 19 d active vs 19 d inactive 2006	ns

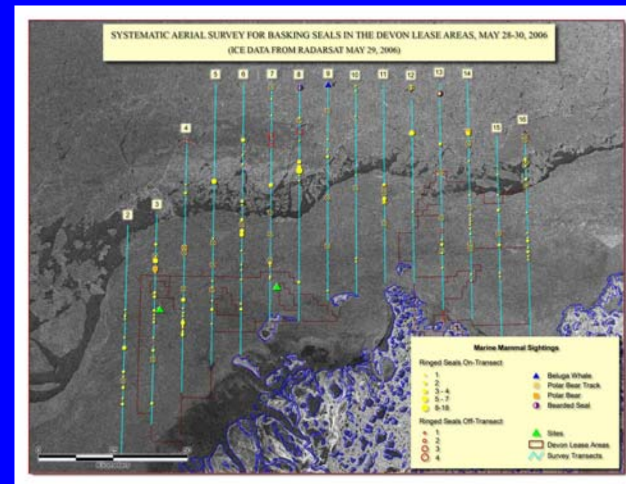



Seal collection
N=63
Spring 2004, 2005, 2006

Results

- ringed seals in the lease area were found to be in good body condition with ample fat stores
- in normal reproductive status,
- negligible levels of PAH's,
- most (40/54 stomachs = 74%) with prey in their stomachs - recent meals of invertebrates, particularly isopods (78% of items),
- Ringed seals were found to successfully use this highly variable offshore fast ice of the south-eastern Beaufort Sea, both as feeding and breeding areas, even during winters such as 2005 when storms had caused a major perturbation in the stability and quality of their fast ice habitat.

Aerial survey – Distribution during basking



Results

- Basking ringed seals were widely distributed at densities in the range of 13.0 - 42.4/100 km^2.
- Densities of basking seals were not significantly different among the different study years
- Densities of basking seals were comparable to densities found in this same area during surveys conducted by CWS in 1974-1979.
- Significant increase in the densities of basking seals near the floe edge
- No detectable relationship between the distribution of basking seals and the Paktoa site in any year.

Conclusions

- **new baseline information on the use of the near shore Beaufort Sea by ringed seals during March-June**
- **Devon was active with well testing, well abandonment and demobilization activities, and had constructed and maintained their ice road and airstrip during our study**
- **Our three lines of evidence revealed a similar result of no direct adverse effects on ringed seals as a result of one season of drilling at Paktoa in 2006**
- **Thresholds/effects of longer exposures, or multiple exposures, are unknown.**

Project Funding 2003-2006

	Funding (%)
Environmental Studies Research Funds	33
Dept of Fisheries and Oceans	33
Polar Continental Shelf Project	11
Dept of Indian and Northern Affairs	7
Panel Energy Research and Development	6
Fisheries Joint Management Committee	6
Beaufort Strategic Regional Plan of Action	3
World Wildlife Fund Canada	1

5.5.2 Populations and Sources of Recruitment in Polar Bears: Movement Ecology in the Beaufort Sea, *Andrew E. Derocher, Gregory Thiemann & Seth Cherry*

[1]Ph.D., Professor, University of Alberta. Email: derocher@ualberta.ca

[2] Ph.D. ,Assistant Professor, York University

[3] Ph.D. candidate, University of Alberta

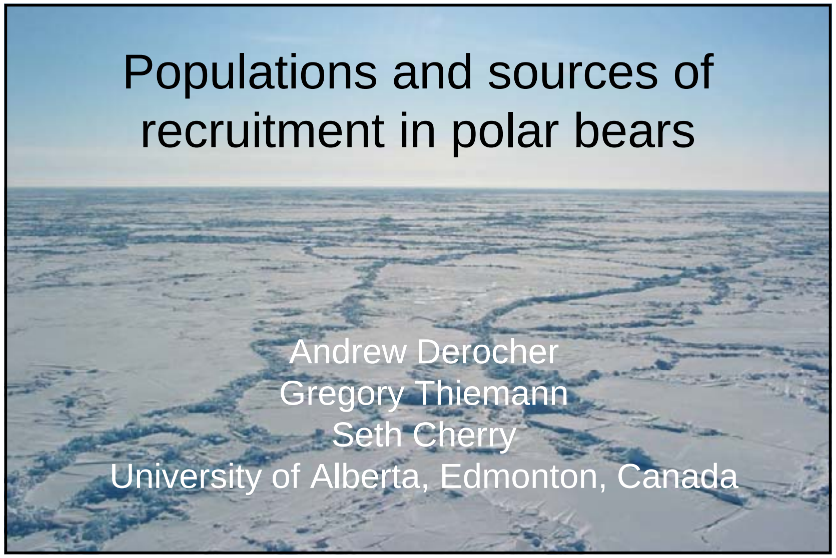
Polar bears are distributed throughout the Beaufort Sea. Changes in the dynamics and distribution of sea ice have resulted in concern about the long-term conservation and management of this species. The primary objective of this study is to examine the movement ecology of juvenile polar bears born in, or near, the southern Beaufort Sea population to test the established hypothesis that polar bears are divided into discrete populations. Of particular concern is the historic emphasis on the movements and distribution of adult females to delineate population boundaries and thus, this study aims to examine how representative such an approach may be by studying the movements of juveniles. Further, the study will enhance analysis of oil-spill/polar bear models and provide direct input to population-recovery models currently under development for the Beaufort Sea region.

The project was initiated in spring 2007 and aims to continue for a five year period. Satellite linked geographic positioning system collars are deployed on subadult polar bears (aged two to four). Adult females are used as controls for movement patterns and for comparison with data collected in the 1980’s. Six locations per day are obtained for each study animal for a period of one to two years. Automatic release mechanisms are built into each collar to minimize risk to study animals.

Low recruitment in the Beaufort Sea population, changes in sea ice distribution, and extended periods of inclement weather have slowed the progress of the study. However, preliminary results indicate that subadults may be less restricted in their movements than adult females although the rapid changes that have occurred in the Beaufort Sea ice conditions have significantly altered the ecological conditions in the study area. Movement rates of juveniles are higher than those from concurrently monitored adult females but larger samples sizes are required before conclusions can be drawn. There is an indication of a northward shift in habitat use reflecting a reduced expanse of landfast ice in recent years.

Future plans are to continue monitoring subadults and to expand the study to adult males so that a full assessment of movement patterns, habitat use and fidelity can be examined.

This research is supported by Minerals Management Service, US Department of the Interior and Polar Continental Shelf Project, Natural Resources Canada.



Overview

- Background
- Objectives
- Methods
- Preliminary results
- Implications
- Future directions
- U.S.A. – Canada co-operation

Background

- Polar bears are a sea ice obligate species
- Sea ice is the primary habitat
- Terrestrial areas are used as refuge and den habitats
- Oil and gas activities are increasing in polar bear habitat

Prey species

Ringed seal

Bearded seal

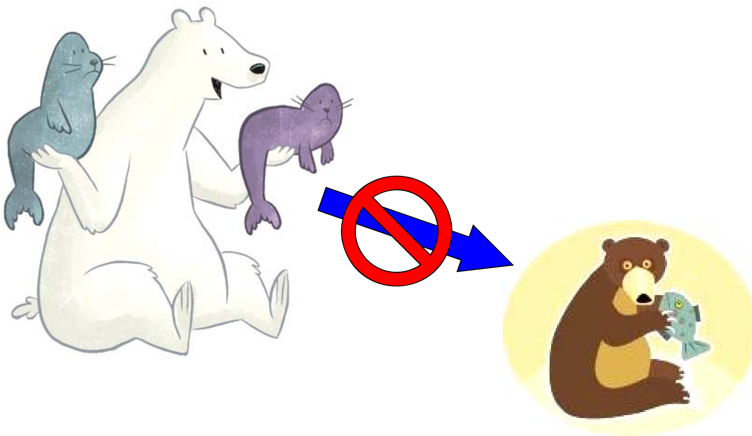
Both species are also dependent upon sea ice

Partially consumed ringed seal

Rapid ecology change

Behavioral
- Changing distribution
- Altered denning areas
- Extralimital occurrence
- Changing diet
- More problem bears
- Drowning

Demographic
- Lower survival
- Declining body mass
- Lower reproductive rates
- Population decline

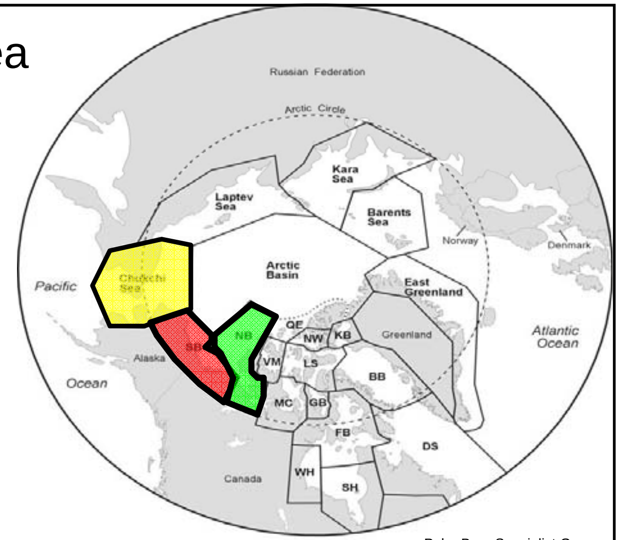


Study area

Southern Beaufort Sea

Northern Beaufort Sea

Chukchi Sea



Polar Bear Specialist Group

Objectives

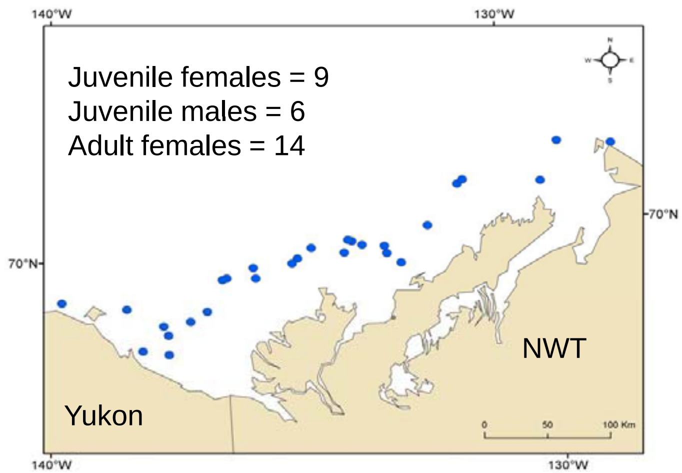
To assess:

- movement and dispersal patterns of juvenile polar bears compared to adult females
- population boundaries as defined by existing methods (adult females only)
- age- and sex-related habitat preferences of polar bears in the Beaufort Sea

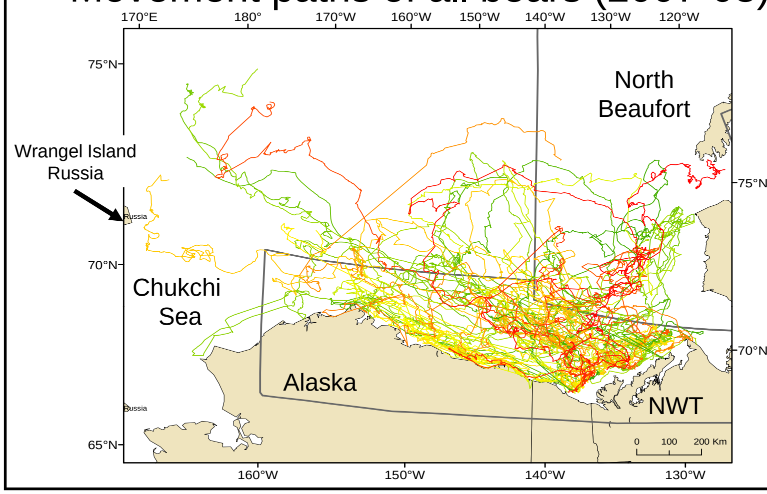
Methods

- Helicopter capture
- Geographic positioning system satellite telemetry
- Automatic release & corroding link to ensure release
- 6 locations/day for 1 or 2 years

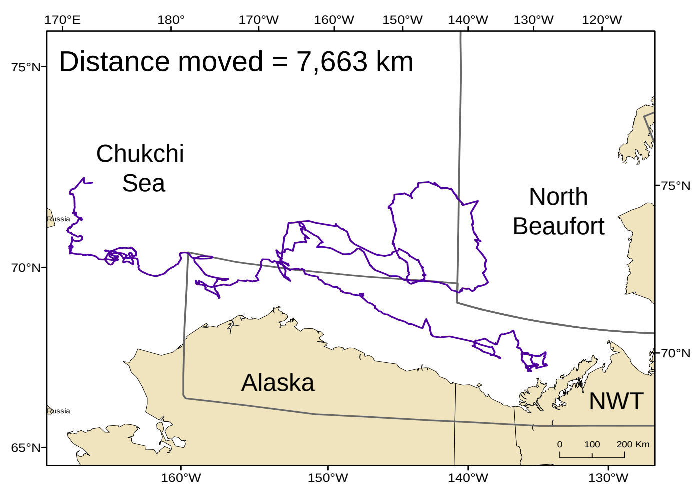
Collars deployed



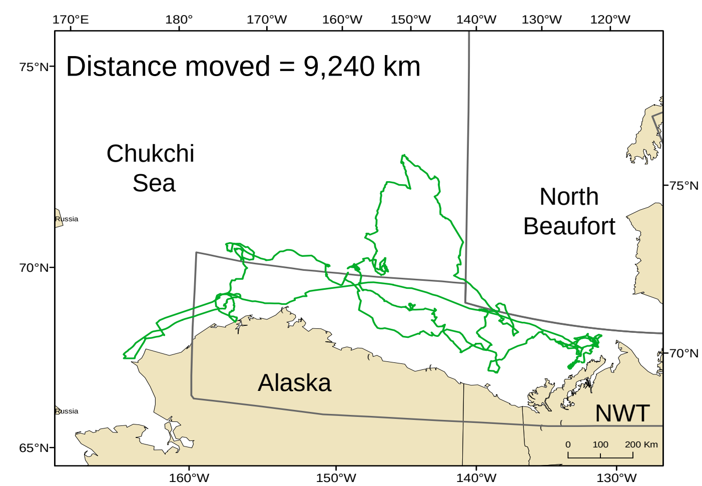
Movement paths of all bears (2007-08)



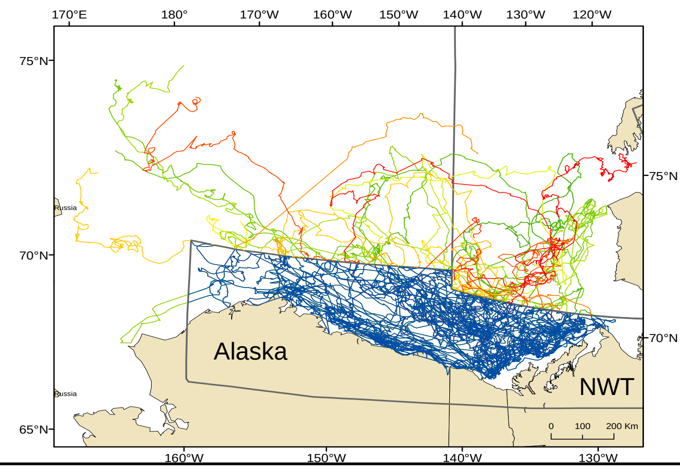
Subadult female



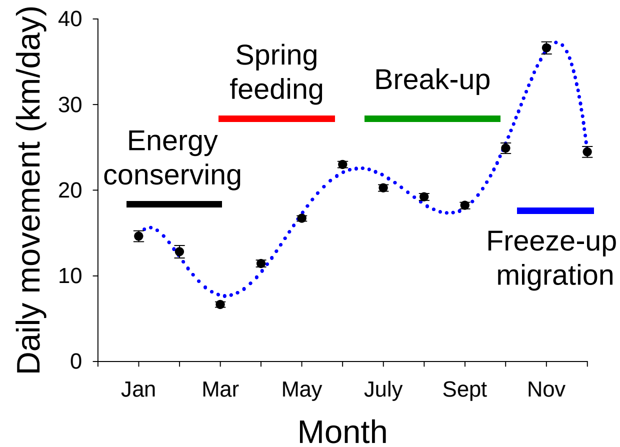
Adult female



Tracks outside Southern Beaufort = 36%



Seasonal movement patterns



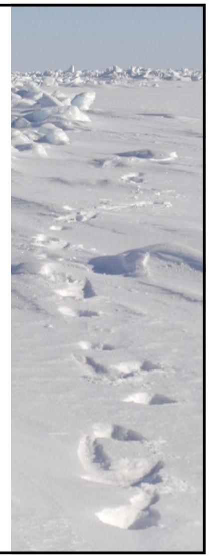
Polar bears on land

- 38% of bears spent <u>*some*</u> time on shore
  - 27% of juveniles
  - 50% of adult females
- Most activity near Kaktovik less near Barrow and Prudhoe Bay
- 2007: 27% *summered* on land (Kaktovik)
- 2008: 18% *summered* on land (Kaktovik & Barrow)

Future directions

- Expand the sample size of bears followed for longer periods
- Examine use of satellite ear tags on adult males
- Examine the role of habitat structure and storm events on movement patterns

Working hypotheses

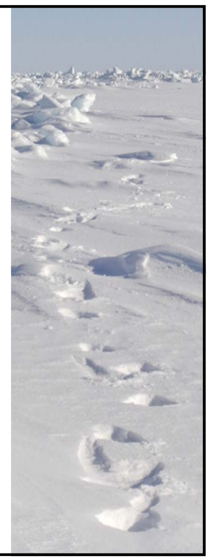


- Loss of habitat has shifted population boundaries
- Split in distribution
  - summer offshore and summer onshore
- Summer refugia on land increasingly important

Implications

- Increased proximity to oil and gas development (higher risk)
- Increased difficulty in monitoring population status
- Increased difficulties for hunters to access bears

Implications



- Research should merge with monitoring for real-time information
- Increased difficulties for Canadian hunters to access bears

U.S.A. – Canada co-operation

1. Identification of important marine and terrestrial habitats for polar bears
2. Re-assessment of population boundaries
3. Continued co-operation on population monitoring

Acknowledgements

Biological Sciences
University of Alberta

POLAR CONTINENTAL SHELF PROJECT

Inuvialuit Game Council

NSERC CRSNG

Canadian Wildlife Service

ArcticNet

Northwest Territories Environment and Natural Resources

Indian and Northern Affairs Canada

5.5.3 Satellite Tracking of the Western Arctic Stock of Bowhead Whales,

Lori Quakenbush, John Citta, Robert J. Small, John "Craig" George, Harry Brower, Jr., Mads Peter Heide-Jorgensen & Lois Harwood

[1] M.S., Principal Investigator, Alaska Dept. of Fish and Game, Email: lori.quakenbush@alaska.gov

[2] Ph.D., Alaska Dept. of Fish and Game. Email: john.citta@alaska.gov

[3] Ph.D., Co-Principal Investigator, Alaska Dept. of Fish and Game. Email: bob.small@alaska.gov

[4] M.S., Sr. Scientist, North Slope Borough, Email: craig.george@north-slope.org

[5] Chairman, Alaska Eskimo Whaling Commission. Email: harry.brower@north-slope.org

[6] Ph.D., Greenland Institute of Natural Resources. Email: mhj@ghsdk.dk

[7] M. S., Biologist, Dept. of Fisheries and Oceans, Canada. Email: lois.harwood@dfo-mpo.gc.ca

Bowhead whales (*Balaena mysticetus*) from the western Arctic stock have been the focus of considerable research because they: 1) are critical to the nutritional and cultural health of Alaska Natives, 2) play a significant role as zooplankton grazers in the Bering, Chukchi, and Beaufort seas, and 3) are vulnerable to possible effects of oil and gas activities during migration and while on their summer range. General migration patterns are known from aerial surveys and from the timing of whaling in coastal villages, yet knowledge of movements during migration relative to bathymetry, ice cover, and important feeding areas is limited. Working with other researchers, subsistence whalers, and local hunters in Alaska and Canada we attached satellite transmitters to bowhead whales during 2006 to 2008. In 2006, we tracked a 45-foot (13.7 m) male bowhead over 2,500 km, from Point Barrow, Alaska, to Amundsen Gulf, Canada, and then to Chukotka, Russia. During the spring migration, between Point Barrow and Amundsen Gulf, this whale passed through seas with 90 to 100% sea ice cover. We also documented the movements of this whale during an active seismic survey offshore of the Tuktoyaktuk Peninsula in Canada. As the ship and the whale converged, the whale deviated course and maintained a minimum of 9.2 km from the ship. We found no statistical relationship between whale behavior and movement with distance from the seismic ship and suspect this was largely due to the ship shutting down seismic operations (as a mitigation measure for a different whale that had coincidentally entered the safety zone) when the tagged whale came closest. Two other whales tagged at Barrow in 2006 and 2007 were also tracked to the Chukotka coast in fall. Tracking data indicate that certain areas in Amundsen Gulf, Chukotka, and near Point Barrow appear to be important feeding areas, at least in some years. We are also analyzing dive behavior of three bowheads tagged near Barrow in August 2007. These whales spent the majority of their time between 10 and 20 m below the surface near the seafloor. One of these whales traveled northwest along the shelf break to the nearshore area of Chukotka passed through a variety of water depths. Over the shelf break, diving behavior was highly variable; within 6 hour intervals, the whale sometimes spent the majority of time at shallow depths (30 m) and sometimes at deeper depths (200 m). Near the Russian coast the whale spent the majority of its time between 20 and 50 m, and was near the bottom approximately half the time. While the three whales were near Barrow, they were within the study area of BOWFEST, another MMS funded project that includes aerial surveys to locate feeding whales and ship-based sampling of zooplankton and oceanographic conditions. Results from these two projects may increase our understanding of the prey types or prey densities bowhead whales selected in the Barrow area.

Cooperators: Alaska Dept. of Fish and Game, North Slope Borough, Alaska Eskimo Whaling Commission, Aklavik and Tuktoyaktuk Hunters and Trappers Committees, Canada Dept. of Fisheries and Oceans, Greenland Institute of Natural Resources. Funding: Minerals Management Service, Fisheries Joint Management Committee, Polar Continental Shelf Project, and Panel for Energy and Research Development.

5.5.4 Bowhead Whale Feeding Variability in the Western Beaufort Sea - Feeding Observations and Oceanographic Measurements and Analyses, *Carin J. Ashjian*

Ph.D., Associate Scientist, Woods Hole Oceanographic Institution. Email: cashjian@whoi.edu

The Alaskan Beaufort Shelf is a feeding region for planktivorous bowhead whales during their autumn migration. This feeding opportunity may be vulnerable to impacts both from climate change and human activities. Oceanography and bowhead whales on the shelf near Barrow, Alaska were investigated during August and September of 2005 to 2008 as part of an ongoing, multi-investigator study to describe oceanographic distributions, to identify and describe oceanographic conditions that produce a favorable feeding environment for the whales, to document short term and inter-annual environmental variability, and to describe whale distributions and feeding behavior. Oceanographic characteristics and whale prey distributions were described by surveys conducted from a small research vessel. Whale distributions were documented during aerial surveys. Whale feeding behavior was studied in 2008 using short-term whale tags and proximate oceanographic and prey sampling to characterize whale diving behavior and prey distribution and small scale oceanographic conditions that aggregate prey.

Multiple water masses were observed each year 2005 to 2008, with close coupling between water mass and biological characteristics. Considerable inter-annual variability was observed. Both 2005 and 2007 were characterized by little or no sea ice and warm surface water (~11 °C in 2007) while melting sea ice in 2006 and 2008 contributed to colder surface waters (<4 °C). Shorter-term variability in conditions on the shelf was intimately tied to the direction and strength of the wind. Based on stomach content analysis from harvested bowhead whales, the whales near Barrow feed primarily on Arctic copepods or on krill (euphausiids) that are advected from the Pacific in the prevailing currents of the Chukchi Sea. Modeling studies have demonstrated that Bering Sea krill introduced into the Chukchi Sea in spring can reach Barrow by early fall to provide an important food resource for the whales. Krill and copepods are upwelled onto the Beaufort Shelf from Barrow Canyon or the Beaufort Sea when winds are from the E or SE. A favorable feeding environment is produced when these krill and copepods are concentrated on the shelf near Barrow as the prevailing westward shelf currents converge with the strong Alaska Coastal Current that flows to the northeast along the eastern side of Barrow Canyon. In addition, krill may be retained in Elson Lagoon under upwelling winds and subsequently flushed out along the barrier islands, providing local krill aggregations as prey for the whales. To date, feeding bowhead whales were observed in association with elevated abundances of krill along the barrier islands of Elson Lagoon (2005) and on the shelf to the east of Barrow Canyon (2006) following wind conditions consistent with the proposed mechanism of prey aggregation.

Funding for this ongoing study has been provided by the NSF, NOAA, MMS, ONR, the Coastal Marine Institute (UAF), and the WHOI Arctic Initiative. The support of the North Slope Borough Department of Wildlife Management, the Barrow Arctic Science Consortium, the Barrow Whaling Captains Association, the Alaska Eskimo Whaling Commission, the North Slope Borough, and the City of Barrow are gratefully acknowledged.

Bowhead Whale Feeding Variability in the Western Beaufort Sea

Carin Ashjian

Woods Hole Oceanographic Institution

On-Going Project

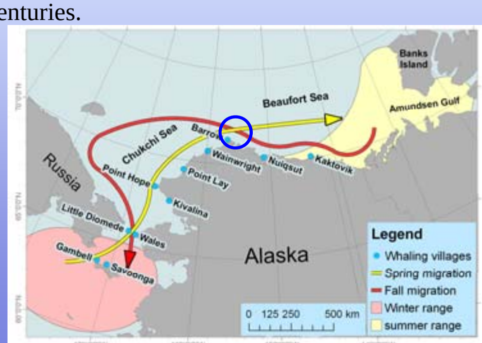
- 2005 & 2006: U.S. National Science Foundation
- 2007: WHOI Arctic Initiative, UAF Coastal Marine Institute, U.S. NOAA/National Marine Mammal Laboratory
- 2008 & 2009: NOAA/NMML, NOPP (National Oceanographic Partnership Program)

Many Collaborators

*Robert Campbell (URI)
*Steve Okkonen (UAF)
Sue Moore (NOAA)
Craig George (NSBDWM)
Ev Sherr (OSU)
Yvette Spitz (OSU)
Barry Sherr (OSU)
Wieslaw Maslowski (NPS)
Dave Rugh (NOAA)
Kim Goetz (NOAA)
Julie Mocklin (NOAA)

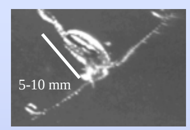
Bowhead Whale Migration

Bowhead whales are recurrently found feeding near Barrow, AK during their fall migration from the Canadian Arctic to the Bering Sea. Bowhead whales are hunted near Barrow by the Iñupiat and have been so for centuries.



Map Courtesy Lori Quakenbush

Bowhead Whale Prey



Copepods - Arctic and Pacific

Euphausiids/Krill - Pacific

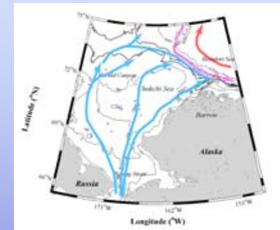
Bowhead Whale Stomach w/Krill

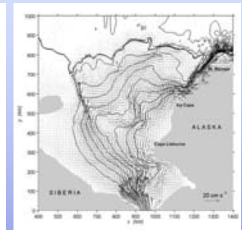
- Analysis of harvested bowhead whale stomach contents shows that the whales feed on both copepods (found in both the Arctic and Pacific) and on euphausiids or krill which are believed to be native to the Bering Sea (or Pacific) but are eaten by the whales harvested near Barrow
- We believe that krill cannot overwinter in the Arctic and hence must be reintroduced annually
- Because the prey is very small, and whales are very large, the whales need very dense concentrations of prey for feeding to be efficient and worthwhile

GOALS OF OUR RESEARCH

- Why do bowhead whales stop at Barrow during their fall migration?
  - Bowhead whales congregate at Barrow in fall because of dense zooplankton patches that form there
- What are the oceanographic conditions that make this a favorable feeding environment?
- Is this an important feeding area for the bowhead whale during their fall migration?
- How might these conditions be impacted by climate change?

Where do krill near Barrow come from?

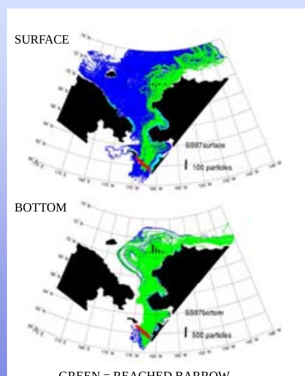




Winsor and Chapman (2004): No wind case.

- Currents bring water, and krill, from the Bering Sea through the Chukchi Sea to the shelf near Barrow
- Much of the water, with intrinsic plankton, particles, and chemicals, that crosses the Chukchi Sea is ultimately funneled past Barrow under most wind conditions.

Where do krill near Barrow come from?



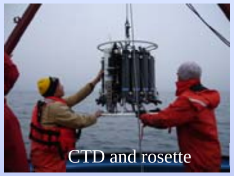
Berline, Spitz, et al. (2008) using Maslowski et al. (2004) model.

- Simulation using modeled circulation from 1997
- 24±22/5 % of the krill in the surface water reach Barrow
- 94.6±6.3% of the krill in the bottom water reach Barrow
- Krill entering the Chukchi Sea in spring can easily make to to Barrow by fall, coinciding with the arrival of the whales
- Note: Krill are adjacent to but not ON the shelf near Barrow

Field Sampling during 2005 - 2008

- Aerial surveys to document distributions of bowhead whales in late August - early September 2005 -2008
- Oceanographic sampling using the 43’ *R/V Annika Marie* from mid-August to mid-September 2005-2008

Oceanographic Measurements


CTD and rosette


“Acrobat”

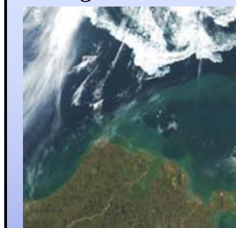

Deploying Acrobat


Nets

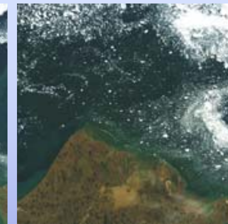
- ACROBAT - Temperature, salinity, pressure, optical backscatter, chlorophyll and CDOM fluorescence
- CTD and Rosette - Temperature, salinity, pressure, fluorescence, water for chlorophyll, nutrient, and microzooplankton determinations
- ADCP (not shown) - Velocity and acoustic backscatter
- Video Plankton Recorder (not shown)
- Plankton nets

Ice Cover

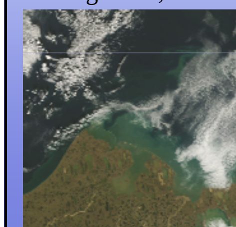
August 14, 2005



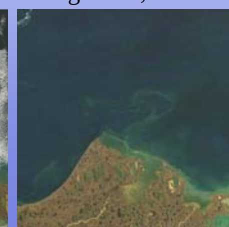
August 23, 2006



August 23, 2007

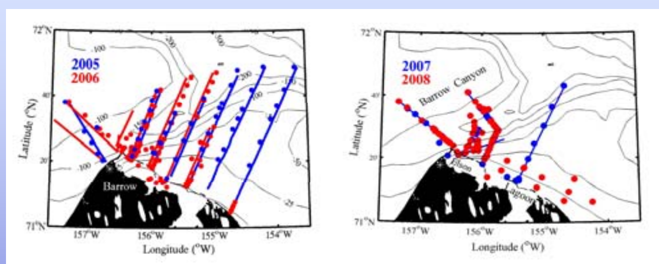


August 23, 2008



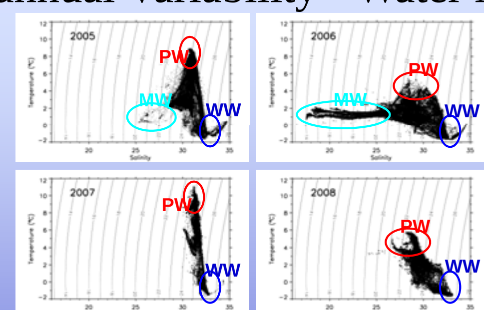
- Much more ice in 2006
- Ice was heavy in 2008 until early August; little ice during sampling
- 2007 least summer ice extent in Arctic, especially Western Arctic; 2008 second least summer ice extent

Oceanographic Sampling



- Underway sampling along solid lines; discrete stations at symbols
- Areal coverage limited in 2006 relative to 2005 and 2007 because of ice cover offshore and to the east
- Sampling in 2007 and 2008 was along lines identified as indicators or sentinels from 2005 and 2006 data. Repeated sampling possible.

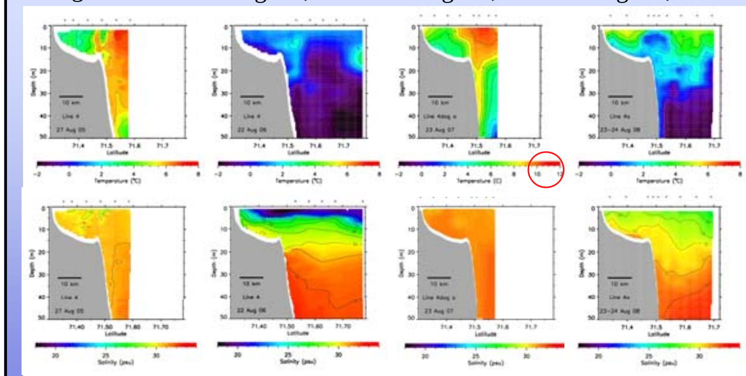
Interannual Variability - Water Masses



- Warm Pacific Water present in 2005 & 2007, much less in 2006 & 2008
- Very warm in 2005 and 2007 (maximum T observed was 11 °C)
- A lot of Melt Water in 2006, when ice was present
- Cold, salty Winter Water in all years, formed during the previous winter

Considerable Interannual Variability - Line 4

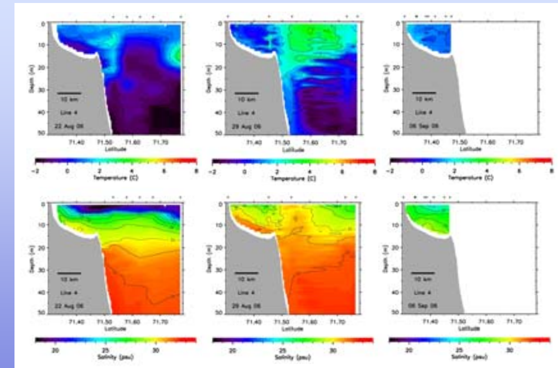
Aug. 27, 2005 Aug. 22, 2006 Aug. 23, 2007 Aug. 23, 2008



- Much colder with much more vertical structure (ice melt) in 2006 and to some extent in 2008
- Very warm and salty in 2007

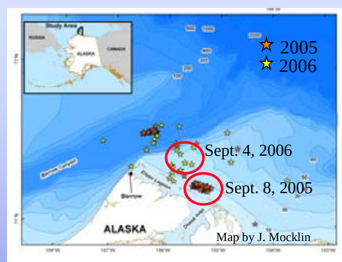
Considerable Short-Term Variability - Line 4

Aug. 22, 2006 Aug. 29, 2006 Sept. 6, 2006

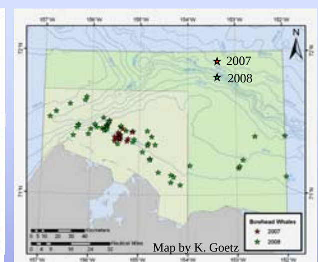


- Much colder, with very fresh upper 5 m due to ice melt, on Aug. 22
- Warmer, with less fresh water, 7 days later
- Cooler, and of intermediate salinity, on the shelf on Sept. 6
- Changes associated with presence of ice and with movement of water by the wind

Bowhead Whale Distributions from Aerial Surveys



Aerial surveys conducted by S. Moore, J. Mocklin, C. George, and C. Monnett



Aerial surveys conducted by D. Rugh, K. Goetz, and J. Mocklin

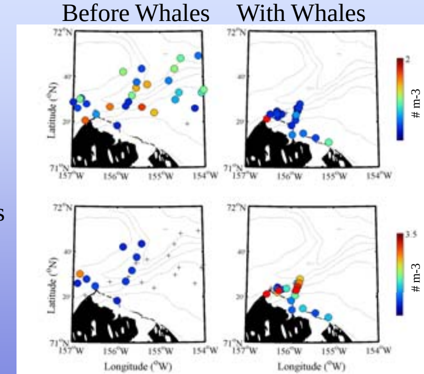
- Whales first observed in early September in both 2005 and 2006
- Whales were seen on Aug. 23 and 24 but not in September of 2007
- Whales were observed in late August and early September in 2008
- Most whales were seen on the shelf along the 15 m isobath, although some were seen near the barrier islands of Elson Lagoon
- The whales observed in 2005, 2006, and 2008 were feeding; the whales seen in 2007 were "passing through"

Distribution of Euphausiids (2005 & 2006)

Before Whales With Whales

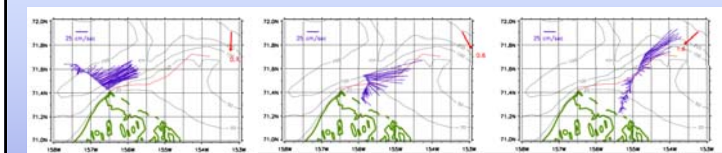
Furcilia

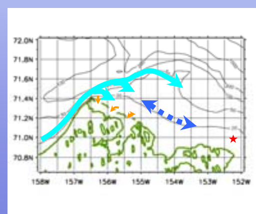
Juveniles and Adults



- Few juveniles and adults present before whales arrived
- Reduced abundances of furcilia when whales present
- Whales present at time when there were higher abundances of their preferred prey

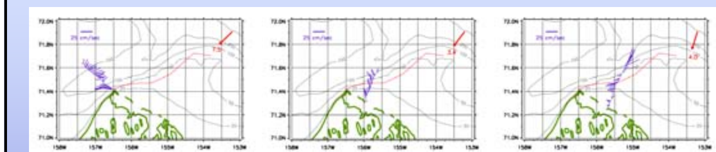
Influence of Wind: Weak (<3-4 m/sec) or from the S-W (not shown)

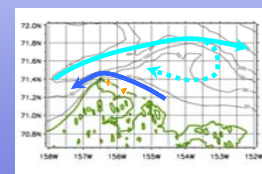




- Strong Alaska Coastal Current adjacent to shelf break in Canyon and Beaufort
- On shelf intrusions of ACC; warm water at shelf break and onto shelf
- Shelf Break Jet is strong and is a barrier to offshelf movement of water
- Weak Currents on Beaufort Shelf

Influence of Wind: Moderate-Strong from the NE





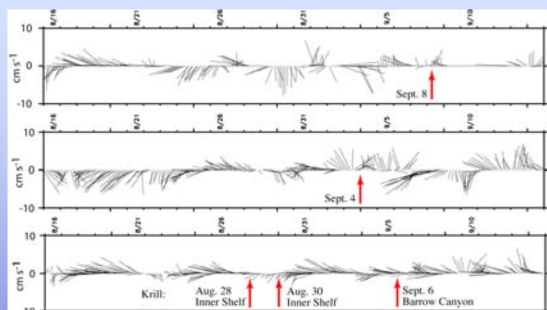
- Alaska Coastal Current is weakened and moves further away from the shelf break
- In turn, NW currents on the inner Beaufort Shelf extend off the shelfbreak and turn SW at Pt. Barrow
- Water on the Beaufort Shelf is exported to the Chukchi
- Winds from E promote upwelling along Beaufort Shelf

Winds at Barrow

2005

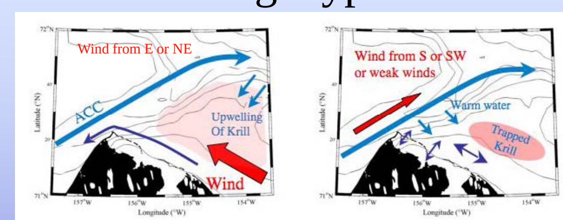
2006

2007



- The 2005 and 2006 observations of feeding bowheads near krill occurred following period of southwest wind
- This corresponds to when the ACC should be tight against the eastern edge of Barrow Canyon
- In 2007, krill were observed on the shelf during a period of low wind (strong ACC) or in Barrow Canyon during upwelling favorable winds

Working Hypothesis



- During periods of winds from the east, krill upwell along the Beaufort Shelf but are diffuse on the shelf
- Water escapes around Pt. Barrow to the SW
- During periods of wind from the S or SW or weak winds, the ACC is strong and close to the eastern side of Barrow Canyon, trapping water on the shelf and concentrating krill
- Water also upwells from Barrow Canyon
- Krill and water also enter Elson Lagoon

Preliminary Conclusions

- The presence of exploitable bowhead whale prey at Barrow is dependent on input of krill from the Bering Sea
- Oceanography and whale prey availability are profoundly impacted by the magnitude and direction of the wind
- Striking interannual and shorter-term variability in the physical (ice, ocean) and biological distributions
- The presence of ice significantly influenced hydrography
- Despite interannual and shorter term variability in ocean conditions, this region at present appears to be a predictable feeding area for the bowhead whales during their fall migration
- These four years of research have been conducted at a critical location in the Arctic during a period of unprecedented change; these data are the start to what should be longer term monitoring and understanding of the ocean at this location

Acknowledgements

•Phil Alatalo (WHOI) and Aaron Hartz (OSU) for field sampling and data analysis

•Bill Kopplin, Ned Manning, Mike Johnson, and Randy Pollock, the captains of the *R/V Annika Marie*, for their valuable inputs to our program

•Charles Monnett (MMS) for providing aircraft support and collaborating on the 2006 aerial survey

•The Barrow Whaling Captains Association, the Alaska Eskimo Whaling Commission, the North Slope Borough, and the community of Barrow for their support

•Glenn Sheehan and the Barrow Arctic Science Consortium Staff for logistic support in Barrow

•VECO/CH2MHill Polar Services for logistic support in Deadhorse / Prudhoe Bay

•Bill Streever, Wilson Cullers, and Tatyana Venegas at British Petroleum for assistance in accessing West Dock in Prudhoe Bay to load the *Annika Marie*

•The ARMADA Program at the University of Rhode Island for the participation of Jeff Manker and Kirk Beckendorf (high school teachers)

•Funded by the National Science Foundation, the University of Alaska Coastal Marine Institute, the Woods Hole Oceanographic Institution Arctic Initiative, and the NOAA National Marine Mammal Laboratory, and the National Oceanographic Partnership Program

5.5.5 Seasonal Distribution of Canadian Beaufort Beluga Whales

Pierre R. Richard

M. Sc., P. Biol., Research Scientist, Fisheries and Oceans Canada. Email: pierre.richard@dfo-mpo.gc.ca

Between 1993 and 2005, a total of 42 beluga whales (*Delphinapterus leucas*) from the Mackenzie Delta have been instrumented with satellite-linked radio transmitters ("tag") and tracked for periods varying between a few days to 15.5 months. The tracking longevity improved with new tag designs from a few months to more than six months to a point where we were able to monitor the tagged beluga's distribution throughout the summer, autumn and winter months. One animal lasted long enough to show its second summer and autumn movements. Tracking results showed that Canadian Beaufort Sea belugas did not simply aggregate in the Mackenzie Delta in summer but that they ranged widely into Amundsen Gulf, M'Clure Strait and Viscount Melville Sound and deep into the offshore pack ice of the eastern Beaufort Sea. A westward autumn migration followed though the Alaskan Beaufort Sea and into the Russia's western Chukchi Sea, near Wrangel Island, where they spend a few weeks before moving south through the Bering Strait. The few tags that lasted long enough to track belugas through the winter showed that.compared to their summer range, they had a narrower winter range in the Bering Sea, mostly in Russian waters and centered to the southwest of St.Lawrence Island. Return migration through the Bering Strait started in late April. One animal was tracked back to the eastern Beaufort in 2005. It arrived there in mid-May and initially ranged well north of the Mackenzie Delta but moved into it in mid-July. It later followed an almost exact series of movements into Viscount Melville Sound and through the Alaskan Beaufort Sea to the western Chukchi Sea and Wrangel Island as it had the previous year.

This research would not have been possible without the support and effort of many Inuvialuit from Inuvik, Tuktoyaktuk and Aklavik and the funding of the Inuvialuit Fisheries Joint Management Committee, the Environmental Studies Research Fund, the Mackenzie Gas Pipeline Fund, ArcticNet and Fisheries and Oceans Canada.

Seasonal Distribution of Canadian Beaufort Beluga Whales

Pierre Richard
with J. Orr, and S. Ferguson,
DFO Arctic Research Division,
and L. Loseto and Natalie Asselin,
University of Manitoba

Fisheries and Oceans Canada
Pêches et Océans Canada
Canadä

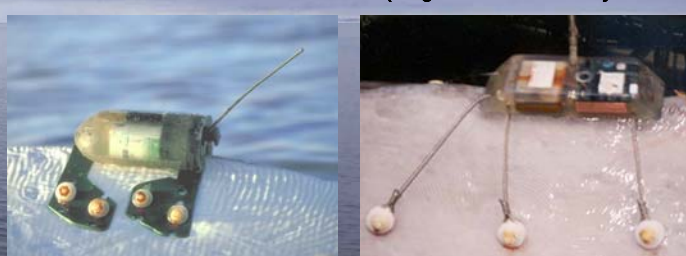
Overview of projects

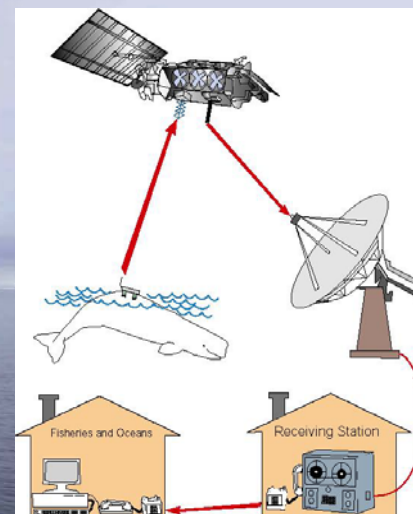
- Satellite Tracking:
  - 1993-1997, 2004-2005 seasonal tracking of beluga to study habitat use in the Beaufort Sea and beyond (Richard et al. 2001, Loseto et al. 2006, Richard unpublished)
- Spring Aerial Surveys:
  - May-June 2008 aerial surveys of the Eastern Beaufort Sea/ Amundsen Gulf : spring beluga distribution and role of sea ice habitat (Asselin, unpublished)

Satellite Tracking

- Main drivers to the project :
  - To further understand the seasonal habitat preference of Beaufort Sea belugas
    - With particular emphasis on present and future interactions with Northern oil and gas activity
  - To provide input to Beluga Co-Management and the Mackenzie Gas Pipeline Environmental Assessment Process

Various satellite-linked transmitters ("tags" used over the years



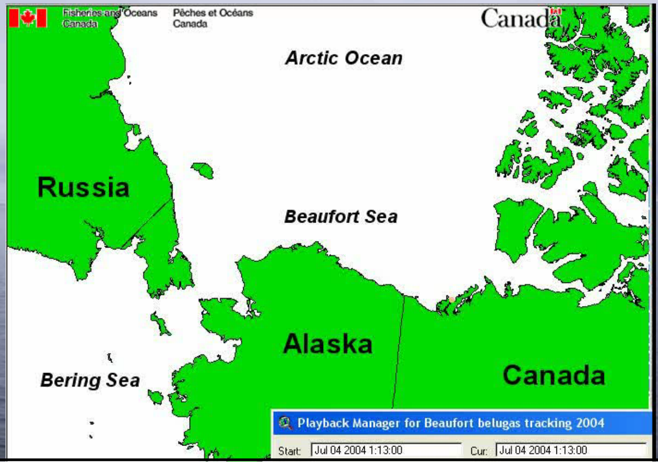


Timeline

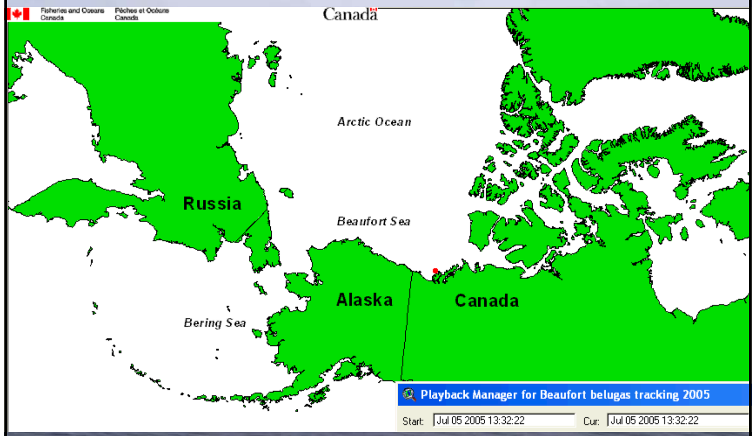
- Past work: 30 belugas tracked in 1993, 1995 and 1997
- 2004: 9 belugas instrumented
- 2005: 4 belugas instrumented
- 2006- and beyond: Analysis and reporting

Tracking results 1993-1997

Tracking July 2004 to October 2005



Tracking July 2005 to April 2006



General **Male** Movement for beluga tagged in July 2004-2005.

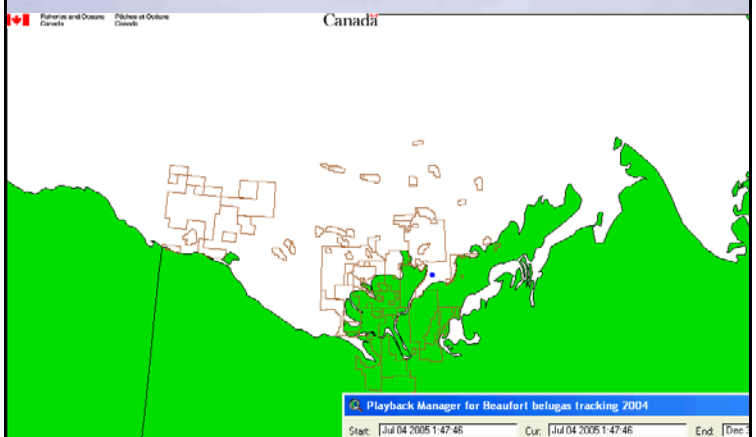
General **Female** Movement for beluga tagged in July 2004-2005.

Summer Resource Selection 93-97

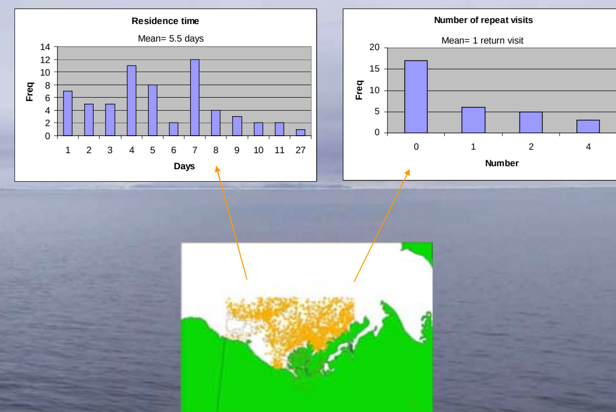
Loseto et al. 2006

- ***Open water near mainland***: females, some with young calves + small males
- ***Ice edge***: small males and females with older calves
- ***Closed sea ice and archipelago passages***: large males

O&G lease area use 1993-2004



O&G lease area use 1993-2004



Conclusions

- The results of these 42 belugas tracks indicate **short stays** on average and **intermittent use** of the **Mackenzie estuary** from July to mid-September.
- **Offshore use is much broader** than would have been expected from beluga studies in other parts of the Arctic.
- Although there have been **large improvements in tag duration**, these are insufficient to fully **document** beluga **spring habitat use**.

Moving ahead

- While tagging with new longer lasting tags showed some promise, it was wise to invest in other means of studying spring habitat use.
- **Spring aerial surveys** informed by **continued summer tagging results** could be useful to document beluga distribution and habitat use.
- **Air-borne observational methods** and **ice-bound acoustic methods** could be useful to study behavioural changes in response to industrial noise.

Spring Aerial Surveys

(May and June 2008)

Thesis Title:

Beluga use of the circumpolar flaw lead in the Banks Island and Amundsen Gulf region.

Photo by Klaus Hochheim

Natalie Asselin
M. Sc. Candidate
Dept of Environment and Geography
Supervisor: Dr. David Barber
University of Manitoba
International Polar Year - Circumpolar Flaw Lead Project

Quickbird satellite monitoring of belugas!?

Expected benefits of those research projects to Inuvialuit and O&G Industry

- Understanding of the seasonal distribution and habitat use of belugas benefits to Inuvialuit & Industry by:
  - Informing them of seasonal habitat requirements of this important Beaufort Sea resource
  - Input to the Mackenzie Gas Pipeline I.A.
  - Establishing baseline information for Northern Oil and Gas impact monitoring

Project Enablers

- **1992-1997:**
  - Funding: FJMC, ESRF, DFO, US MMS, WWF
  - Support: IGC, Aklavik, Inuvik and Tuktoyaktuk HTOs
  - hired field help from Inuvik, Aklavik and Tuktoyaktuk
- **2004-2005:**
  - Funding: Devon Petroleum, LOMA, FJMC, WWF, DFO
  - Support: IGC, Aklavik, Inuvik and Tuktoyaktuk HTOs
  - Hired field help from Aklavik, Inuvik and Tuktoyaktuk + FJMC supported students
- **2005-2006:**
  - Funding: MGP, FJMC, DFO
  - Support: IGC, Aklavik, Inuvik and Tuktoyaktuk HTOs
  - Hired field help from Aklavik and Inuvik + FJMC supported students
- **2008-2009:**
  - Funding: CFL-IPY, CFI, ArcticNet, NSERC, DFO
  - Support: CCG
  - Numerous volunteer observers.

Further questions

Pierre Richard
Arctic Aquatic Research Division/DFO
pierre.richard@dfo-mpo.gc.ca

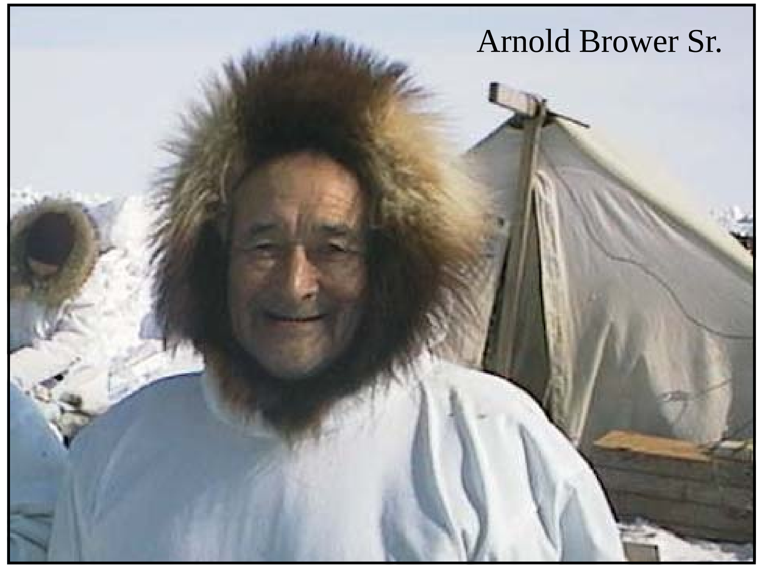
5.5.6 Bowhead and Beluga Whales in the Alaskan Beaufort and Chukchi Seas: Implications of Oil and Gas Development and Climate Change, *Robert Suydam*

Wildlife Biologist; North Slope Borough Department of Wildlife Management and Committee of Scientific Advisors Marine Mammal Commission. Email: Robert.Suydam@north-slope.org

Bowhead (Balaena mysticetus) and beluga (Delphinapterus leucas) whales migrate through the Chukchi and Beaufort seas twice a year. Most of those whales winter in the Bering Sea and migrate north through the Chukchi Sea to summering areas in the eastern Beaufort Sea, although it appears some animals remain in the Chukchi and western Beaufort seas throughout the summer. One stock of belugas aggregates in nearshore areas of the Chukchi Sea in early summer before moving north to summering areas near the shelf break of the eastern Chukchi and western Beaufort seas. The population size and trend of bowheads is well known (about 10,500 animals in 2001 and growing at ~3.4% per year) but not so with belugas. Arctic environments are changing rapidly for many reasons; key among them is the record retreat of summer sea ice. Other changes include: increasing offshore oil and gas exploration and possible development, and the possibility of increased international shipping traffic, ecotourism and commercial fishing. These changes and additional pressures from human activities raise concerns about negative impacts to bowhead and beluga populations. Impacts to whale populations will also impact subsistence hunts by Alaska Natives. In many cases, concerns are heightened because of limited or outdated knowledge. For example, little is known about how bowheads and belugas utilize the area, especially the Chukchi Sea. Predicting and mitigating impacts is difficult, if not impossible, with limited knowledge. Science and traditional knowledge show that bowheads are very sensitive to low levels of anthropogenic sounds but little is known about the biological significance of those impacts or from the cumulative impacts from multiple oil and gas operations. Increasing our knowledge of how Arctic whales respond to a changing environment and understanding impacts from increased anthropogenic activities will help in predicting and planning for the future. Information is needed to help mitigate impacts from oil and gas activities on whales and subsistence communities that depend on them.

Bowheads and Belugas in the Beaufort and Chukchi seas: impacts from Climate Change and Oil and Gas

Robert Suydam
North Slope Borough
Barrow, AK



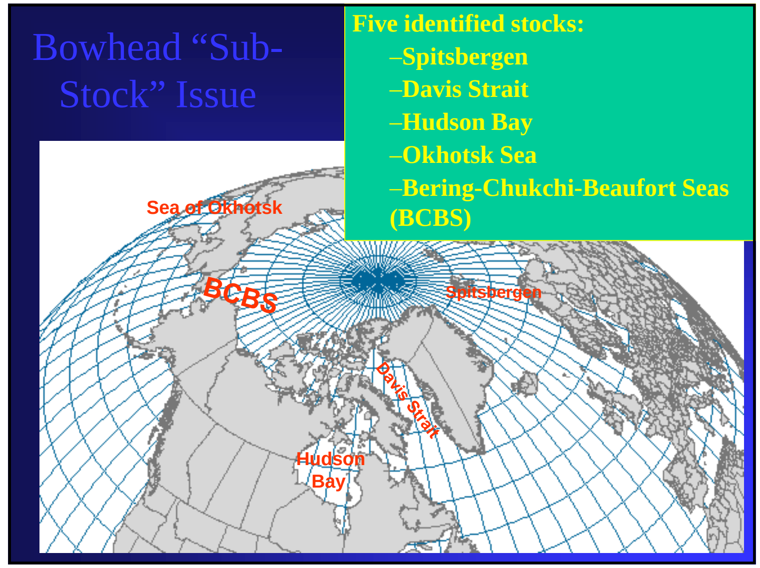
Arnold Brower Sr.

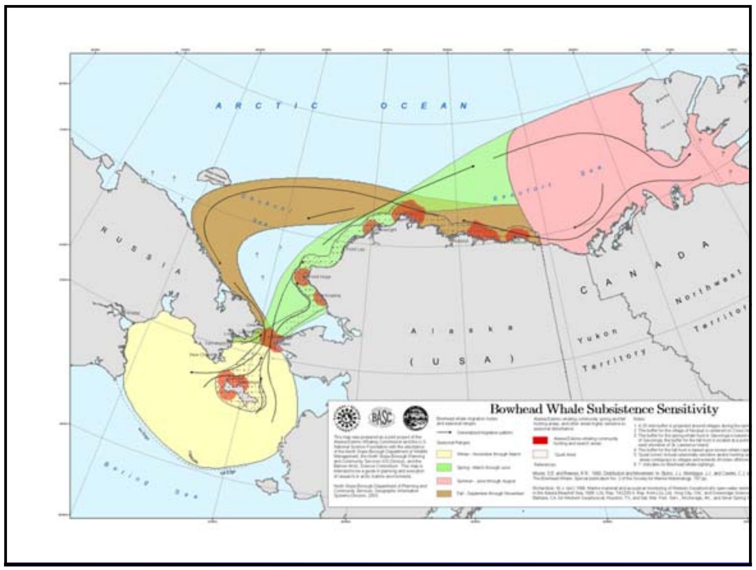
Acknowledgements

- U.S. Marine Mammal Commission
- North Slope Borough
- Subsistence hunters
  - Alaska Eskimo Whaling Commission
  - Alaska Beluga Whale Committee
- Sue Moore, Lois Harwood, Amanda Joynt, Kate Stafford

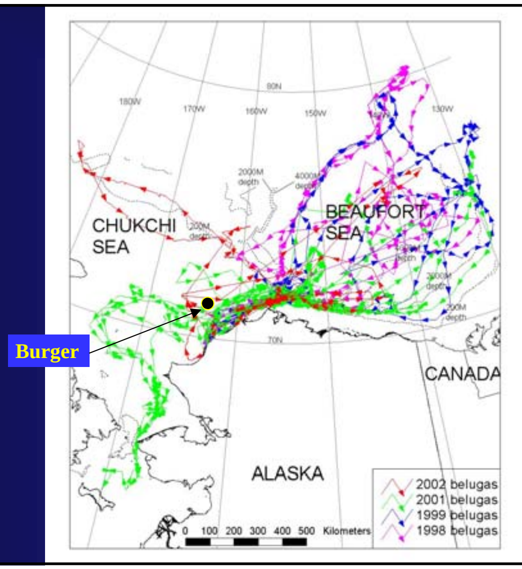
Outline

- Bowheads
- Belugas
- Climate change
- Industry
- Data needs


Bowhead "Sub-Stock" Issue
Five identified stocks:
–Spitsbergen
–Davis Strait
–Hudson Bay
–Okhotsk Sea
–Bering-Chukchi-Beaufort Seas (BCBS)
Sea of Okhotsk
BCBS
Spitsbergen
Davis Strait
Hudson Bay

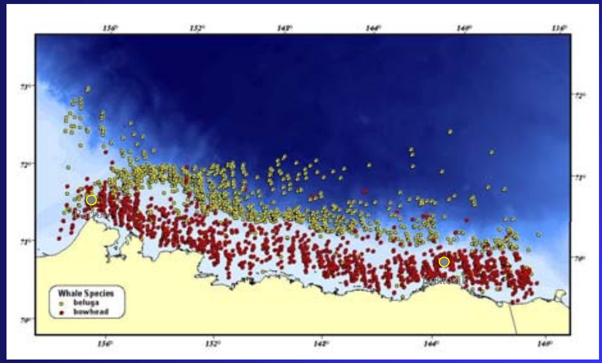

ARCTIC OCEAN
RUSSIA
CANADA
Alaska
(USA)
Yukon Territory
Bowhead Whale Subsistence Sensitivity

Beluga whale stocks in Alaska



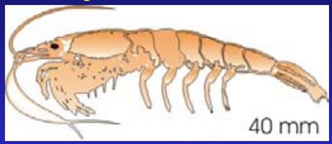
Summer and autumn movements of Chukchi Sea belugas

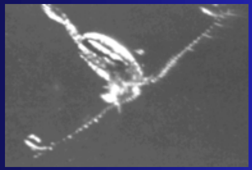
In autumn, bowheads and belugas migrate westward along the Beaufort Sea shelf



Copepods

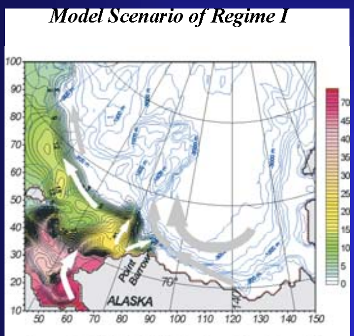
Euphausiids



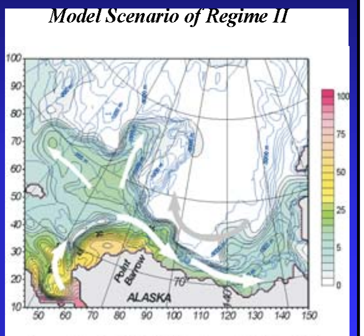


- Copepods are found in both Bering Sea and Arctic Water
- Euphausiids are more common in Bering Sea Water

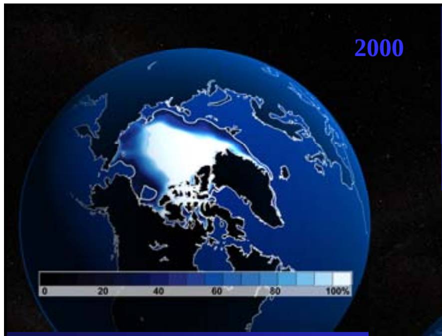
Climate Variability: Two Climate Regimes



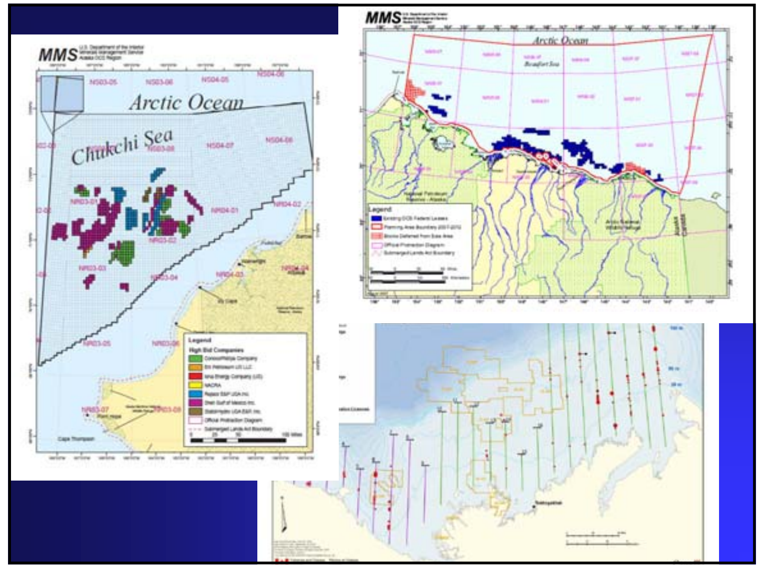
A snapshot of the Pacific Water tracer distribution (%) at depth 20-45 m for September 1981

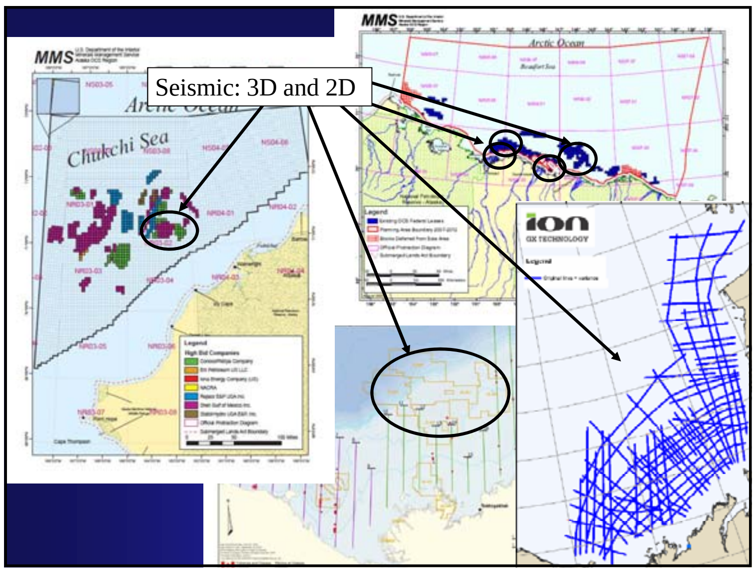


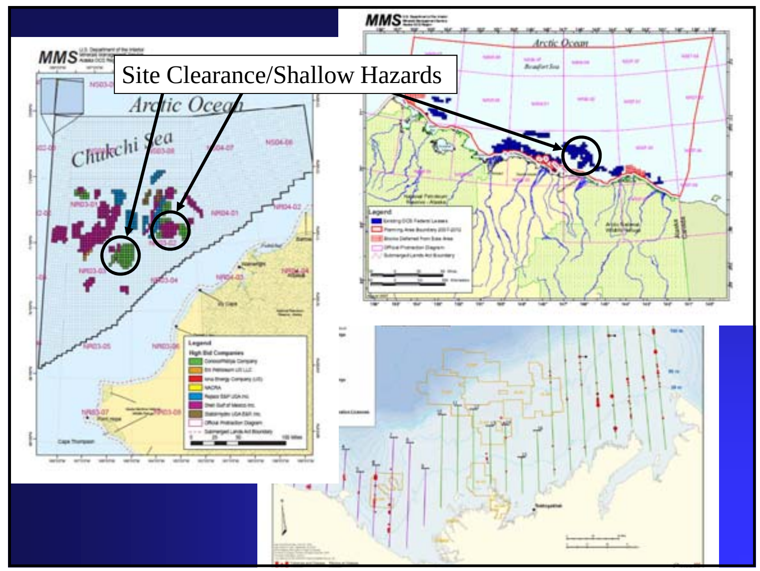
A snapshot of the Pacific Water tracer distribution (%) at depth 20-45 m for September 1992

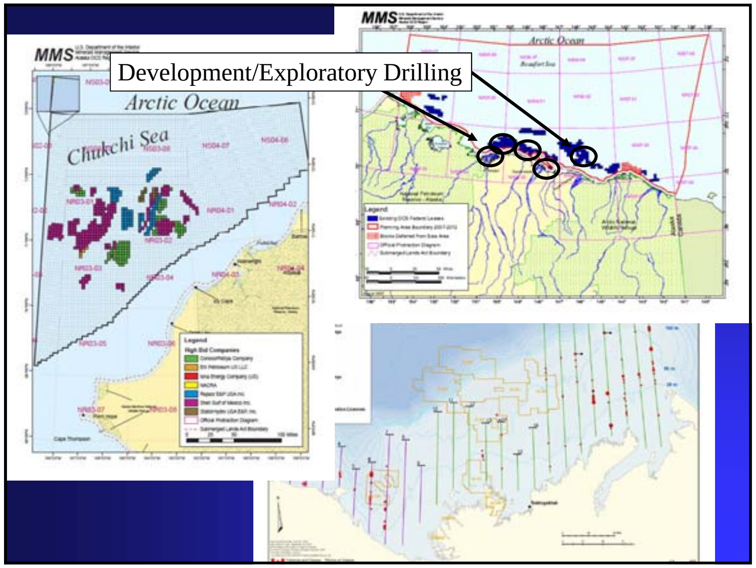


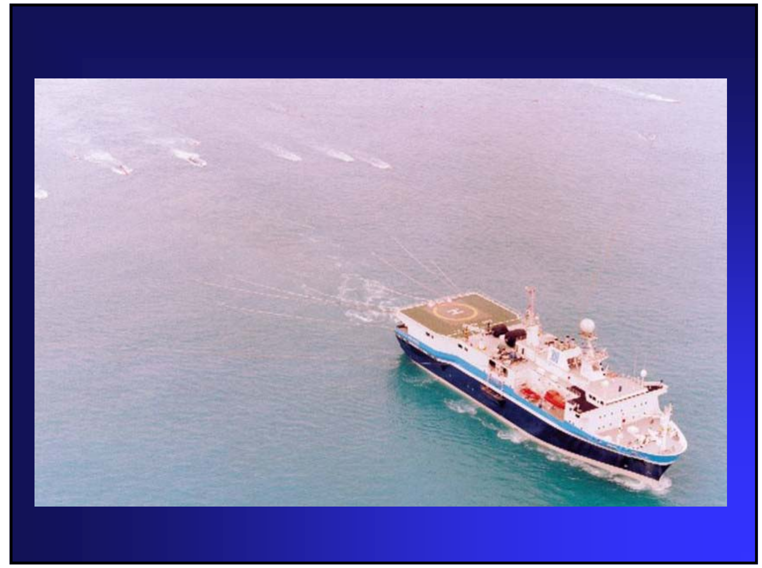
Factors affect whale distribution can also affect hunting success





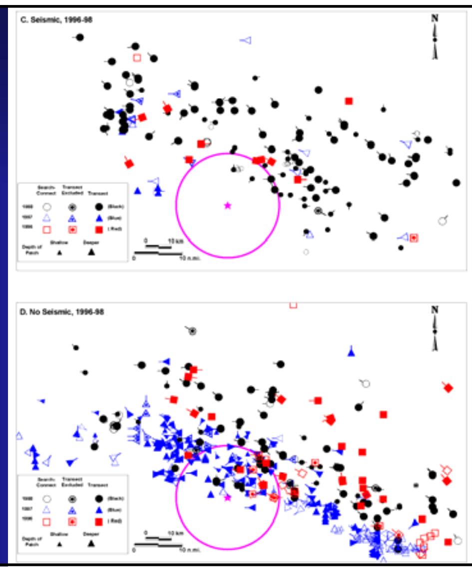


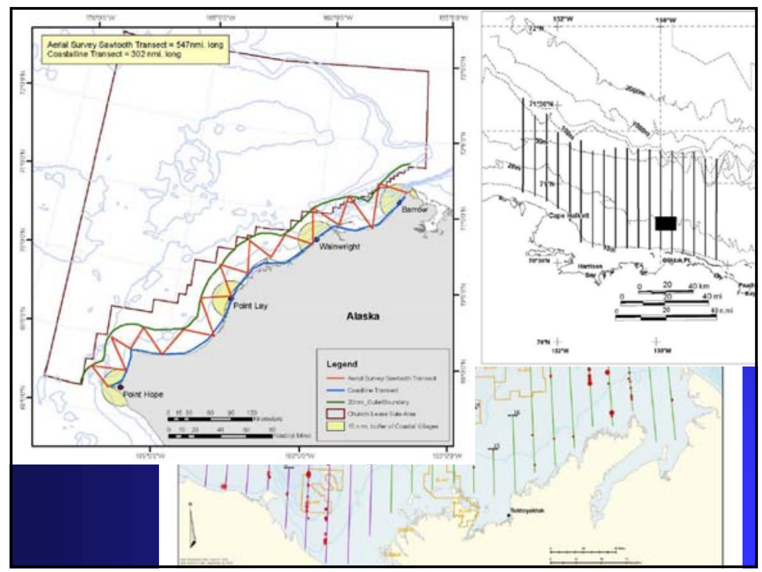


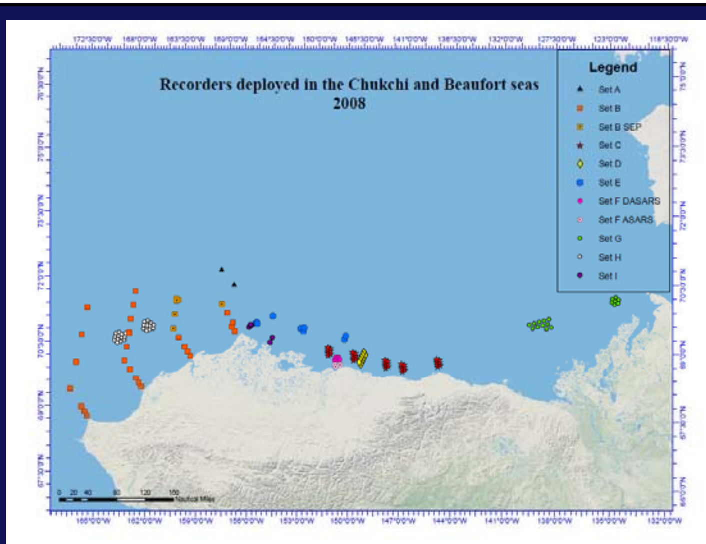


Impacts to bowheads from seismic exploration

Richardson et al. 1999







Conclusion

- **Climate changing in the Arctic**
- **Increasing amounts of Oil & Gas activity**
- **Lots of data needs.**
  - **Chukchi Sea**
  - **Cumulative Impacts**
- **Information is necessary for making science-based decisions and mitigating impacts.**
- **Marine mammals and subsistence hunting are protected.**

5.5.7 Fish Research in the Western Canadian Arctic in support of Hydrocarbon Development, *James D. Reist*

Ph.D., Research Scientist, Fisheries and Oceans Canada. Email:Jim.Reist@dfo-mpo.gc.ca

Aquatic habitats and their biota experience many stressors which affect ecosystem structure and function. These stressors include: 1) climate variability and change, 2) industrial development, 3) exploitation, 4) contaminants, and, 5) increased human population and infrastructure activities. Individual stressors affect both the fishes (e.g., individual and population levels) and their habitats (e.g., shifts in physical habitat quality and quantity) directly; these stressors also exert indirect effects mediated through effects on other biota (e.g., shifts in food quality and quantity) and/or habitat (e.g., shifts in production pathways and energy flows). Moreover, these suites of individual stressors interact to result in cumulative effects on aquatic systems. Thus, the key to sustainable development in this area is to understand effects of the stressors individually as well as cumulatively and to manage the biota and systems within this context.

Fishes are key components of western Arctic aquatic ecosystems including the Beaufort Sea and adjacent fresh and estuarine waters of Canada. The approximately 90 fish species present in this area represent three types: a) obligate marine species, b) obligate freshwater species, and, c) and amphidromous (i.e., anadromous/catadromous) species which move between fresh and marine waters. Many species are pivotal members of the relevant aquatic ecosystem occupying central positions in trophic patterns. Additionally many are sensitive to the effects of stressors exhibiting large responses to small changes in the stressors. Thus, the best fundamental understanding of both the environment and stressor effects results from studies of sensitive or pivotal species across a range of habitat and ecosystem types. This is particularly true for migratory anadromous species that occupy many habitats seasonally and throughout life, thus integrate effects from multiple stressors.

The overall objectives are to understand the biology and effects of stressors on fishes in this area through a series of linked studies. These studies increase basic knowledge of all aspects of the fishes' biology, habitat usage and trophic interactions. Such information provides the context within which effects from individual stressors can be assessed. The ultimate aim is to apportion importance (or at least rank) the effects of the various stressors upon these indicator species both at local levels and throughout the ecosystems generally. This presentation will focus upon key findings from four projects being conducted in this area. 1) Within freshwater systems along the Mackenzie River valley the research aims to understand habitat associations and potential effects of hydrocarbon activity for non-migratory freshwater species such as Arctic grayling and bull char. 2) In the lower Mackenzie and Yukon north slope freshwaters, work focuses upon Dolly Varden to assess conservation status, link habitat with biology, and understand climate change effects. 3) North Slope coastal studies assess present migratory patterns and habitat usage of nearshore fishes, and are the basis for understanding long-term shifts in this ecosystem. 4) Offshore studies on the Beaufort Sea shelf provide information on marine fish distribution and their pivotal role in both pelagic and benthic ecosystems in this area. Understanding from this work will provide a baseline against which effects of specific developments can be assessed and will place this in the context of pervasive stressors also affecting these fishes.

These studies have been variously supported through funding provided by Indian and Northern Affairs Canada, Panel on Energy Research and Development, Species at Risk, land claim groups (i.e., Inuvialuit, Gwich'in and Sahtu peoples), and DFO.

Fish Research in the Western Arctic in Support of Hydrocarbon Development

James D. Reist
& many DFO biologists

US-Canada Northern Oil & Gas Forum
Anchorage, Alaska
October 2008

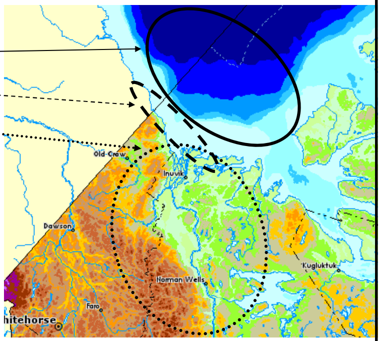
Fisheries and Oceans Canada   Pêches et Océans Canada

Talk Outline

1. Introduce ~ **95 species** of Canadian western Arctic fishes
2. Discuss **stressors** affecting fish, habitats & ecosystems
3. Overview some **ongoing fish studies** DFO is conducting

A Fish's Perspective of the Western Arctic

- Three kinds of water:
  - Marine
  - Mixed
  - Fresh
- Wide seasonal extremes
  - Low flow, ice most of year
  - Spring breakup/freshet
  - Summer, open, warm
- Wide inter-annual variation
  - Areal extent of phenomena
  - Timing of key events
- Habitat/ecosystems structured within extremes & variation
- All environments are rapidly changing with 'downstream' effects (climate shifts)



Three Kinds of Water
= Three General Fish Habitat Types
= Three Major Ecological Fish Groups

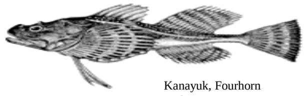
Three Kinds of Fish - 1

Marine

- ~60 species in Canadian waters
- ~17 more possibly there (not recorded or present in Alaska)
- Nearshore to offshore habitats
- High to low salinities
- Benthic/pelagic/ice habitats
- Some are <u>pivotal</u> ecosystem elements (e.g., Arctic cod)
- Some may have fishery potential (e.g., herring) <u>but</u> are episodic in abundance with a patchy distribution

Piqquatitaq, Pacific herring

Uugavik, Arctic cod



Kanayuk, Fourhorn sculpin

Three Kinds of Fish - 2

Anadromous (sea-run)

- Migrate between fresh water & mixed water (summer feeding)
- ~10 species primarily (plus 4 occasional vagrants)
- Most are salmonids - the mainstay of fisheries in the area
- At sea, usually in nearshore to shallower offshore habitats
- Mostly pelagic habitats
- Some are top predators and are very sensitive to perturbations (e.g., Dolly Varden)
- Arctic cisco & Dolly Varden are transboundary migrants


Anaakliq, Broad whitefish


Qaaktaq, Cisco

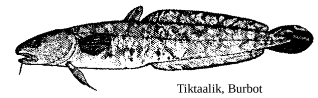

J. Johnson photo

Dolly Varden

Three Kinds of Fish - 3

Fresh Water

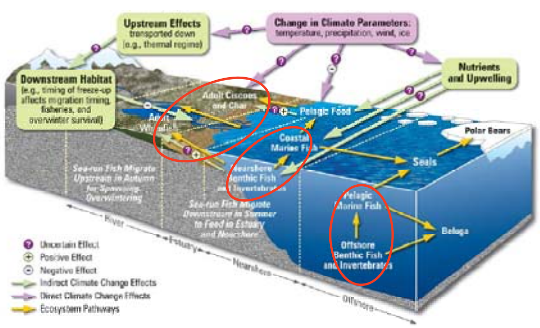
- ~25 species in Canadian waters
- Lake and river habitats
- Migratory to sedentary
- Some are fished – e.g., burbot
- Small species are pivotal in ecosystems (e.g., minnows, stickleback) – food for others
- Many are ‘Sensitive’ (e.g., bull trout) – small fragmented populations, restricted habitat needs, multiple stressors, & poor recovery potential


Tiktaalik, Burbot


J. Stewart photo

Bull trout

Stressors and Complex Aquatic Ecosystems



Stressors

- Climate Variability & Change
- Industrial Development (all types)
- Exploitation
- ‘Contaminants’ (incl. sediment)
- Human population & infrastructure

Responses/Effects

- Direct on fish
- Indirect on local & upstream habitats
- Indirect on ecosystem structure & function (i.e., other, new species)
- Individual and cumulative effects

Some Difficult but Key Questions

- What is baseline state of the aquatic ecosystems and biota?
- How do the systems vary inter-annually and change over time?
- How do fishes and other ecosystem elements respond to change?
- What portion of variation and change is natural vs. anthropogenic?
- What human activities contribute most (& how) to anthropogenic driven change (i.e., pathways of effects)?
- How much anthropogenically change/variation is too much?
- How do we minimize effects of particular stressors including cumulative issues?
- How do we balance sustainable development with conservation and the integrity of ecosystems and services they provide?
- For perturbations/problems what activity or who should be blamed?

The Path to Some Answers???

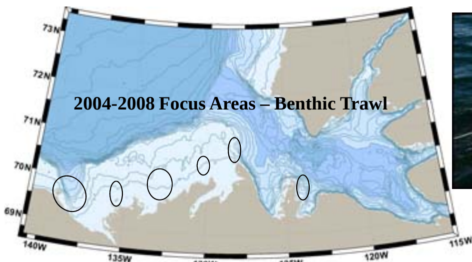
- Establish good baseline information for ecosystem structure (components) and function (energy transfer)
- Monitor status and change in species and ecosystems and link to stressors – attribute cause if possible
- General Research Themes for Fish Program:
  - Sensitive and pivotal species as key **indicators** of ecosystem health
  - Linkages **within** ecosystems (e.g., food web/trophics)
  - Linkages **among** ecosystems (e.g., fish migrations)
  - Habitat use and critical or limiting aspects
  - Fish within various ecosystem types

Some Western Arctic Fish Studies

1. **Marine Fishes (Nahidik)**
   - A. Majewski, lead biologist
2. **Coastal Fishes**
   - J. Johnson, lead biologist
3. **Dolly Varden**
   - N. Mochnacz – field
   - R. Bajno – genetics
4. **Sensitive Freshwater Fishes**
   - N. Mochnacz – field
   - C. Sawatzky – lab
5. Sediment Risk/Benthos
   - L. Rempel - scientist

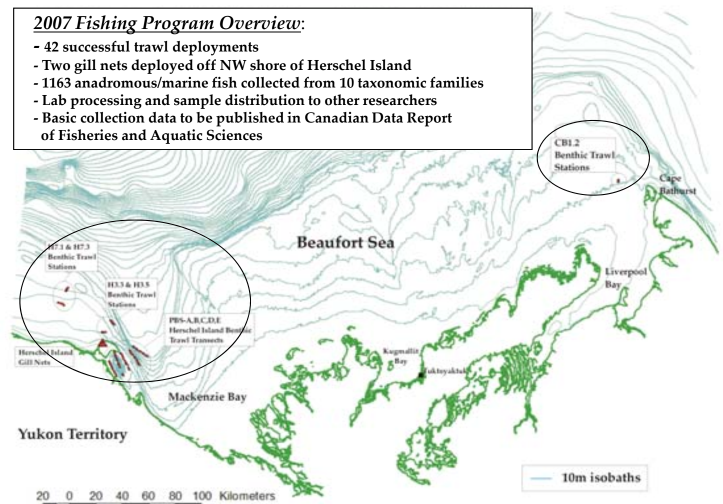
- **Role of Biodiversity**
  - Taxonomic, life history types, stocks, distribution
- **Habitat use, associations and limiting factors**
  - Predict potential effects of habitat change/impacts
- **Sensitivity/Response to Stressors**
  - Climate change, exploitation, development, contaminants
- **Present & Future Status**
  - Sensitive or ‘at risk’ species, ‘predict’ change ecosystem structure

1. Marine Fishing Program Objectives

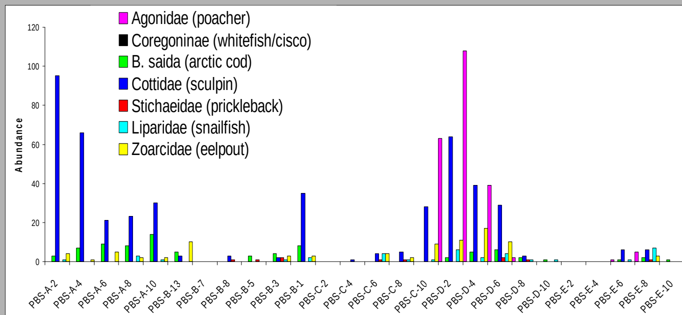


- **Role of Marine Fishes in Ecosystem:**
  - On/off-shore & <u>benthic</u>/pelagic fishes on Beaufort Shelf; Trophic structure; Biology of Pivotal species
- **Diversity and distribution:**
  - Relative abundance; Co-occurrence in ecological groups; New potential colonizers
- **Habitat Associations:**
  - Key areas/processes; Predictive models of occurrence & regulatory needs

<u>2007 Fishing Program Overview</u>:
- 42 successful trawl deployments
- Two gill nets deployed off NW shore of Herschel Island
- 1163 anadromous/marine fish collected from 10 taxonomic families
- Lab processing and sample distribution to other researchers
- Basic collection data to be published in Canadian Data Report of Fisheries and Aquatic Sciences



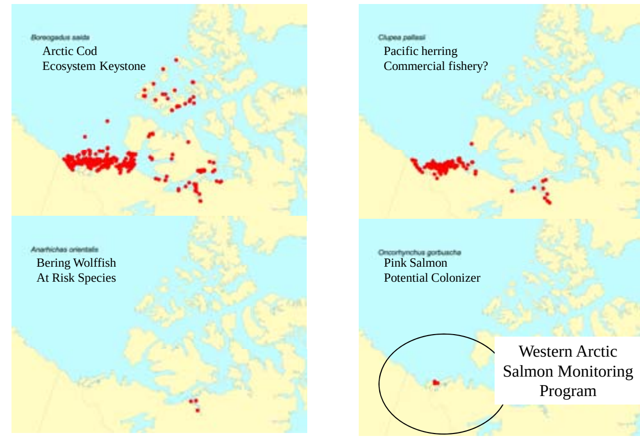
RESULTS 2007 (Ptarmigan Bay)



10 m isobath | 50-70 m within bay | 10-20 m Sill | 50 m Off Sill | 70-100 m Offshore

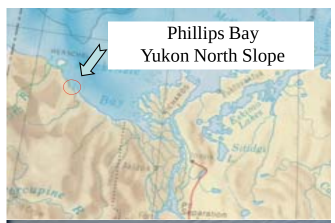
Family (and species) Composition and Relative Abundance Shifts

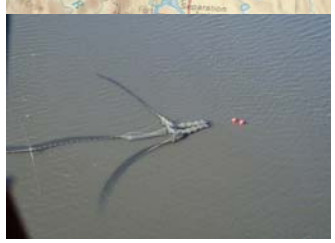
Fish Distribution Mapping
Updating Occurrences and Entry of New Species



2. Coastal Fishes and Trophic Structuring

- Nearshore fishes – migrations, habitat use, ecosystem structure.
- Repeat study from 1980's - long-term change.
- Field sampling by trapnets in 2007 and 2008.
- Primary objectives:
  - Baseline fish data for nearshore ecosystem
  - Assess changes to fish community over 20 years
  - Investigate nearshore trophic (foodweb) structure and function by stable isotope analysis





Coastal Study - Selected Catch Composition for 2007, 2008 compared to 1986

	Totals (2007/2008)	Total 1986 catch	% of 2007 catch	% of 2008 catch	% of 1986 catch
Totals (all species)	45351 / 56025	142797			
Anadromous Species					
Arctic cisco	9537 / 12755	52988	21.0	22.8	37.1
Least cisco	6846 / 5729	20482	15.1	10.2	14.3
Marine Species					
Arctic flounder	15314 / 16510	44974	33.8	29.5	31.5
Saffron cod	1904 / 5358	2473	4.2	9.6	1.7
Starry flounder	492 / 345	0	1.1	0.6	0.0
Pacific herring	381 / 229	7	0.8	0.4	<0.1
Pacific salmon	0 / 18	0	0.0	<0.1	0.0

Relative abundance: fewer sea-run fishes but more marine; salmon present (climate shift??), but…could simply be high variability

3. Dolly Varden - an 'at risk' North Slope Anadromous Fish

- ~6 populations in Canada, ~10 in Alaska
- Coastal migrants, feed in near- and offshore, and are trans-boundary
- Three life history types:
  - Sea-run, males & females
  - Residual, males only
  - Isolated, stream resident
- Multiple stocks, mixed at sea
- Some local populations declining
- Local habitat change & past harvesting likely proximal causes for declines
- Climate change & 'evolution' are likely pervasive causes for declines
- Habitat might be the key, especially over-wintering holes at spring inflows

Dolly Varden Research Program

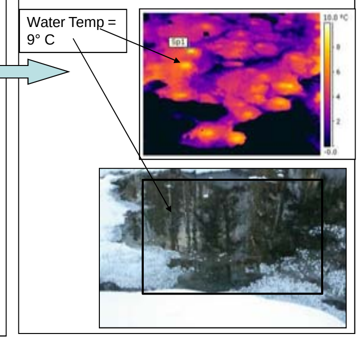
Research Activities

- Life history
- Genetics (stock structure)
- Monitor an index population
- **Habitat research**

Management Actions

- Limit fishing (voluntary closures)
- Protect habitat
- Formally assess status as species at risk (underway)

Does habitat limit over-winter survival? Infra-red winter surveys of pools for 2009.



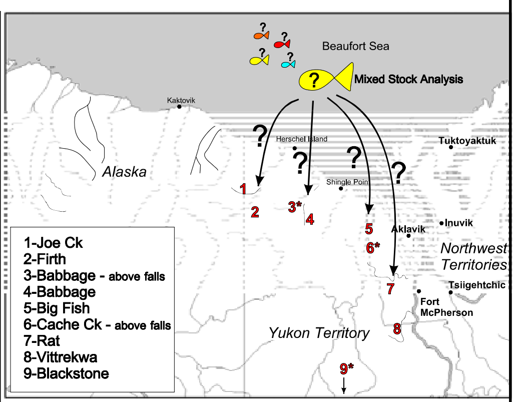
Dolly Varden Population Genetics

Baseline Genetic Results

• Stocks are Structured by river: allozymes, mtDNA, otolith microchemistry, morphology & microsatellite DNA

Next Steps

• Composition of mixed coastal groups
• Temporal trends in effective population size
• Fish movements between Alaska and Canada
• Genetic basis to life history type
• Genetic monitoring of an index population



4. Sensitive Fishes and Habitats – Mackenzie River

Objectives:

- Synthesize existing information on habitat use and distribution
- Research habitat use by sensitive species
- Research distribution & taxonomy of chars
- Advice to habitat managers (e.g., pipeline crossings)

- ~35 sp. of freshwater fishes (includes sea-run)
- ~12 sp. are 'sensitive'
  - Populations small & fragmented
  - Restricted habitat needs
  - Multiple stressors
  - Poor recovery potential
- Trophic patterns, colonizing species & ecosystem shifts are ongoing themes

Sensitive Fish – Information Synthesis

- Fish Taxonomy and Distributions updated → 2007. Distributions of freshwater and anadromous fishes from the mainland Northwest Territories, Canada. Can. Manuscr. Rep. Fish. Aquat. Sci. 2793: xiv + 239p.
- Fish Life History and Habitat Use synthesized (4 completed, 8 underway) → 2007. Fish life history and habitat use in the Northwest Territories: Arctic grayling (*Thymallus arcticus*). Can. Manuscr. Rep. Fish. Aquat. Sci. 2797: vi + 55p.
- Fish Diet information synthesized (4 completed, 8 underway) → 2007. Fish diets and food webs in the Northwest Territories: round whitefish (*Prosopium cylindraceum*). Can. Manuscr. Rep. Fish. Aquat. Sci. 2794:vi+21p.
- Char Taxonomy → 2008 in prep. Confirmation of sympatric bull trout, and Dolly Varden in the Mackenzie River Valley, Northwest Territories, with notes on distribution and biology. Arctic

DFO Reports at http://inter01.dfo-mpo.gc.ca/waves2/index.html (search reist)

Sensitive Fish Habitat Research – Mackenzie River

Objectives

1. Identify key habitats important for each life stage (i.e., eggs, juveniles, adults).
2. Habitat availability vs use for life stages - which habitats are limiting (e.g., fish holes or overwintering sites with groundwater seeps).
3. Understand habitat use for each species and life history type.
4. Develop a monitoring program for critical habitats and key species.

Sensitive Fish Species Field Component Products

- Primary Research
  - Biology of key species
  - Habitat use by key species
  - Ecosystem Function
- Advice on Habitat, Species and Ecosystems
- Advice on Effects of Stressors
  - Fisheries
  - Climate Change
  - Habitat Change
  - Industry & Development
  - Contaminants
- Data, reports, publications

Sample Preliminary Reports

- 2007. Biological and habitat data for fish collected during stream surveys in the Sahtu Settlement Region, Northwest Territories, 2006. Can. Data Rep. Fish. Aquat. Sci. 1189: vii + 40 p.
- 2008 in press. Biological and Habitat Data for Fish Collected During Stream Surveys in the Southern and Central Northwest Territories, 2007. Can. Data Rep. Fish. Aquat. Sci. ****
- DFO Reports at http://inter01.dfo-mpo.gc.ca/waves2/index.html (search reist)

Primaries on the way….

Thanks!

5.5.8 Northern Marine Coastal and Ecosystem Studies on the CCGS Nahidik in the Canadian Beaufort Sea, *Patricia Ramlal*

Ph.D., Research Scientist, Fisheries & Oceans Canada. Email: Patricia.Ramlal@dfo-mpo.gc.ca

The Canadian Beaufort Sea Shelf, strongly influenced by the Mackenzie River discharge, provides habitat for resident and migratory fish and marine mammal populations. The need to understand the basic ecology and food web structure of the Beaufort Sea Shelf is imperative as changes in the environment occur from various factors including: climate change, increased oil and gas exploration and increased marine traffic. These types of changes will have direct effects on the Beaufort Sea, as will changes that occur in the watershed of the Mackenzie River. For example, changes in the degree of permafrost, increased run-off and greater use of the river may lead to an increased sediment load from the river to the Beaufort. This will have immediate effects on primary production as the light and nutrient regimes change, and affect benthic organisms as their habitat is altered. These changes will ultimately lead to changes in the higher trophic levels of this aquatic food web. As a result of the Beaufort Sea Habitat Mapping Workshop held in Winnipeg in 2002 the need for more environmental information about this region of the Beaufort Sea was identified.

We have established a multidisciplinary program on the CCGS *Nahidik* to increase our baseline understanding of a number of parameters. The work on the *Nahidik* is divided into 3 main research areas: Leg 1 is focused on the physical, chemical and biological parameters; Leg 2 deals with the study of the geotechnical properties of the sediment; and Leg 3 mainly involves the benthic habitat mapping program. This presentation will provide and overview of the current studies done on the Leg 1 portion of the field season. These studies include the influence of the Mackenzie River plume, sites of upwelling, surface water gas exchange (carbon dioxide, methane and oxygen), distribution and biomass of phytoplankton, zooplankton, meiofauna, larval fish, as well as fish in the higher trophic levels. Ultimately this study will contribute to a better understanding of the relative importance of the Beaufort Shelf productivity to the larger Beaufort Sea Ecosystem. This information will serve as the basis for filling information gaps regarding the structure of the lower food web in the coastal regions of the Canadian Beaufort Sea.

Funding for this research has been provided by Fisheries and Oceans Canada, the Program for Energy Research and Development, and the Fisheries Joint Management Committee.

Northern Marine Coastal and Ecosystem Studies on the CCGS *Nahidik* in the Canadian Beaufort Sea


Photo: A. Majewski


Photo: C. Munroe

Patricia Ramlal
Fisheries & Oceans Canada
Freshwater Institute, Winnipeg

Why the program was established

- Beaufort Sea Habitat Mapping Workshop (2002)
  - Identified areas of interest to the government, industry and communities in the coastal regions of the Beaufort
- Each field season is separated into 3 Legs:
  - Leg 1 "Biological Leg"
  - Leg 2 Sediment Geotechnical Properties
  - Leg 3 Geohazards and Seabed Mapping


Photo: C. Munroe

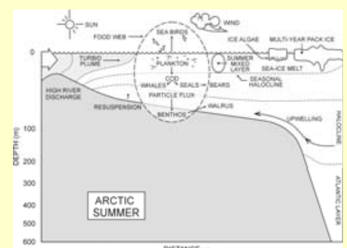
Program Goals

- Understanding of Ecosystem: species, areas, processes
- Identify critical/sensitive habitats which may require special planning to avoid harm
- Support to other Beaufort Sea programs (whales, seals)
- Development of future monitoring programs
- Ongoing for the next 5-10 years


Photo: C. Munroe

Overview of the work that we do on Leg 1

- Oceanography
- Adult Fish
- Larval fish and Zooplankton
- Benthos (organisms living in or on substrate)
- Acoustics and seabed classification
- Carbon and lower trophic structure
- Integrates with Legs 2&3 NRCan



Nahidik Ecosystem Studies

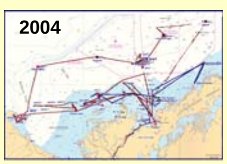
Multi-agency

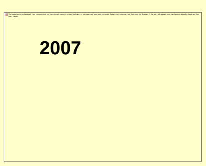
- Indian and Northern Affairs Canada, Natural Resources Canada, Fisheries & Oceans Canada (Northern Oil and Gas Science Research Initiative)
- Fisheries Joint Management Committee (ISR)
- Program for Energy Research and Development
- Canadian Museum of Nature
- Polish Institute of Oceanology – Interchange Canada
- University of Manitoba
- University of Saskatchewan

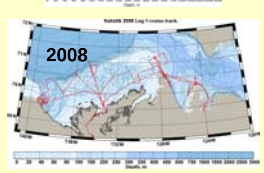
The CCGS *Nahidik*

- 2 m draft; 53.4 m length, cruising speed of 12 kts
- 15 Science crew
- Approx July 20-August 20
- Cruise Plan adapted for conditions (ice, wind)

Cruise Tracks: 2004-2008







Physical Oceanography

- Circulation on the Canadian Beaufort Shelf
- Mackenzie River Plume
  - extent, variability
  - dispersal and mixing
  - fate of freshwater
- Upwelling of nutrient rich water to the shelf
- Help build more robust ecosystem models

Fisheries and Oceans Canada Pêches et Océans Canada

Adult Fish Program

- Contribute to basic biological/ecological information of offshore and nearshore Arctic fish populations
- Information on species composition and distribution and use of physical features as fish habitat
- Provide samples for follow-on analysis:
  - Stable isotope analysis (food web dynamics)
  - Contaminant (e.g. Hg) and fatty acid analyses
  - Genetics research on stock structure of marine and anadromous fish species (e.g. Arctic cod, Dolly Varden and eelpouts)

Canada

Fisheries and Oceans Canada Pêches et Océans Canada

Zooplankton and Marine Larval Fish in the Canadian Beaufort Sea Shelf

- Assessment of the ichthyoplankton (larval fish) and zooplankton distribution
- Special interests in:
  - plume front work
  - bowhead whale feeding areas
  - Identification of "hotspots" for larval fish

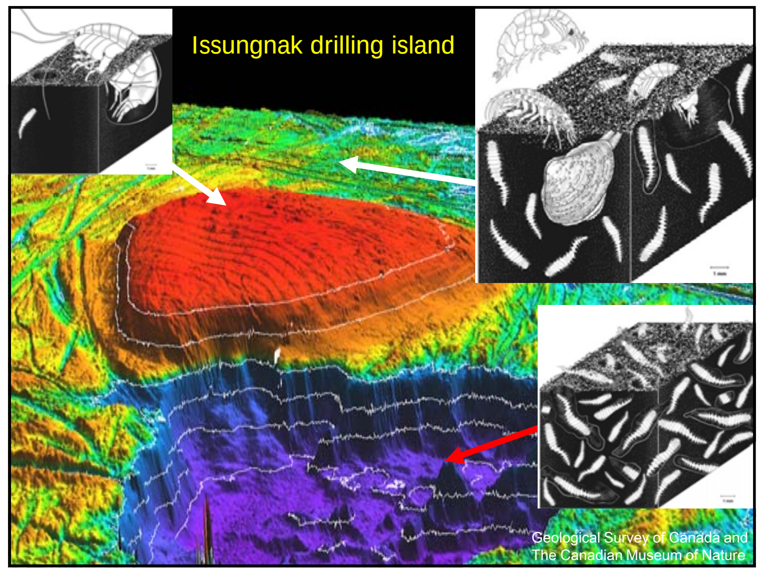
Canada

Fisheries and Oceans Canada Pêches et Océans Canada

Benthic Program (Part 1)

- Features based studies
  - Gas vents
  - Artificial islands
  - Ice scours
- Distribution and abundance
- Kathy Conlan, Alec Aitken, Ed Hendrycks, Christine McClelland, Megan Foss, Quinn Eggertson

Canada

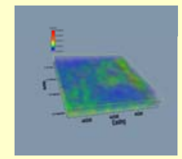


Benthic Program (Parts 2&3)

- Sediment Physics: Kevin MacKillop
  - Structural properties
- Epibenthos (video): Vladimir Kostylev, Lise Chapman, Megan Foss
  - Macro-invertebrate abundance and distribution over large areas

Acoustics Program

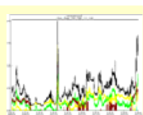
- QTC-V Seabed Classification
- 3D Rendering
  - Interpolation of acoustic grid data into 3-D density information.
  - Used to derive phytoplankton, zooplankton and fish abundance.
  - Allows samples to be compared to acoustic distribution



Carbon flux and lower trophic structure

Goals:

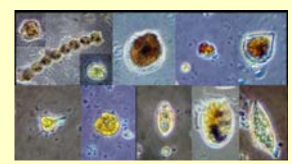
- Develop a model of the structure and function of the lower food web of the Beaufort Sea Shelf and establish the linkages of those food resources to fish and marine mammals.
- Develop rapid assessment techniques to monitor changes in biota of the lower food web

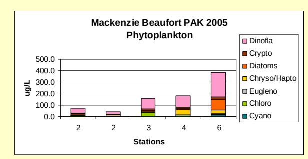


Carbon flux and lower trophic structure

The components of the food web in the water:

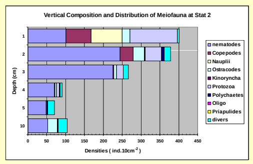
- Particulate matter (non-living)
- Bacteria
- Algae (10µ net)
- Zooplankton (153µ net)
- Ichthyoplankton and others (500µ net)





Carbon flux and lower trophic structure

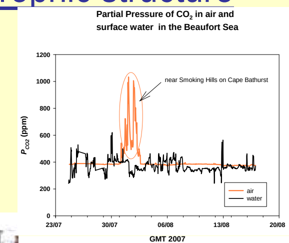
The components of the food web in the sediment:
•Particulate matter (non-living)
•Bacteria
•Algae (10µm)
• Meiofauna (40 to 1000µm)



Fisheries and Oceans Canada Pêches et Océans Canada

Carbon flux and lower trophic structure

- Gas exchange at the air-water interface
  - Climate change
  - Gas fluxes (a source or sink of carbon dioxide)
  - Primary production
- Water chemistry of particulate and dissolved nutrients



Canada

Fisheries and Oceans Canada Pêches et Océans Canada

Carbon flux and lower trophic structure

Modeling will incorporate results from:

- Stable isotope measurements
- Taxonomic distribution
- Biomass estimates
- Fatty Acid Analyses (new for 2008)
- Chemistry
- Sediment structure
- Other studies

Canada

Fisheries and Oceans Canada Pêches et Océans Canada

Community Outreach

- Yearly consultations with the communities on the Canadian Beaufort Sea regarding ongoing research programs
- FJMC students
- Open house tours of the CCGS *Nahidik*

Canada

Future Directions

- Continued emphasis of research on the Beaufort Shelf and at the Shelf break
- Acquire ship time on larger vessel for deep water research
- Acquire dedicated fish trawler for broader coverage
- Exploring research interests with industry, government, academia and international partners (including the USA) in the Canadian Beaufort Sea
- Anticipate an increase in active research with new leases in the offshore regions as well as continuing MGP-related research

Other *Nahidik* Talks and Posters

- Yukon North Slope/Mackenzie Delta Fish Studies
  Jim Reist, Fisheries and Oceans Canada
- Benthic Studies associated with the Northern Coastal Marine Program
  Kathy Conlan,Canadian Museum of Nature
- Initial Ichthyoplankton Analysis of the Mackenzie Plume Front
  Sally Wong, Michael Papst, Wojciech Walkusz, and Joclyn Paulic, Fisheries and Oceans Canada
- Hotspot and Biogeographic Analysis of Marine Larval Fish in the Nearshore Canadian Beaufort Sea
  Joclyn Paulic, Fisheries and Oceans Canada
- Oceanographic Studies associated with the Northern Coastal Marine Program
  Bill Williams, Fisheries and Oceans Canada

Thank you.

5.5.9 Timing and location of king eiders staging in the Beaufort and Chukchi Seas

Abby N. Powell & Steffen Oppel

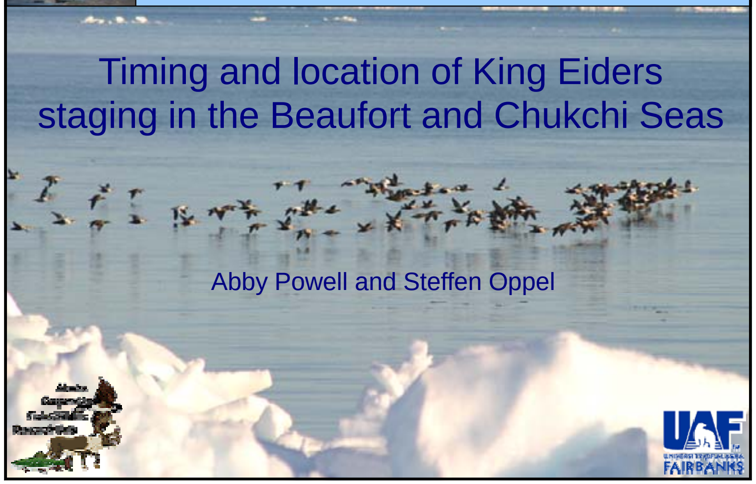
[1] Ph.D., Assistant Unit Leader, Alaska Cooperative Fisheries and Wildlife Research Unit, University of Alaska, Fairbanks, AK. Email: ffanp@uaf.edu

[2] Ph. D. candidate, Department of Biology and Wildlife, University of Alaska, Fairbanks

King eiders (*Somateria spectabilis*) use the Eastern Chukchi and Beaufort Seas as staging areas on their migration between breeding areas in Siberia and western North America and wintering areas in the Bering Sea. Little is known about the timing of migration, spatial extent of staging areas, or proportion of the population using these areas. We present data on king eider staging collected through satellite tracking of adult and juvenile eiders captured on breeding grounds on Alaska's North Slope from 2002-2007. In late summer, over 75% of satellite-tracked king eiders migrating south from breeding areas used the Beaufort and Eastern Chukchi Seas between mid June and mid November. On spring migration, king eiders used the same areas in the Beaufort and Eastern Chukchi Seas between mid-April and early June. The timing and distribution of use in both areas differed by sex, breeding status, and age. All birds migrating to breeding grounds in western North America, and 6 of 11 males migrating to breeding grounds in Siberia used the Eastern Chukchi Sea on spring migration, demonstrating that this is a crucial staging area for the entire western North American and the majority of the Siberian king eider population. Ledyard, Smith, and Harrison Bays were all important staging areas for king eiders for an extended portion of the annual cycle, from mid-April through early November. Use of these areas by North American and Siberian breeding king eiders need to be considered when evaluating the potential impacts of offshore oil and gas exploration.

Timing and location of King Eiders staging in the Beaufort and Chukchi Seas

Abby Powell and Steffen Oppel



Arctic Oil

USGS Press Release
(7/23/2008)

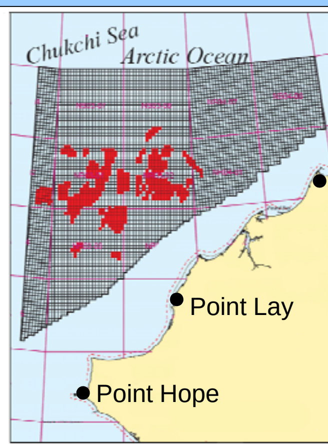
Arctic Alaska
- 29,960 MMBO
- 221,397 BCFG

84% offshore

Chukchi Sea

Estimated Oil Resources:
1-14 billion barrels

Insufficient data from most bird species

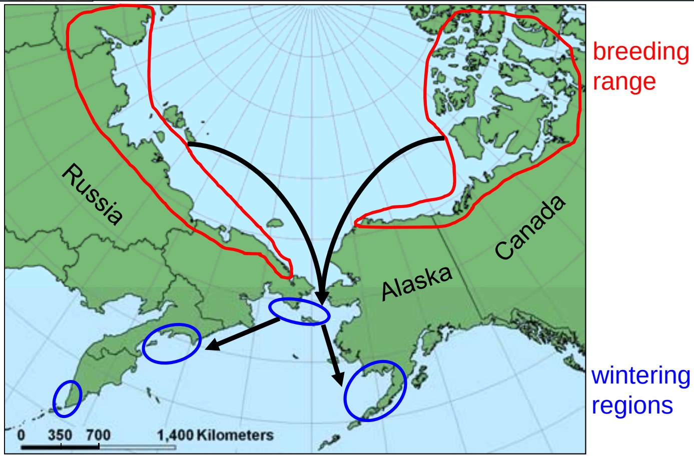


Source: www.mms.gov/alaska

Background

- King Eiders are large sea ducks
- spend >10 months per year at sea
- forage on benthic prey by diving to sea floor

Background

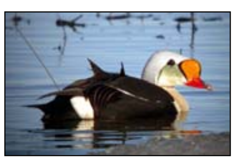


Questions

- When are King Eiders in the Eastern Chukchi and Beaufort Seas?
- What proportion of the population stages in the Eastern Chukchi Sea?
- Where do individuals occur and concentrate?

Methods

- 144 birds caught in 2002-2007 in AK
- birds fitted with satellite transmitter
- calculated arrival and departure dates
- used 20 June for cutoff date for Beaufort Sea



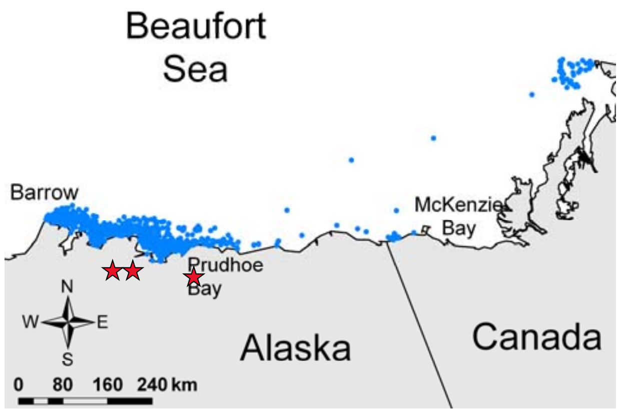
Results: southward migration

Beaufort Sea

•mid June through mid October

- staging times different between age/sex classes:
  - adult females averaged 28 days (range: 1 - 107)
  - adult males averaged 20 days (range: 1 - 46)
  - juveniles averaged 19 days (range: 3 - 33)
- 100% of tracked birds used Beaufort Sea

Results: southward migration



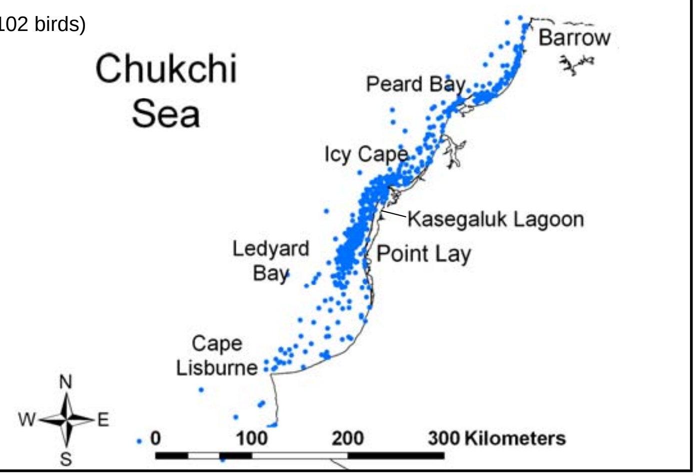
Results: southward migration

Eastern Chukchi Sea

- mid June through early November
- staging times different between age/sex classes:
  - adult females averaged 7 days (range: 2 - 66)
  - adult males averaged 16 days (range: 2 - 32)
  - juveniles averaged 19 days (range: 2 - 56)
- 74% of tracked birds use Eastern Chukchi Sea

Results: southward migration

(*n* = 102 birds)



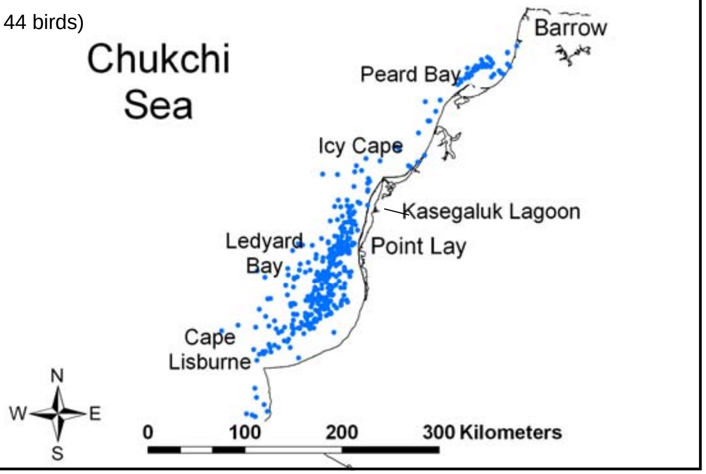
Results: spring migration

Eastern Chukchi Sea

- spring staging mid-April – early June
- mean staging time 23 days (range: 3 - 45 days)
- 100% of North American breeders use the area
- 55% of Siberian breeders use the area (*n* = 11)

Results: spring migration

(*n* = 44 birds)

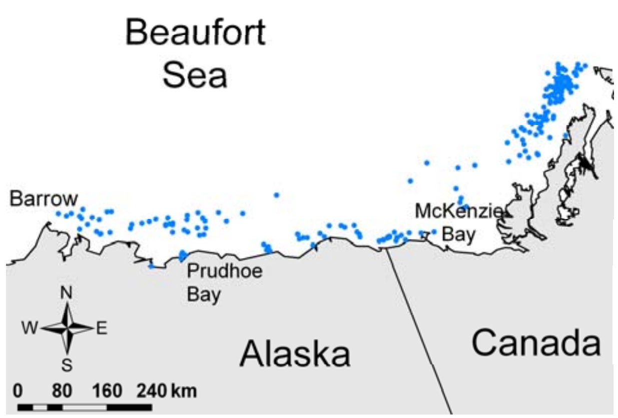


Results: spring migration

Beaufort Sea

- spring staging begins in late-April
- mean staging time differed between sexes:
  - females averaged 13 days (range: 4 - 23)
  - males averaged 23 days (range: 4 - 51)

Results: spring migration



Conclusions

- Eastern Chukchi and Beaufort Seas are crucial staging areas
- Beaufort Sea is used from late April through mid October
- Eastern Chukchi Sea is used mid April through early November

- Largest concentrations within 50 km of coast
- American and Russian birds use Eastern Chukchi Sea

Future directions

- How many sea ducks use the Chukchi and Beaufort Seas?
- What do sea ducks forage on in the Chukchi and Beaufort Seas?
- How will prey be affected by climate change?

Acknowledgments

US Fish and Wildlife Service
Minerals Management Service
Sea Duck Joint Venture
Coastal Marine Institute
North Slope Borough
ConocoPhillips, Alaska, Inc.
US Geological Survey
ABR, Inc.
Service Argos, Inc.
Microwave Telemetry, Inc.
German Academic Exchange Service (DAAD)
Troy Ecological Research Associates, Inc.
Alaska Cooperative Fish and Wildlife Research Unit

Rebecca Bentzen
Laura Phillips
Cheryl Scott
Chris Latty
Robert Suydam
Eric Taylor

…and a very large number of field assistants…

Questions?

http://mercury.bio.uaf.edu/kingeider

pictures © Kim Hanisch, Ray Fellner, and Keith Brady

5.5.10 Subsistence Mapping of Nuiqsut, Kaktovik, and Barrow

Stephen R. Braund

M.A., Anthropology, Principal Investigator; Stephen R. Braund & Associates, Anchorage, Alaska. Email: srba@alaska.net

The purpose of this project is to develop and collect data for a GIS (Geographic Information System) capable of describing contemporary subsistence use patterns in Barrow, Kaktovik, and Nuiqsut and capable of measuring changes in these patterns over time. In 2004, Stephen R. Braund & Associates (SRB&A), in association with the North Slope Borough Department of Wildlife and under contract to Minerals Management Service, initiated a subsistence mapping study in Nuiqsut, Kaktovik, and Barrow. SRB&A interviewed 146 harvesters, systematically selected as active and knowledgeable harvesters, in Nuiqsut (33 harvesters), Kaktovik (38 harvesters), and Barrow (75 harvesters) to gather data relevant to subsistence uses of key species among the three communities. SRB&A gathered subsistence use data for multiple resources including caribou, moose, bowhead whale, Arctic cisco, Arctic char, broad whitefish, burbot, geese, eider, ringed seal, bearded seal, walrus, wolf, and wolverine. Geographic features collected during the interviews included subsistence use areas, most recent harvest locations, hunting camp and cabin locations, and travel routes. Associated information such as months of use, travel method, harvest gear, number of participants, and duration of effort were also gathered and provide additional context to the geographic features collected. The study team incorporated the data collected into a GIS system designed by the team to permit measurement of changes in subsistence patterns over time. The GIS system is being used to develop maps and tables to be included in the final report. The final report provides the results of the 146 subsistence mapping interviews in the three study communities and illustrates how the data collected may be used to measure changes in subsistence patterns over time.

Subsistence Mapping Study for Nuiqsut, Kaktovik, and Barrow

Stephen R. Braund & Associates
North Slope Borough Dept of Wildlife Management
Jack Kruse
Jeffrey Johnson, East Carolina University
Encompass Data & Mapping

Presented at the U.S. and Canada Northern Research Forum
30 October 2008
Project Funded by Minerals Management Service

Purpose of the Subsistence Mapping Study

- Provide current subsistence uses and use area information for Barrow, Nuiqsut, and Kaktovik
- Inform assessment of potential changes to subsistence uses resulting from potential effects of OCS development
- Support the National Environmental Policy Act (NEPA) process

Purpose of the Subsistence Mapping Study

- Focus on key species identified by MMS
- Coordinate with North Slope community organizations to conduct fieldwork in Barrow, Kaktovik, and Nuiqsut
- Develop a GIS that can be used to describe contemporary subsistence use patterns in Barrow, Kaktovik, and Nuiqsut and that will support analyses of changes in subsistence use patterns over time

Objectives of SRB&A Subsistence Mapping Study

- Identify and interview informants who are knowledgeable about the hunting of the selected species (“experts”) using social network methods
- Use the GIS to describe current subsistence use patterns in the three study communities

SRB&A Subsistence Mapping Interviews

	Number of Households (2000)	Population (2000)	Number of Persons Identified for Interviews	Number of People Interviewed	Number of Interview Workshops	Number of Interview Trips to Community
Barrow	1,371	4,851	222	75	69	5
Kaktovik	89	293	90	38	36	3
Nuiqsut	110	433	62	33	40*	4

*Some individuals participated in interviews for a second time after the final field protocol had been developed

SRB&A Subsistence Mapping Study Key Species

- Caribou
- Moose *
- Bowhead whale
- Arctic cisco
- Arctic char
- Broad whitefish
- Burbot *
- Geese
- Eider
- Ringed seal
- Bearded seal *
- Walrus *
- Wolf/Wolverine *

* SRB&A Added to SOW

SRB&A Subsistence Interviews

- Subsistence Use Areas – last 12 months
  - Most Recent Harvest Location
    - » Number of Participants
    - » Duration of hunt (time away from community)

SRB&A Subsistence Interviews

- Subsistence Use Areas – last 10 years (SRB&A added)
  - Month Used
  - Travel Method

SRB&A Subsistence Interviews

- Camps and Cabins
- Travel Routes
- Harvest Gear

Measuring Change in Subsistence Patterns

- SRB&A illustrates how changes in subsistence patterns could be measured over time
- Compares recent (last 10 year and last 12 month) use area data with use area and harvest site data collected prior to 1990

Measuring Change in Subsistence Patterns Subsistence Use Areas

- Compares previous harvest site and use area data (1987-1989) to last 12 month use areas collected from 2004 to 2006 (Barrow only)
- Compares lifetime use area data to last 10 year (3 communities) and 1987-1989 use areas (Barrow only)

Future Research & Development Directions

- Development and periodic updating of subsistence GIS information will inform the assessment of changes in subsistence uses over time
- Given North Slope Iñupiat concerns related to oil and gas development, especially offshore development, future research should include continued documentation of subsistence uses, including use areas, and assessment of changes

Synergies for Research

- Develop communication between indigenous groups and scientists from Canada and the US regarding resource biology and changes in resource health and availability, including the sources of these changes
- Address problems subsistence users experience in US vs Canada related to oil and gas exploration and development
  - What solutions are being explored or implemented?

Synergies for Research - *Qaaktaq*

- Arctic cisco (*qaaktaq*) are an important subsistence resource in Nuiqsut
- *Qaaktaq* spawn in tributaries of the Mackenzie River and juveniles return to the Colville River for 5-8 years where Nuiqsut fishers harvest them
- The *qaaktaq* return to the Mackenzie River to spawn
- The status and condition of the Arctic cisco spawning population is unknown to Alaskans
  - Are there sufficient number of spawners in the Mackenzie River to produce “enough” juveniles for Nuiqsut fishers?

5.5.11 Effects of Oil Field Infrastructure on Calf Growth and Survival in the Central Arctic Caribou Herd

Stephen M. Arthur

Ph.D., Research Biologist, Alaska Department of Fish and Game, Fairbanks, AK

Email: steve.arthur@alaska.gov

Previous studies of the Central Arctic caribou herd (CAH) suggested that intensive industrial development associated with petroleum production in the Prudhoe Bay region of northern Alaska caused a shift in the area used for calving by some of the herd, and that quality of calving habitat was reduced as a result of this change. However, population-level effects of the change in distribution have not been demonstrated, and the herd grew substantially during the period when development occurred. This study was designed to examine physiological mechanisms by which industrial disturbance might affect caribou population dynamics, so as to detect effects that might be masked by the intrinsic variability of caribou populations and low precision of population estimates. We captured and radiocollared caribou calves at birth, then again at three and nine months of age to compare rates of growth and survival between calves from two distinct calving areas used by the CAH during 2001 to 2006. The eastern calving area was relatively undisturbed, while the western area had been subject to extensive oil field development. During all years, calves born in the eastern area were larger and heavier at birth, gained more mass during summer, and were heavier during September (ANOVA, all $P < 0.05$) in comparison to calves born in the western area. Annual survival rates varied among years and were not statistically different between calves from the two areas. However, consistent with other studies of northern ungulates, calves that were heavier in September were more likely to survive the following winter (logistic regression, $P < 0.01$). This suggests that displacement from preferred calving ranges to areas with poorer-quality habitat has the potential to reduce calf recruitment by reducing calf condition at birth and summer growth rates. For the CAH, the effects of displacement were likely mediated by the availability of alternative calving areas. These effects would likely be greater in areas where calving habitat is limited and during periods of reduced adult survival and fecundity. Additional research is needed to identify specific attributes of calving areas that may promote calf growth and survival. Studies that quantify the effects of disturbance on specific biological parameters that can be measured with precision and that are likely to have demographic effects are more useful and less subject to differences in interpretation than are general assessments of caribou distribution and population trends.

This study was supported by grants from ConocoPhillips, Alaska, Inc, the U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, National Park Service, and Federal Aid in Wildlife Restoration funds provided to the Alaska Department of Fish and Game.

Bowhead Whale Feeding Variability in the Western Beaufort Sea

Carin Ashjian

Woods Hole Oceanographic Institution

On-Going Project

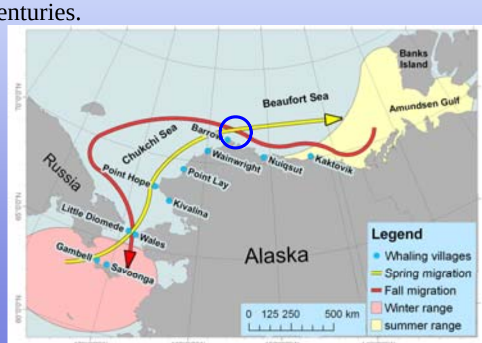
- 2005 & 2006: U.S. National Science Foundation
- 2007: WHOI Arctic Initiative, UAF Coastal Marine Institute, U.S. NOAA/National Marine Mammal Laboratory
- 2008 & 2009: NOAA/NMML, NOPP (National Oceanographic Partnership Program)

Many Collaborators

*Robert Campbell (URI)
*Steve Okkonen (UAF)
Sue Moore (NOAA)
Craig George (NSBDWM)
Ev Sherr (OSU)
Yvette Spitz (OSU)
Barry Sherr (OSU)
Wieslaw Maslowki (NPS)
Dave Rugh (NOAA)
Kim Goetz (NOAA)
Julie Mocklin (NOAA)

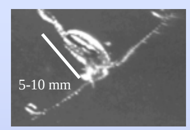
Bowhead Whale Migration

Bowhead whales are recurrently found feeding near Barrow, AK during their fall migration from the Canadian Arctic to the Bering Sea. Bowhead whales are hunted near Barrow by the Iñupiat and have been so for centuries.



Map Courtesy Lori Quakenbush

Bowhead Whale Prey



Copepods - Arctic and Pacific

Euphausiids/Krill - Pacific

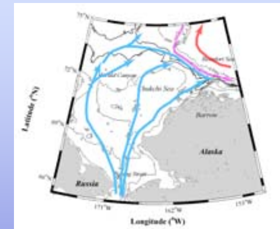
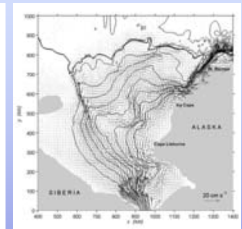
Bowhead Whale Stomach w/Krill

- Analysis of harvested bowhead whale stomach contents shows that the whales feed on both copepods (found in both the Arctic and Pacific) and on euphausiids or krill which are believed to be native to the Bering Sea (or Pacific) but are eaten by the whales harvested near Barrow
- We believe that krill cannot overwinter in the Arctic and hence must be reintroduced annually
- Because the prey is very small, and whales are very large, the whales need very dense concentrations of prey for feeding to be efficient and worthwhile

GOALS OF OUR RESEARCH

- Why do bowhead whales stop at Barrow during their fall migration?
  - Bowhead whales congregate at Barrow in fall because of dense zooplankton patches that form there
- What are the oceanographic conditions that make this a favorable feeding environment?
- Is this an important feeding area for the bowhead whale during their fall migration?
- How might these conditions be impacted by climate change?

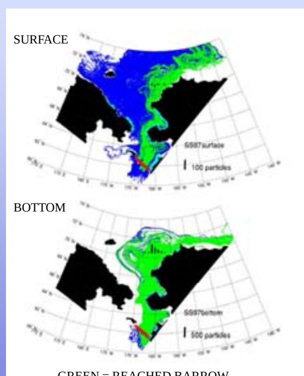
Where do krill near Barrow come from?

Winsor and Chapman (2004): No wind case.

- Currents bring water, and krill, from the Bering Sea through the Chukchi Sea to the shelf near Barrow
- Much of the water, with intrinsic plankton, particles, and chemicals, that crosses the Chukchi Sea is ultimately funneled past Barrow under most wind conditions.

Where do krill near Barrow come from?



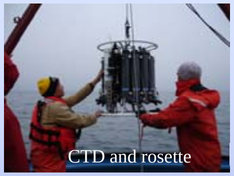
Berline, Spitz, et al. (2008) using Maslowski et al. (2004) model.

- Simulation using modeled circulation from 1997
- 24±22/5 % of the krill in the surface water reach Barrow
- 94.6±6.3% of the krill in the bottom water reach Barrow
- Krill entering the Chukchi Sea in spring can easily make to to Barrow by fall, coinciding with the arrival of the whales
- Note: Krill are adjacent to but not ON the shelf near Barrow

Field Sampling during 2005 - 2008

- Aerial surveys to document distributions of bowhead whales in late August - early September 2005 -2008
- Oceanographic sampling using the 43' *R/V Annika Marie* from mid-August to mid-September 2005-2008

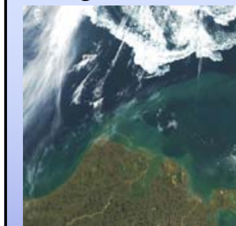
Oceanographic Measurements



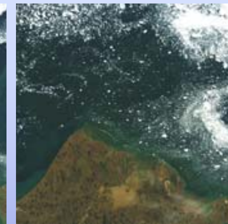
- ACROBAT - Temperature, salinity, pressure, optical backscatter, chlorophyll and CDOM fluorescence
- CTD and Rosette - Temperature, salinity, pressure, fluorescence, water for chlorophyll, nutrient, and microzooplankton determinations
- ADCP (not shown) - Velocity and acoustic backscatter
- Video Plankton Recorder (not shown)
- Plankton nets

Ice Cover

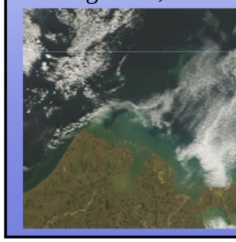
August 14, 2005



August 23, 2006



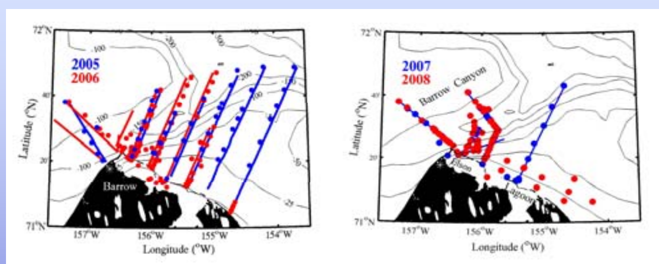
August 23, 2007



August 23, 2008

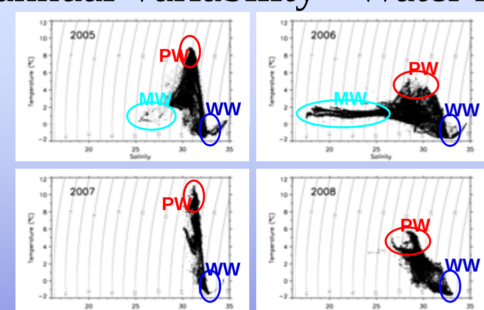
- Much more ice in 2006
- Ice was heavy in 2008 until early August; little ice during sampling
- 2007 least summer ice extent in Arctic, especially Western Arctic; 2008 second least summer ice extent

Oceanographic Sampling



- Underway sampling along solid lines; discrete stations at symbols
- Areal coverage limited in 2006 relative to 2005 and 2007 because of ice cover offshore and to the east
- Sampling in 2007 and 2008 was along lines identified as indicators or sentinels from 2005 and 2006 data. Repeated sampling possible.

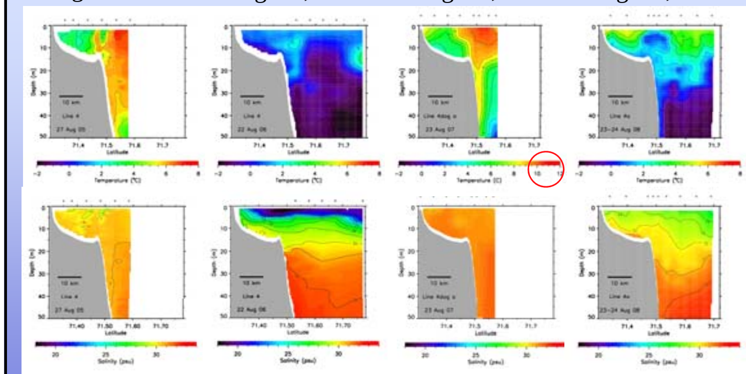
Interannual Variability - Water Masses



- Warm Pacific Water present in 2005 & 2007, much less in 2006 & 2008
- Very warm in 2005 and 2007 (maximum T observed was 11 °C)
- A lot of Melt Water in 2006, when ice was present
- Cold, salty Winter Water in all years, formed during the previous winter

Considerable Interannual Variability - Line 4

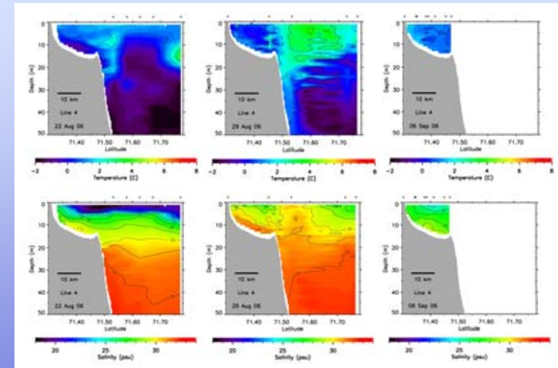
Aug. 27, 2005 Aug. 22, 2006 Aug. 23, 2007 Aug. 23, 2008



- Much colder with much more vertical structure (ice melt) in 2006 and to some extent in 2008
- Very warm and salty in 2007

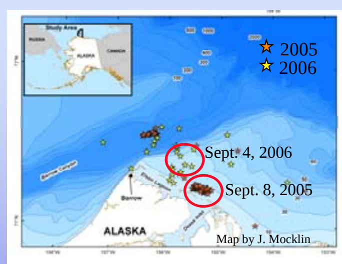
Considerable Short-Term Variability - Line 4

Aug. 22, 2006 Aug. 29, 2006 Sept. 6, 2006

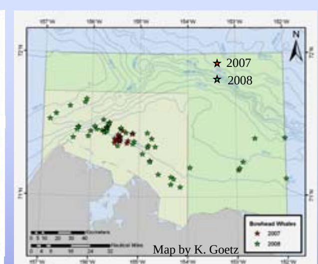


- Much colder, with very fresh upper 5 m due to ice melt, on Aug. 22
- Warmer, with less fresh water, 7 days later
- Cooler, and of intermediate salinity, on the shelf on Sept. 6
- Changes associated with presence of ice and with movement of water by the wind

Bowhead Whale Distributions from Aerial Surveys



Aerial surveys conducted by S. Moore, J. Mocklin, C. George, and C. Monnett



Aerial surveys conducted by D. Rugh, K. Goetz, and J. Mocklin

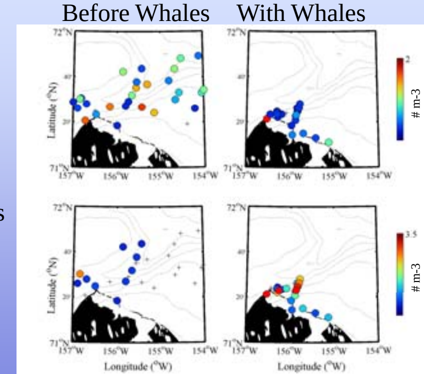
- Whales first observed in early September in both 2005 and 2006
- Whales were seen on Aug. 23 and 24 but not in September of 2007
- Whales were observed in late August and early September in 2008
- Most whales were seen on the shelf along the 15 m isobath, although some were seen near the barrier islands of Elson Lagoon
- The whales observed in 2005, 2006, and 2008 were feeding; the whales seen in 2007 were "passing through"

Distribution of Euphausiids (2005 & 2006)

Before Whales With Whales

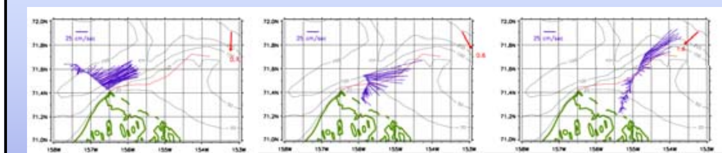
Furcilia

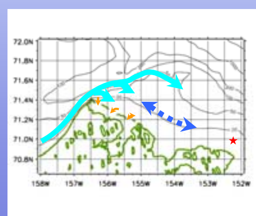
Juveniles and Adults



- Few juveniles and adults present before whales arrived
- Reduced abundances of furcilia when whales present
- Whales present at time when there were higher abundances of their preferred prey

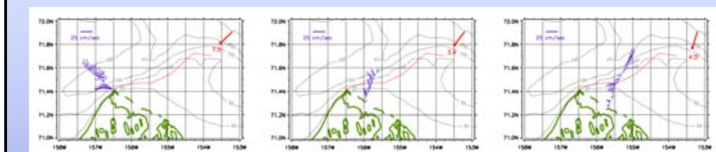
Influence of Wind: Weak (<3-4 m/sec) or from the S-W (not shown)

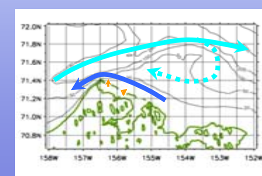




- Strong Alaska Coastal Current adjacent to shelf break in Canyon and Beaufort
- On shelf intrusions of ACC; warm water at shelf break and onto shelf
- Shelf Break Jet is strong and is a barrier to offshelf movement of water
- Weak Currents on Beaufort Shelf

Influence of Wind: Moderate-Strong from the NE





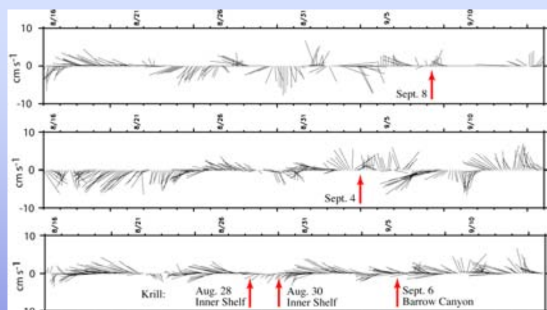
- Alaska Coastal Current is weakened and moves further away from the shelf break
- In turn, NW currents on the inner Beaufort Shelf extend off the shelfbreak and turn SW at Pt. Barrow
- Water on the Beaufort Shelf is exported to the Chukchi
- Winds from E promote upwelling along Beaufort Shelf

Winds at Barrow

2005

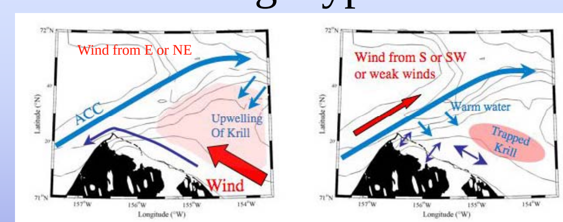
2006

2007



- The 2005 and 2006 observations of feeding bowheads near krill occurred following period of southwest wind
- This corresponds to when the ACC should be tight against the eastern edge of Barrow Canyon
- In 2007, krill were observed on the shelf during a period of low wind (strong ACC) or in Barrow Canyon during upwelling favorable winds

Working Hypothesis



- During periods of winds from the east, krill upwell along the Beaufort Shelf but are diffuse on the shelf
- Water escapes around Pt. Barrow to the SW
- During periods of wind from the S or SW or weak winds, the ACC is strong and close to the eastern side of Barrow Canyon, trapping water on the shelf and concentrating krill
- Water also upwells from Barrow Canyon
- Krill and water also enter Elson Lagoon

Preliminary Conclusions

- The presence of exploitable bowhead whale prey at Barrow is dependent on input of krill from the Bering Sea
- Oceanography and whale prey availability are profoundly impacted by the magnitude and direction of the wind
- Striking interannual and shorter-term variability in the physical (ice, ocean) and biological distributions
- The presence of ice significantly influenced hydrography
- Despite interannual and shorter term variability in ocean conditions, this region at present appears to be a predictable feeding area for the bowhead whales during their fall migration
- These four years of research have been conducted at a critical location in the Arctic during a period of unprecedented change; these data are the start to what should be longer term monitoring and understanding of the ocean at this location

Acknowledgements

•Phil Alatalo (WHOI) and Aaron Hartz (OSU) for field sampling and data analysis

•Bill Kopplin, Ned Manning, Mike Johnson, and Randy Pollock, the captains of the *R/V Annika Marie*, for their valuable inputs to our program

•Charles Monnett (MMS) for providing aircraft support and collaborating on the 2006 aerial survey

•The Barrow Whaling Captains Association, the Alaska Eskimo Whaling Commission, the North Slope Borough, and the community of Barrow for their support

•Glenn Sheehan and the Barrow Arctic Science Consortium Staff for logistic support in Barrow

•VECO/CH2MHill Polar Services for logistic support in Deadhorse / Prudhoe Bay

•Bill Streever, Wilson Cullers, and Tatyana Venegas at British Petroleum for assistance in accessing West Dock in Prudhoe Bay to load the *Annika Marie*

•The ARMADA Program at the University of Rhode Island for the participation of Jeff Manker and Kirk Beckendorf (high school teachers)

•Funded by the National Science Foundation, the University of Alaska Coastal Marine Institute, the Woods Hole Oceanographic Institution Arctic Initiative, and the NOAA National Marine Mammal Laboratory, and the National Oceanographic Partnership Program

5.5.12 Ichthyoplankton Analysis of the Mackenzie Plume Front

Sally Wong & Michael Papst

[1] B. Sc., Arctic Science Program Officer & Graduate Student for the Nahidik Program, Fisheries and Oceans Canada and University of Manitoba. Email: Sally.Wong@dfo-mpo.gc.ca

[2] Ph.D., Senior Oceans Ecosystem Advisor, Fisheries and Oceans Canada.

Email: Mike.Papst@dfo-mpo.gc.ca

Ichthyoplankton was sampled in the nearshore region of the southeastern Beaufort Sea during the open water season (July and August) to examine their association with the Mackenzie plume front. The Mackenzie River transports approximately 300 km^3 of freshwater annually to the Canadian Beaufort shelf. In the summer the plume waters can extend approximately 60,000 km^2 and can exceed 6 m in depth. The plume waters are warm, turbid and nutrient-rich creating an important driver for productivity for the Beaufort shelf. Using 500 µm Bongo nets, ichthyoplankton was collected at three different water masses: nearshore, plume front and offshore waters along five transects. Arctic cod (*Boreogadus saida*) and Pacific herring (*Clupea pallasii pallasii*) were the most abundant larval fish in the collection. Initial analysis revealed significant size differences among Arctic cod. A preliminary analysis suggests that the plume may play an important role in the ecology of marine larval fish on the Canadian Beaufort Shelf.

5.5.13 Landward and Eastward Shift of Alaskan Polar Bear Denning Associated with Recent Sea Ice Changesabstract

Anthony S. Fischbach, Steven A. Amstrup & David C. Douglas

U.S. Geological Survey, Alaska Science Center, Anchorage, AK. Email: afischbach@usgs.gov

Polar bears in the northern Alaska region den in coastal areas and on offshore drifting ice. We evaluated changes in the distribution of polar bear dens between 1985 and 2005, using satellite telemetry. We determined the distribution of maternal dens occupied by 89 satellite collared female polar bears between 137°W and 167°W longitude. The proportion of dens on pack ice declined from 62% in 1985-1994 to 37% in 1998-2004 (P=0.044) and among pack ice dens fewer occurred in the western Beaufort Sea after 1998. We evaluated whether hunting, attraction to bowhead whale remains, or changes in sea ice could explain changes in den distribution. We concluded that denning distribution changed in response to reductions in stable old ice, increases in unconsolidated ice, and lengthening of the melt season. In consort, these changes have likely reduced the availability and quality of pack ice denning habitat. Further declines in sea ice availability are predicted. Therefore we expect the proportion of bears denning in coastal areas will continue to increase, until such time as the autumn ice retreats far enough from shore that it precludes offshore pregnant females from reaching the Alaska coast in advance of denning. The oil and gas industry and State, Federal and local governments should be mindful of this change in denning distribution of polar bears because of the potential disturbance of maternal polar bear dens from increased human activities in coastal areas of the southern Beaufort Sea.

5.5.14 Measuring Bioavailable Hydrocarbons in the Nearshore Beaufort Sea: Comparison of Caged Mussels (Mytilus trossulus) and Semipermeable Membrane Devices (SPMDs),

John L. Hardin, Jerry M. Neff, Greg S. Durell & Frederick C. Newton III

[1] Battelle, 5205 Avenida Encinas, Suite J, Carlsbad CA Email :hardinj@battelle.org

[2] Neff & Associates LLC. 20 Templewood Drive, Duxbury, MA. Email: neffjm@comcast.net

[3] Battelle, 397 Washington St., Duxbury, MA. Email: durell@battelle.org

[4] Battelle, 5205 Avenida Encinas, Suite J, Carlsbad, CA Email: newtonf@battelle.org

Measuring dissolved, bioavailable contaminants in seawater is a challenging task in any environment, but is even more problematic in the Arctic. As part of the U.S. Minerals Management Service (MMS) Continuation of Arctic Nearshore Impact Monitoring in Development Area (cANIMIDA) multidisciplinary monitoring program, MMS undertook an investigation to compare bivalve (*Mytilus trossulus)* tissue uptake to passive non-biological Semi-Permeable Membrane Devices (SPMDs). The primary objectives of the comparisons were to determine which method best characterized bioavailable PAH assemblages in the nearshore Alaskan Beaufort Sea and to estimate relative contributions from offshore oil and gas development activities and other petrogenic (e.g., boat fuel) and pyrogenic (e.g., combustion PAH deposited from arctic aerosol into coastal peat) PAH sources.

Exposure systems were deployed at locations proximate to an active oil production site and several reference areas with varying levels of human activity. Method comparison studies were conducted in 2002 and 2004. Subsequent mussel only deployments were performed in 2005 and 2006. Both systems provided data useful in assessing environmental impacts of oil and gas development activities.

5.5.15 Bowhead Whale Feeding Aggregations in the Canadian Beaufort Sea (2007 – 2008), and Their Role in the Mitigation of Effects of Seismic Underwater Noise, *Lois Harwood, Amanda Joynt & Sue Moore*

[1] Dept. of Fisheries and Oceans, Arctic Aquatic Research Division, Yellowknife, NT
Email: lois.harwood@dfo-mpo.gc.ca

[2] Dept. of Fisheries and Oceans, Habitat Management Division, Inuvik, NT
Email: Amanda.joynt@dfo-mpo.gc.ca

[3] NOAA/ Alaska Fisheries Science Center, Seattle, WA USA Email: sue.moore@noaa.gov

A systematic strip-transect aerial survey of the SE Beaufort Sea was flown August 22 and 23, 2007 (7,166 km^2) and August 2 to 20, 2008 (4,703 km^2), to update our knowledge of the distribution and use of the Canadian Beaufort Sea by bowhead whales, and to contribute to an adaptive mitigation plan for seismic surveys underway at the time of, and following, the aerial surveys. A total of 24 north-south transect lines were flown, at approximately 10% survey coverage from the Alaska-Canada border east to the Bathurst Peninsula, and from the 5 m isobath seaward approximately 100 km and/or to beyond the shelf break. Survey conditions were good-excellent for spotting whales on all transect lines flown, although in 2008, there were unavoidable interruptions in survey progression due to weather. Low ceilings/fog prevented surveys along northern portions of the western transect lines in 2008. Primary observers recorded 132 bowhead whales on-transect in 2007 and 136 bowheads on-transect in 2008. This study was not designed to estimate the size of the stock, however it is instructive that the number of bowhead whales sighted on-transect in 2007 and 2008 was approximately twice that seen on similar surveys flown in the 1980's.

On-transect sightings made by primary observers were assigned to 20 x 20 km grid cells, and densities of surfaced bowheads were calculated for each grid cell with survey coverage (n=199 in 2007; n=148 in 2008). Our working definition of a bowhead whale feeding aggregation area (>5 surfaced bowheads/100 km^2 surveyed) indicated bowheads occurred in three main regions in the SE Beaufort Sea in each of August of 2007 and 2008. The proportion of the grid cells with survey coverage in which bowheads were aggregated was 15.1% in 2007 and 14.9% in 2008. In both years, bowheads aggregated offshore of the Tuktoyaktuk Peninsula in waters mainly 20 to 50 m deep. However the locations of other aggregation areas differed between 2007 and 2008. The 2007 aggregations occurred in near shore Yukon coastal waters between Komakuk Beach and Shingle Point and near the shelf-break north of the Mackenzie River estuary, while in 2008, bowheads were aggregated in the Mackenzie Canyon and Kugmallit Canyon. In both years, bowheads were known to aggregate in at least one area not covered by our survey flights (offshore NW Banks Island in 2007; offshore Cape Bathurst 2008). Survey results for the SE Beaufort Sea were used in both 2007 and 2008 in the development of a mitigation strategy for minimizing the effects of seismic surveys on feeding bowhead whales. The third and final year of the aerial survey is planned for August 2009.

Funding for the surveys was provided by the Polar Continental Shelf Project (PCSP), Panel on Energy Research and Development (PERD), Fisheries Joint Management Committee (FJMC), Imperial Oil Resources Ventures Ltd., ConocoPhillips Canada Resources Corp. and ION Geophysical Inc.

5.5.16 Concept Study: Exploration and Production in Environmentally Sensitive Arctic Areas,

Rich Haut, Tom Williams, Mike Lilly, Shirish Patil, Yuri Shur, Cathy Hanks & Mikhail Kanevskiy

[1] Ph.D., Houston Advanced Research Center. Email: rhaut@harc.edu

[2] TerraPlatforms, L.L.C. Email: twilliams@afsolutionsinc.com

[3] Geo-Watersheds Scientific. Email: mlilly@gwscientific.com

[4] Ph.D., University of Alaska – Fairbanks. Email: s.patil@uaf.edu

[5] Ph.D., University of Alaska – Fairbanks. Email: ffys@uaf.edu

[6] Ph.D. University of Alaska – Fairbanks. Email: chanks@gi.alaska.edu

[7] Research Assistant Professor/University of Alaska – Fairbanks. Email: ffmzk@uaf.edu

The Alaskan North Slope possesses one, if not the greatest, opportunity to increase domestic oil and gas production. However, this region faces some of the greatest environmental and logistical challenges to produce oil and gas in the world. Weather patterns in this region are warming and the number of days the tundra surface is adequately frozen for tundra travel each year has declined. Operators are not allowed to explore in undeveloped areas until the tundra is sufficiently frozen and adequate snow cover is present. Using the best available methods, exploration in remote arctic areas can take up to three years to identify a commercial discovery, and then years to build the infrastructure to develop and produce. This makes new exploration costly. It also increases the costs of maintaining field infrastructure, pipeline inspections, and later environmental restoration efforts. New technologies are needed or oil and gas resources may never be developed outside limited exploration step-outs from existing infrastructure.

Industry has identified certain low-impact technologies suitable for operations, and has made improvements to reduce the footprint and impact on the environment. *Additional improvements are needed for exploration and economic field development and end-of-field restoration*. One operator, Anadarko Petroleum Corporation, built a prototype elevated, modular and mobile platform for drilling wells in the Arctic. The system was tested while drilling one of the first hydrate exploration wells in Alaska during 2003-2004. This technology was identified as a potentially enabling technology by an on-going Joint Industry Program (JIP) Environmentally Friendly Drilling (EFD). EFD is headed by Texas A&M University and the Houston Advanced Research Center (HARC) and co-funded by the National Energy Technology Laboratory (NETL).

The overall objective of the project is to document various potential applications, locations, and conceptual designs for the inland platform serving oil and gas operations on the North Slope, Alaska. The University of Alaska – Fairbanks assisted HARC/TerraPlatforms team with the characterization of potential resource areas, geotechnical conditions associated with the continuous permafrost terrain, and the potential end-user evaluation process.

The team discussed the various potential applications with industry, governmental agencies and environmental organizations. Industry benefits and concerns of using the technology were identified. Meetings were held with 5 operating companies. Three other operating companies and two service companies were contacted by phone. A questionnaire was distributed and responses were also provided and will be included in the report. Meetings were also held with State of Alaska Department of Natural Resources officials and Federal BLM regulators.

Funding for the work was provided by the U.S. Department of Energy/National Energy Technology Laboratory.

5.5.17 Temporal Distributions and Patterns of Habitat Use by Black Brant Molting in the Teshekpuk Lake Special Area, Alaska,

Tyler L. Lewis, Paul L Flint, Joel A. Schmutz, & Dirk V. Derksen

U.S. Geological Survey, Alaska Science Center, Anchorage, Alaska

Each July, tens of thousands of Pacific Black Brant (Branta bernicla nigricans, hereafter Brant) migrate from various breeding areas to undertake a flightless wing molt in the Teshekpuk Lake Special Area (TLSA), located on the Arctic Coastal Plain of Alaska. The TLSA contains known oil and gas deposits and has been proposed as an area for future development. Planning to minimize the effects of oil and gas development on molting Brant populations requires a clear understanding of patterns of habitat use by undisturbed birds throughout the entire molting period. However, the only data currently available to assess patterns of habitat use of molting Brant in the TLSA are based on a single annual survey conducted by the U.S. Fish and Wildlife Service. This two-day survey results in a single annual population census and is not useful for describing patterns of habitat use within the three to six week molting season. To determine patterns of movement and habitat use by molting Brant, as well as provide baseline data for future detection and/or measurement of disturbance by potential oil and gas development, we: 1) conducted six replicate aerial surveys, each survey being temporally separated by one week, of the 36 primary wetlands/lakes used by molting Brant in the TLSA and 2) affixed molting Brant with GPS transmitters, which collected precise locations (± 5 m) every six hours throughout the entire molting period. Our survey data demonstrate the temporal and geographic variation in Brant distributions within the TLSA. Brant stage along the coast and on brackish wetlands prior to the flightless wing molt. At onset of molt, Brant redistribute across both coastal, brackish wetlands and inland, freshwater lakes, before returning to coastal, brackish wetlands as soon as they regain flight. Data from transmittered birds shows precise patterns of habitat use during the flightless period, including home range size, inter-lake movements, and habitat preferences.

5.5.18 Population of Origin of Arctic Cisco (Coregonus autumnalis) Collected in the Colville River Subsistence Fishery, *Jennifer L. Nielsen*

Ph.D., Supervisory Research Fisheries Biologist, U.S. Geological Survey, Alaska Science Center.
Email:jennifer_nielsen@usgs.gov

Arctic cisco (*Coregonus autumnalis*) harvested from the Colville River subsistence fishery are thought to be anadromous, overwintering migrants from the Mackenzie River, Canada. Local fishermen currently question sustainable recruitment to this fishery based on potential climate change and development impacts in the near-shore waters of the Beaufort Sea. Our study tests population-of-origin hypotheses for Colville River Arctic cisco by comparing genetic data derived from Colville River Arctic cisco with anadromous spawning populations collected in the Arctic Red and Peel rivers, both tributaries of the Mackenzie River. We analyzed genetic variation at eleven polymorphic microsatellite loci and direct sequence information for a 594 nucleotide fragment of the mitochondrial ATPase subunit VI gene. Microsatellite allelic frequencies revealed no significant differences in pairwise F_{ST} among these populations supporting the hypothesis that the Mackenzie River watershed is the primary source of Arctic cisco recruiting to the Colville River fishery. Differences in mitochondrial DNA haplotypes suggest some fish within the Colville River sample collection may be misidentified to species or are hybrids with other Arctic coregonids. Sampling of additional possible source populations upriver in the Mackenzie River will take place August 2008. Data from fish collected from these streams will be critical to understanding the population dynamics of Arctic cisco in the Beaufort Sea and the sustainability of the Colville River fishery.

We wish to acknowledge the following partnerships: Paulo Flieg and Larry Greenland, Aurora Research Institute; Shawn Norbert, Tsiigehtchic resident; Gwich'in Renewable Resource Board, Inuvik; Tetlit Renewable Resource Council, Fort McPherson; Gwichya Renewable Resource Council, Tsiigehtchic.

5.5.19 Hotspot and Biogeographic Analysis of Marine Larval Fish in the Nearshore Canadian Beaufort Sea, *Joclyn E. Paulic*

B.Sc., Marine Environmental Quality Project Officer/Master’s Student, Fisheries & Oceans Canada/University of Manitoba. Email: Joclyn.Paulic@dfo-mpo.gc.ca

The impacts from coastal pollution and habitat degradation have put fisheries at risk by adversely affecting recruitment (Lazzari et al. 2003). The early life history stages of fish are highly vulnerable to both natural mortality and changes in environmental variables (Houde 2001). The identification of critical habitat for marine larval fish is essential for the conservation of marine biodiversity in Large Ocean Management Areas (LOMA) such as the Beaufort Sea. The objective of this study was to identify areas within the Mackenzie Estuary (<50 m) that are important for marine larval fish. Data from the Northern Oil and Gas Action Program (1985 to 1987) and the Northern Coastal Marine Program Study (2003 to 2005) were complied for samples taken in August using a bongo net. A total of 108 stations were represented in the data set. Species richness and larval fish abundance were calculated and mapped using the inverse distance weighted spatial analyst tool in ArcGIS® 9 (ArcMapTM Version 9.2). To identify hotspots the two map layers (species richness and abundance) were summed using the spatial analyst tool; cell statistics. A biogeographic analysis was performed using the species distribution information but re-worked and grouped by family. The coastline of the study area was divided into 4 horizontal sections and 4 vertical sections. A binary MS Excel spreadsheet was created using the 12 sections and the family distribution information. The 12 x 12 matrix was input into PRIMER v 6.1.6 package and the cluster analysis (using Bray-Curtis similarity) and multidimensional scaling (MDS) statistics were used to determine biogeographic zones within the Mackenzie Estuary. Results of the hotspot analysis indicated increased species richness and larval abundances at two locations in the Mackenzie Estuary. One area was located north of Pullen Island and the other at the eastern most point of the Tuktoyaktuk Peninsula. Results from the biogeographic analysis suggest that the hotspot located north of Pullen Island is the most representative area for marine larval fish. The identification of this critical habitat within the nearshore area is necessary in order to properly develop mitigation measures to ensure the protection and sustainability of marine fish populations and diversity within the LOMA.

5.5.20 Ecological Change in the Teshekpuk Lake Special Area: Effects on the Distributions of Arctic-nesting Geese, *Joel Schmutz*

Ph.D., U.S. Geological Survey, Alaska Science Center, 4210 University Drive, Anchorage, AK

Email: jschmutz@usgs.gov

Climate patterns in the Arctic are changing, and this has led to a cascading series of physical and ecological consequences in Arctic landscapes. Because the Department of the Interior (DOI) manages many resources that are affected by this landscape evolution, it is incumbent upon us to understand these processes. We present here a single effort by an interdisciplinary team to understand how physical and ecological changes have caused and will continue to cause redistributions of geese that aggregate in northern Alaska to undergo their sensitive molting period. Our study area is the Teshekpuk Lake Special Area (TLSA) in the northeast corner of the National Petroleum Reserve–Alaska. An analysis of 27 years of goose survey data from the TLSA indicates eastward shifts over time in their distribution, most noticeably for Greater White-fronted Geese and Black Brant. We hypothesize that high rates of coastline erosion and periodic storm surges have led to the breaching and salinization of lakes, which has led to direct (salt-induced mortality) and indirect (changes in lake water quality) effects on the shoreline plant communities that geese use for feeding. Using a time series analysis of LANDSAT imageries, we documented that rates of coastline erosion along the TLSA have recently increased. Our data on warming permafrost temperatures support a hypothesis of increased vulnerability of tundra to erosive action. Analyses of lake water samples clearly show strong inter-lake differences in salinity. Also, temperatures in these shallow, mixed lakes are responsive to recent warming, which may be affecting productivity of these ecosystems. We found evidence of long-term change in nearshore plant communities, and we are presently pursuing higher resolution data to address this issue. Further, we are assessing how the present distribution of geese is related to productivity and nutrient content of select plant communities. Collectively, these data will be used to model the magnitude of future erosion and saline influence on lakeshore habitats used by geese, and the consequent expected changes in distribution of geese in response to these habitat changes. Given the need to also manage the spatial distribution of petroleum development in this area, it will become increasingly important to predict where the preferred habitats of these geese will be in the future.

5.5.21 Design and Operation of Arctic Oilfields to Minimize Conflicts with Grizzly Bears, *Richard Shideler*

Wildlife Biologist, Alaska Department of Fish & Game, Fairbanks, AK. Email:dick.shideler@alaska.gov

Grizzly bears inhabit much of the western Canadian and the entire Alaskan Arctic region where oil and gas exploration and production currently occur. Experience with grizzly bear interactions with oil development in Alaska's North Slope oilfield region has shown that site design and operations can reduce conflicts. Three major approaches—structural design features, modifications of human behavior, and modifications of bear behavior—have been used during oil exploration and production on the North Slope. Facility design features such as barriers to bear access, increased lighting, and minimization of anthropogenic cover can reduce bear occupancy around areas of human activity. Operational features, including management to reduce grizzly bear attractants--chiefly human-generated waste-- and measures to affect bear behavior, such as trained personnel to haze bears away from human activity, can be effective if applied early in oilfield development and maintained consistently thereafter. Incentives, and in some cases disincentives, for oilfield personnel to take personal responsibility for proper waste management are important, but appear to be the weakest link in the chain. The goal of oilfield operations should be to minimize the impact of oil development on bears while maintaining safety of its personnel. This does not appear to be an unreasonable goal if planning and operations occur with grizzly bears in mind.

5.5.22 Science-Based Decision Making: The Mackenzie Gas Project and Environmental Impacts on Birds, *Craig Machtans*

M.Sc., Forest Bird Biologist, Environment Canada, Canadian Wildlife Service. E-mail: craig.machtans@ec.gc.ca

The Canadian Wildlife Service of Environment Canada and its conservation partners invested substantial financial and staff resources in pre-project science studies and submissions for the public hearings of the Mackenzie Gas Project (MGP). That investment is being made to ensure our conservation objectives for our mandated areas of responsibility are met. Meeting those objectives is achieved in practice by presenting concise, credible, science-based recommendations from the department to the review panel for the project. Meeting those three conditions simultaneously is not a simple task.

The MGP proposes to develop and transport natural gas reserves from the Mackenzie Delta to southern markets. It is one of the largest industrial projects currently proposed in Canada. Two of three anchor fields for the MGP are inside Kendall Island Bird Sanctuary, an area under federal protection for the conservation of birds and their habitat. If approved, the project will open the resource basin for development and stimulate additional, incremental development including more development inside the bird sanctuary. The basin-opening nature of the project and the presence of substantial gas reserves under the bird sanctuary were principle factors in making our science investments. Yet the very nature of such a large, complex project (economically, physically, and socially) means that recommendations to meet our mandated objectives cannot be made in a science-bubble, especially an imperfect one. While seemingly obvious, this point is often understated or completely overlooked by researchers.

This talk will provide a brief summary of the science projects conducted by the Canadian Wildlife Service and its partners to highlight what outstanding priorities were addressed through the research program. Then, to demonstrate how wildlife science alone is insufficient to provide credible advice on such a complex project, a case study will be described. The case-study will focus on the recommendations made for regulating noise emissions from the gas production facilities inside the bird sanctuary. Scientific information on the impact of noise on birds was considered in concert with engineering and economic data for the facilities, in addition to regulatory restrictions in place in other jurisdictions. While it was not a full trade-off analysis, the obvious consideration of these other factors provided the balance needed by the department to make a credible recommendation that met our conservation objectives.

Science-based Decision Making:

The Mackenzie Gas Project and Environmental Impacts on Birds

Craig Machtans
Canadian Wildlife Service
Yellowknife, Northwest Territories

US-Canada Northern Oil and Gas Research Forum

Anchorage, AK October 30, 2008

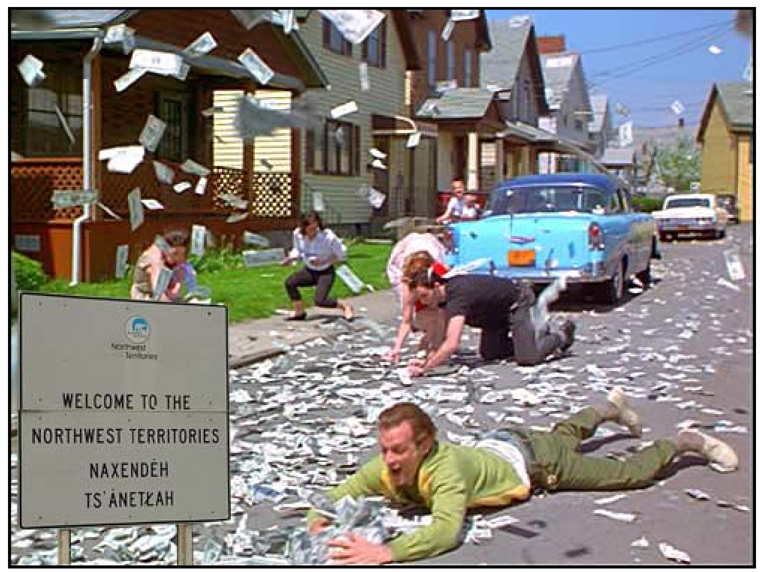
Disclaimer

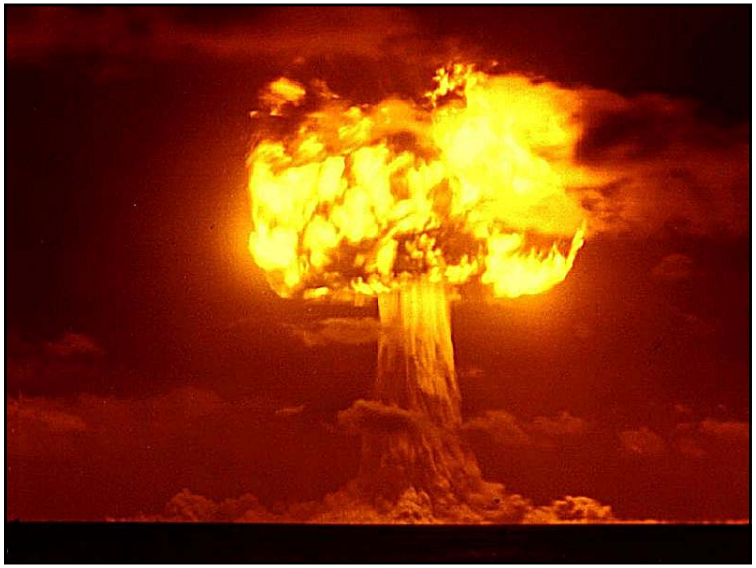
WARNING

The Surgeon General has determined that viewing too many PowerPoint presentations induces "heavy eye lid syndrome" and can lead to habit-forming consumption of caffeinated products.

Overview

- Context of Mackenzie Gas Project
- Science investments made by Canadian Wildlife Service
- Example of science+ and application to decision making





CREDIT: Slide from MGP Public Registry, item #J-IORVL-00418

The Mackenzie Gas Project

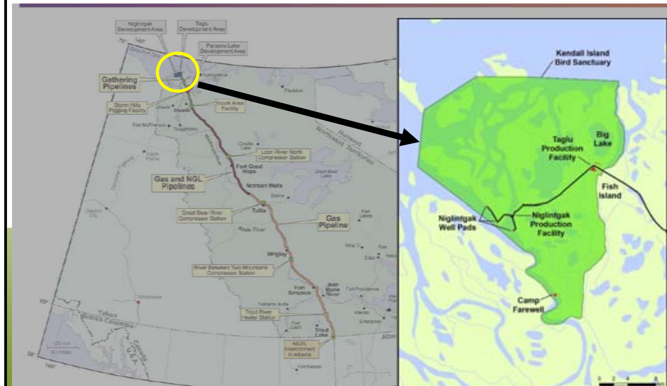
Onshore development of three anchor fields:
- Sweet natural gas and natural gas liquids
- Well pads and gas conditioning facilities

Mackenzie Gathering System:
- 190 km of gathering pipelines from anchor fields
- Gas processing facility near Inuvik
- 457 km NGL pipeline to Norman Wells

Mackenzie Valley Pipeline:
- 1,194 km gas pipeline from Inuvik to an end point in Alberta
- Initial facilities include three compressor stations and a heater station
- Expandable by adding compressor stations

NOTE:
NOVA Gas Transmission Ltd. (NGTL) will apply separately to the Alberta Energy Utilities Board to extend the existing Alberta pipeline system to the NGTL interconnect facility

Kendall Island Bird Sanctuary



heater station
- Expandable by adding compressor stations

NOTE:
NOVA Gas Transmission Ltd. (NGTL) will apply separately to the Alberta Energy Utilities Board to extend the existing Alberta pipeline system to the NGTL interconnect facility

Mackenzie Gas Project – Project Description, Inuvik - February 15, 2006 4

Science Approach

- Early gap analysis
- Specialist meetings, prioritization
- Department and inter-departmental challenges
- Treasury Board of Canada submissions for $$

Investment

- Projects and support: ~$7M over 5 years
- Significant external money and support added
- 13 additional "sunset" full-time staff plus seasonal staff

Key Areas of Research

- Migratory Birds
  - Shorebirds
  - Waterfowl
  - Landbirds
- Protected Areas
- Polar Bears
- Other science supporting the environmental review

Shorebirds

- Population estimates for Mackenzie Delta (PRISM)
- Habitat preferences of large shorebirds (3 species)
- Nest success of Red-necked Phalarope
- Surveys of boreal forest shorebirds

Hudsonian Godwit

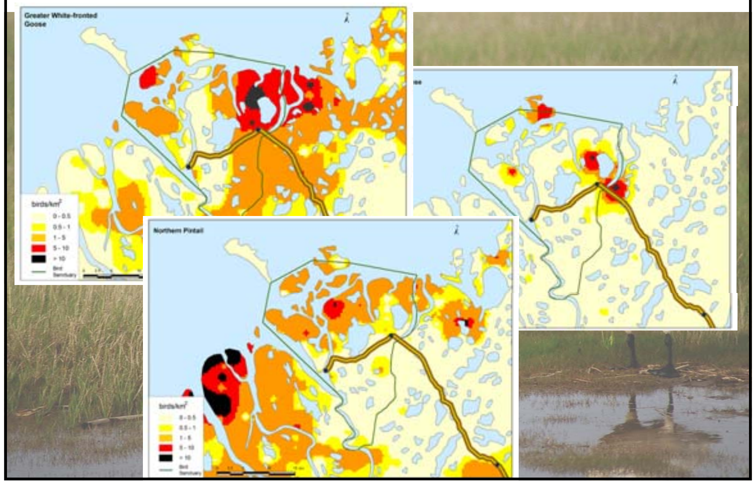
Image courtesy of Lisa Pirie

Waterfowl

Tundra Swan

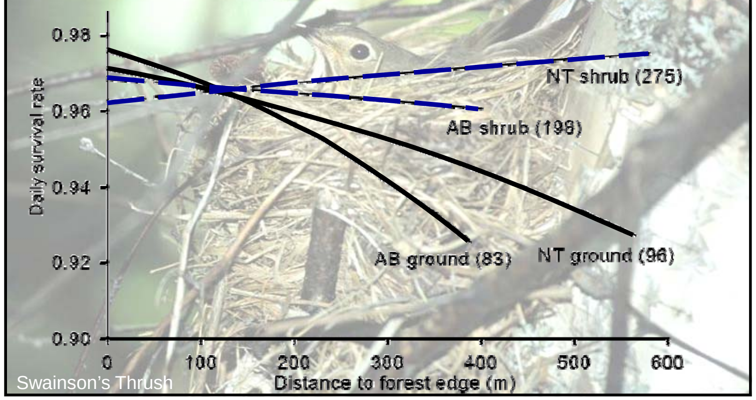
Image courtesy of Cindy Wood

Waterfowl



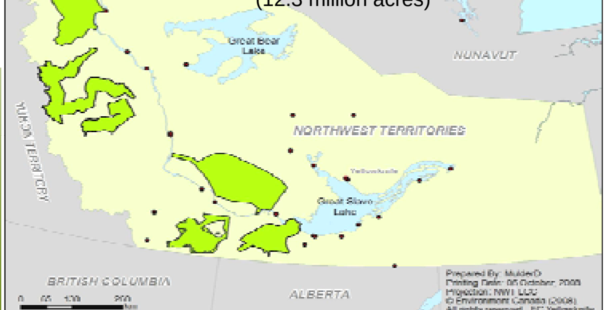
Landbirds

- Baseline bird densities at select locations
- Edge effects of pipelines on songbirds



Protected Areas

- Ecological assessments of candidate protected areas
- 50,000 km^2 assessed to date (12.3 million acres)



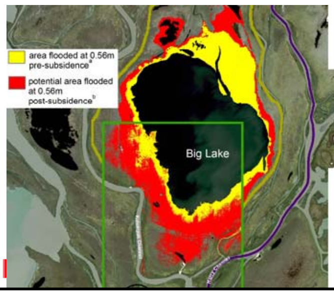
Polar Bears

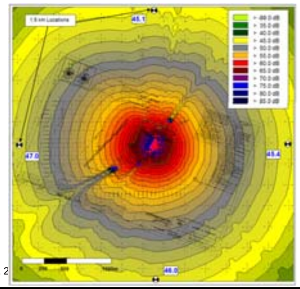
- Beaufort Sea population assessments with USGS
  - Plus genetics, climate change, diet
- Mackenzie Delta Studies
  - Denning surveys and potential mapping
  - Spill response models
  - Harvesting - industry overlaps

Image courtesy of Dr. Ian Stirling

Other Science

- Subsidence modeling (surface impacts of flooding)
- Above/below ground pipeline comparison
- Study on sumps
- Independent noise modeling, ambient characterization

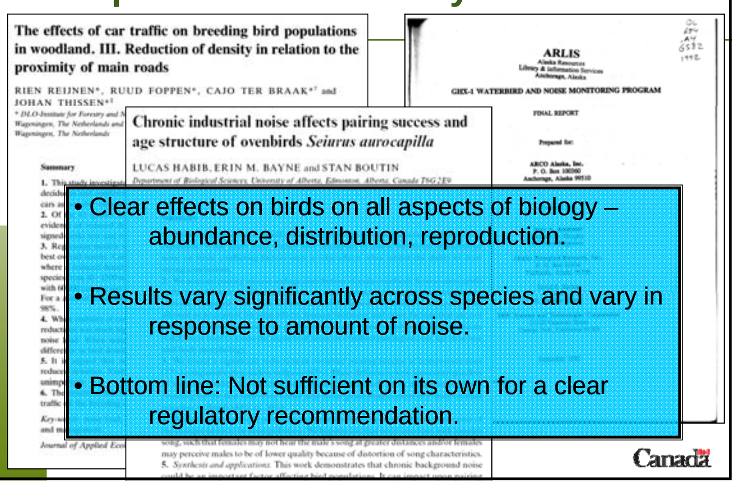




Noise

- Issue
  - Potential impacts on birds of continuous noise from 2 gas processing facilities inside the Kendall Island Bird Sanctuary
- Relevant Concerns
  - Substantial noise in a sanctuary free from industrial noise
  - No noise regulations in NWT
  - Noise regulations typically apply to humans
  - Small body of relevant scientific literature on effects on birds
  - Environment Canada has never regulated noise

Step 1: Visit the Library


The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to the proximity of main roads

RIEN REIJNEN*, RUUD FOPPEN*, CAJO TER BRAAK*† and JOHAN THISSEN*†

Chronic industrial noise affects pairing success and age structure of ovenbirds *Seiurus aurocapilla*

LUCAS HABIB, ERIN M. BAYNE and STAN BOUTIN

Department of Biological Sciences, University of Alberta, Edmonton, Alberta, Canada T6G 2E9

ARLIS
Alaska Resources Library & Information Services
Anchorage, Alaska

GHX-1 WATERBIRD AND NOISE MONITORING PROGRAM

FINAL REPORT

Prepared for:

ARCO Alaska, Inc.
P. O. Box 100360
Anchorage, Alaska 99510

- Clear effects on birds on all aspects of biology – abundance, distribution, reproduction.
- Results vary significantly across species and vary in response to amount of noise.
- Bottom line: Not sufficient on its own for a clear regulatory recommendation.

Step 2: Look at neighbours

- Alberta has solid regulatory guidance for noise.
- FERC issued obscure ruling that was stringent – relevant for Alaska operations
- Proponent proposed to use Alberta standard


EUB Alberta Energy and Utilities Board

640 – 5 Avenue SW Calgary, Alberta Canada T2P 3G4 Tel 403 297-8311 Fax 403 297-7336 www.eub.ca

Directive 038

Revised edition February 16, 2007

Noise Control

The Alberta Energy and Utilities Board (EUB/Board) has approved this directive on February 16, 2007.

[Original signed by]

M. N. McCrank, Q.C., P.Eng.
Chairman

Contents

Step 3: Independent Analyses

- Contracted leading firm for independent noise analysis by specialized engineers. Identify best practices solution, verify.
- Novel approach for CWS.
- Included economic costs of meeting “reasonable” targets - $4M of a $1.6B facility (0.2% of total)

TABLE 4
Maximum Predicted Facility Levels at 1,500 m (AMEC and ANM)

AMEC Predicted Levels (dBA)	ANM Predicted Levels (dBA)
40	47

The 7dB difference represents more than a doubling in the sound energy radiated by the plant.

Step 4: Consider the future

- Additional development likely inside the Sanctuary.
- Critical to be aware of cumulative impact.

Step 5: Recommendation

- Synthesize the science: science foundation.
- Follow Alberta guideline: regulatory foundation.
- Apply independent analysis: engineering and economic foundation.
- Act with caution given location and future.

It is EC’s position that continuous noise emissions, as measured under the terms and conditions of EUB Directive 038, not exceed 50 dBA L_{eq} at 300 metres (40 dBA at 900 m), as measured from the fence line of the facility, for the period when birds are present in KIBS (10 May to 30 September). Environment Canada recognizes that the appropriateness, both technically and economically, of the proposed regulatory requirement will be further informed when the detailed design and Noise Impact Analysis is available and independently verified, prior to finalizing permit conditions.

Step 6: Manage blowback

- Recommendation unpopular with proponent.
- Called a “show stopper”.
- Places significant pressure on senior managers.
- Forces continual review, briefing, meetings to ensure foundation is solid.
- Defend recommendation in cross-examination in hearings during environmental review.
- ... and repeat for permitting phase!

Conclusions

- Using science for regulatory decisions much different than just conducting science
- Rare that science, on its sole merits, can dictate regulatory decisions.
- Difficult decisions easier with solid science foundation.

Conclusions

- Scientists need to be mindful of the endpoint:

  Data → Information → Knowledge → Application

- The best scientists can form those bridges.
- Endpoint usually reached by bridging disciplines.

Contact

craig.machtans@ec.gc.ca
867-669-4771

Canada Warbler

5.5.23 Sites of Upwelling on the Canadian Beaufort Shelf, *William J. Williams & Eddy C. Carmack*

[1] Fisheries and Oceans Canada. Institute of Ocean Sciences, P.O. Box 6000, 9860 West Saanich Road, Sidney, British Columbia, V8L 4B2, Canada. Email: Bill.Williams@dfo-mpo.gc.ca

[2] Fisheries and Oceans Canada. Institute of Ocean Sciences, P.O. Box 6000, 9860 West Saanich Road, Sidney, British Columbia, V8L 4B2, Canada. Email: Eddy.Carmack@dfo-mpo.gc.ca

The nutrient maximum of the layer of Pacific-origin water in the Beaufort Sea is at about 150 m deep. Wind driven surface-stress over Canadian Beaufort Shelf has large interannual variation but is, on average, upwelling-favourable in 2 out of every 3 years. Upwelling circulation causes nutrient rich Pacific water to upwell across the shelf-break onto the Canadian Beaufort Shelf where it can potentially reach the euphotic zone to be used in the presence of light by growing phytoplankton. Upwelling will occur across the 500 km-long shelf break of the Canadian Beaufort Shelf but is also topographically enhanced at 3 locations: Mackenzie Trough, Kugmallit Valley and Cape Bathurst. At Cape Bathurst nutrient rich Pacific water upwells directly to the surface. Benthic samples near the cape show high numbers and diversity of organisms which suggest that nutrients brought to the surface there allow additional primary production that ultimately feeds the benthos.

5.6 PHYSICAL SCIENCES

5.6.1 Seabed Geo-environmental Constraints to Offshore Hydrocarbon Development, Canadian Beaufort Sea, *Steve Blasco*

C.M., B.Sc. (Eng), P.Eng., Marine Environmental Geoscience Subdivision, Geological Survey of Canada, Dartmouth, NS, Canada. Email: sblasco@nrcan.gc.ca

The seabed of the Canadian Beaufort Shelf presents unique challenges to Arctic offshore hydrocarbon development. The impact rates of extreme ice scours/gouges need to be understood to determine trenching and burial depths for subsea pipelines. The extent and engineering properties of ice-bearing permafrost to depths of 700 m below seabed must be clearly defined to constrain production well design. Seabed foundation conditions including soft sediments and slope stability need to be assessed for stable gravity based structure emplacement. The distribution of seabed geohazards including over-pressured shallow gas zones, mud volcanism, diapirism, pockmarks and faulting have to be determined to mitigate exploration drilling risks. Knowledge of the distribution of ecologically and biologically sensitive benthic ecosystems is necessary to avoid conflict with development plans. With renewed vessel traffic, navigation hazards such as submerged abandoned artificial drilling islands from the first phase of exploration in the 1970's need to be investigated. Adequate knowledge of these geo-environmental impediments to offshore hydrocarbon development is required to set appropriate and timely codes, standards and regulations as well as to feed engineering design scenarios for offshore structures. Survey technologies such as multibeam sonar and high resolution multichannel reflection seismic profilers combined with seabed sampling are well suited to investigate geo-environmental issues. Knowledge gained from this type of research will allow development to proceed while minimizing the risk to the environment and ensuring human safety.

Seabed Geoenvironmental Constraints to Arctic Offshore Hydrocarbon Development Canadian Beaufort Sea

Robbie Bennett, Kevin MacKillop, Vlad Kostylev, Bob Harmes, Walli Rainey, John Hughes Clarke, Steve Blasco

Research Priorities Consultation Process

- Inuvialuit (HTCs)
- National Energy Board
- Canadian Association of Petroleum Producers
- Federal Government Departments
- Aurora Research Institute
- ArcticNet

Natural Resources Canada Ressources naturelles Canada Canada

Seabed Geoenvironmental Priority Research Issues Provide Regional Framework

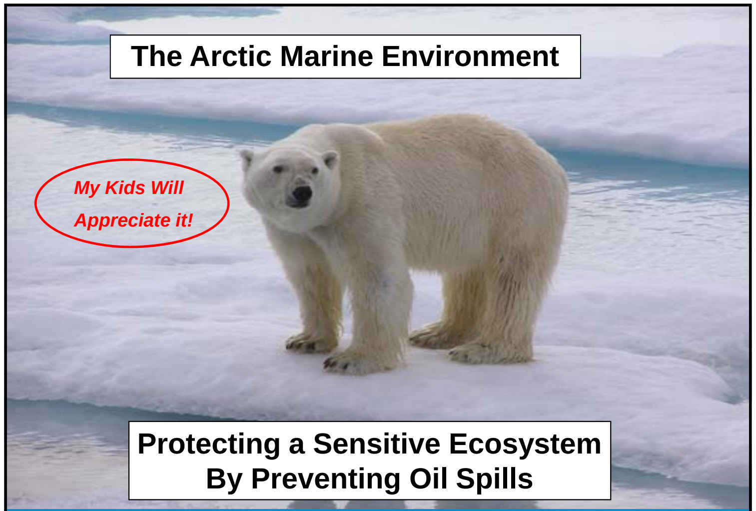
- seabed scouring by pressure ridge ice keels
- foundation conditions for exploration and production structures
- bottom sediment mobility
- shallow gas/faults
- subsea permafrost
- ecologically significant benthic habitats

Natural Resources Canada Ressources naturelles Canada Canada

Annual Consultations

Six Communities Feb, 2009

Natural Resources Canada Ressources naturelles Canada Canada



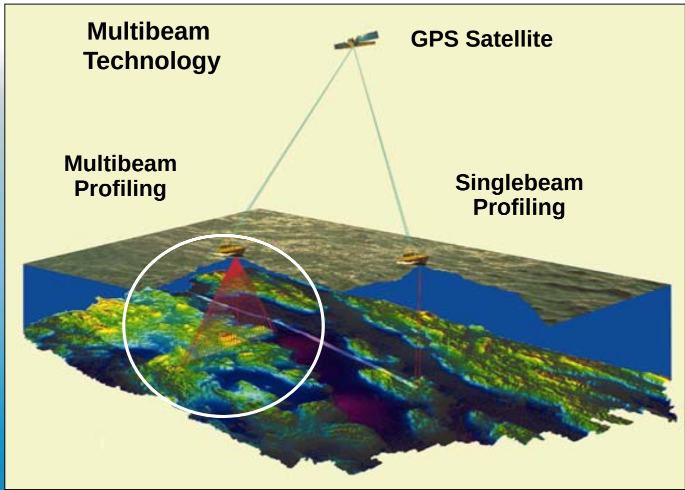
Funding

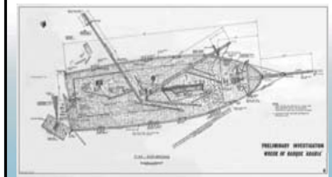
- Indian and Northern Affairs
- Natural Resources Canada
- Panel on Energy R&D
- Fisheries and Oceans Canada
- GNWT
- Industry
- ArcticNet

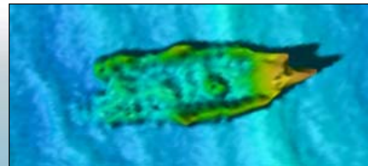
Survey Platforms

CCGS Nahidik

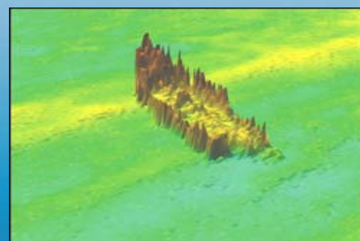
Ice strengthened and open water vessels







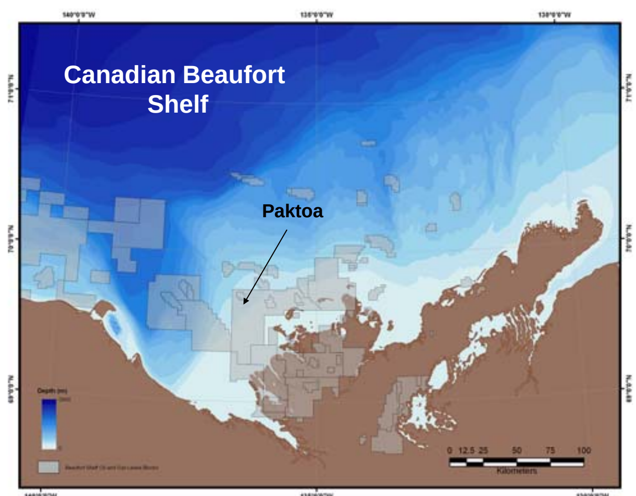
Multibeam of Shipwreck



Input to Decision Making Processes A Case History

Devon Paktoa Drillsite, 2006
Beaufort Sea
13m water depth

First Arctic Offshore Well in 16 years



Seabed Geoenvironmental Issues

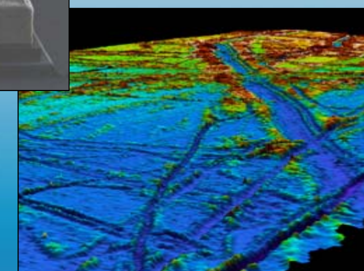
Research results to:

- NEB
- Inuvialuit
- Industry
- DFO

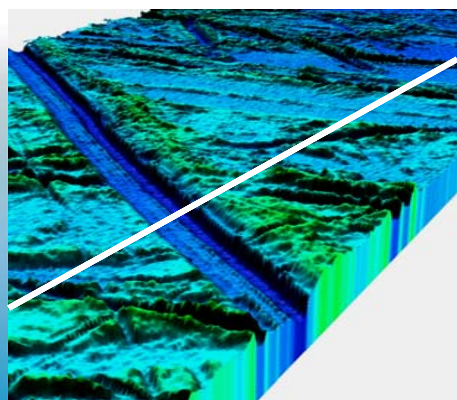
Seabed Geoenvironmental Constraints

- seabed scouring by pressure ridge ice keels
- foundation conditions for drilling and production structures
- bottom sediment mobility
- shallow gas/faults
- subsea permafrost
- ecologically significant benthic habitats



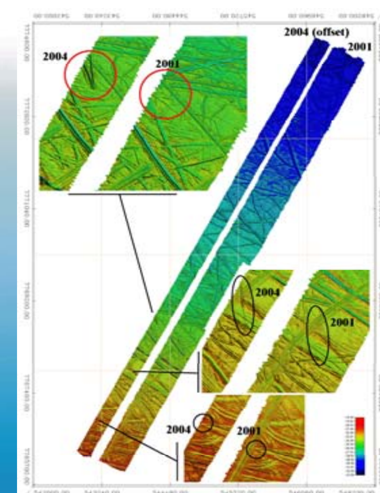


Seabed Scouring By Pressure Ridge Ice Keels

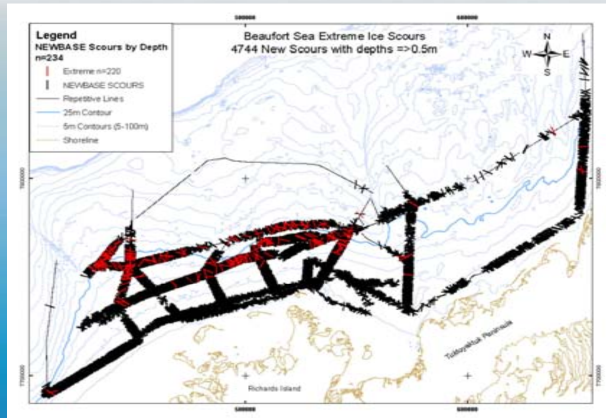


Pipeline Route: extreme features?

Multibeam Repetitive Mapping

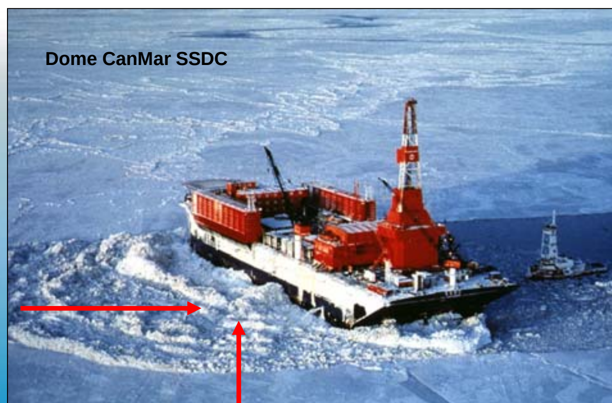


Distribution of New Scours => 0.5 m

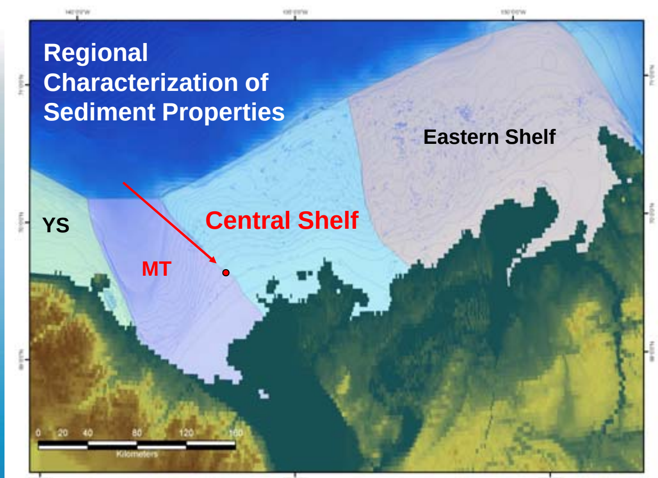


Seabed Geoenvironmental Constraints

- seabed scouring by pressure ridge ice keels
- foundation conditions for drilling and production structures
- bottom sediment mobility
- shallow gas/faults
- subsea permafrost
- ecologically significant benthic habitats



Foundation Conditions



Gravity Based Structures
Devon Paktoa Drillsite, 2006

Seabed Sampling

Natural Resources Canada Ressources naturelles Canada Canada

Inuvialuit Students Onboard
CCGS Nahidik, Amundsen

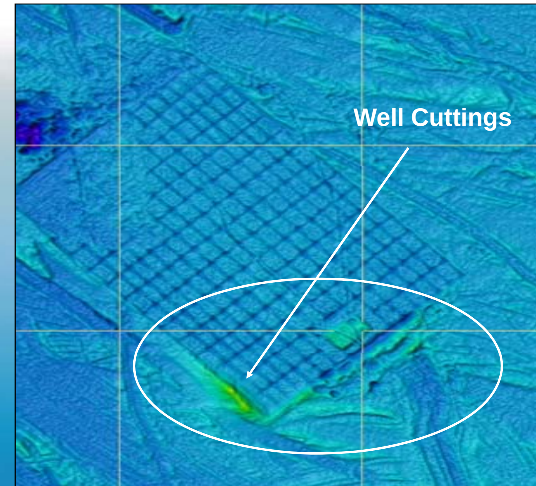
Natural Resources Canada Ressources naturelles Canada Canada

Seabed Geoenvironmental Constraints

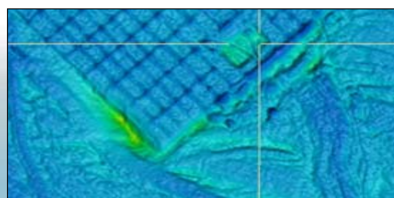
- seabed scouring by pressure ridge and iceberg ice keels
- foundation conditions for drilling and production structures
- bottom sediment mobility
- shallow gas/faults
- subsea permafrost
- contaminants
- ecologically sensitive benthic ecosystems

Natural Resources Canada Ressources naturelles Canada Canada

Well Cuttings

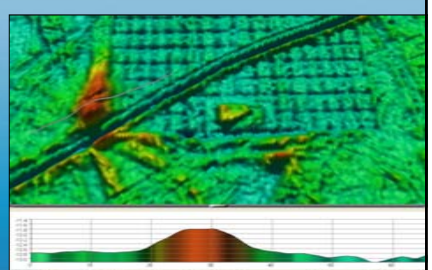


Natural Resources Canada Ressources naturelles Canada Canada



2006

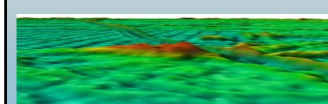
2007



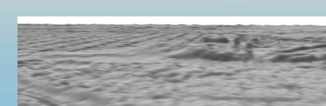
Natural Resources Canada Ressources naturelles Canada Canada

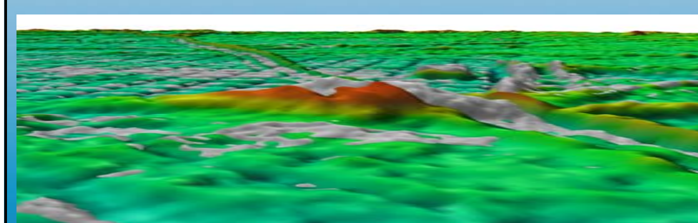
Beaufort Sea 2007 Paktoa SDC Site

2007



2006



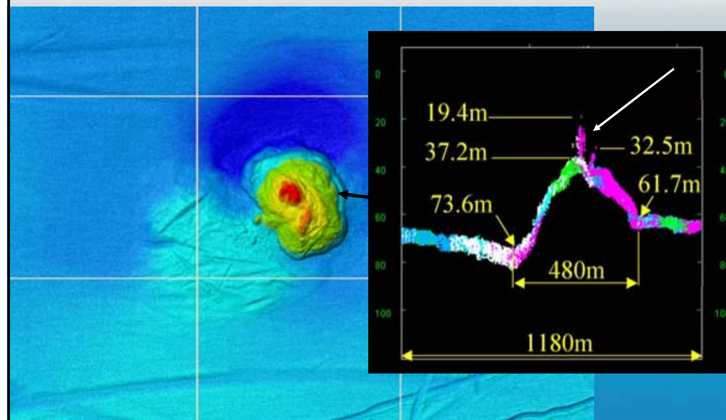


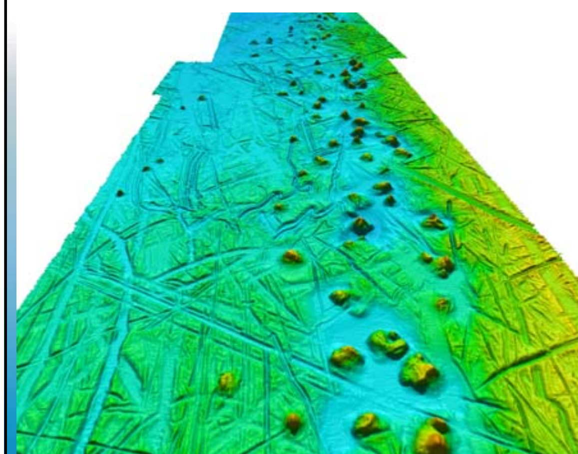
Natural Resources Canada Ressources naturelles Canada Canada

Seabed Geoenvironmental Constraints

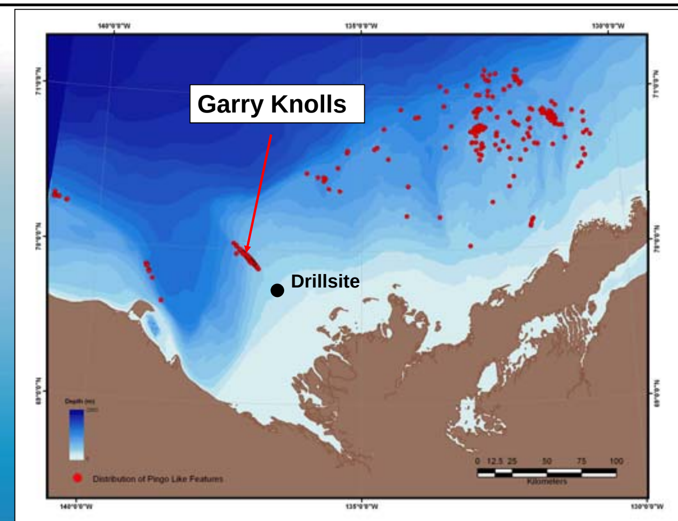
- seabed scouring by pressure ridge ice keels
- foundation conditions for drilling and production structures
- bottom sediment mobility
- shallow gas/faults
- subsea permafrost
- ecologically significant benthic habitatss

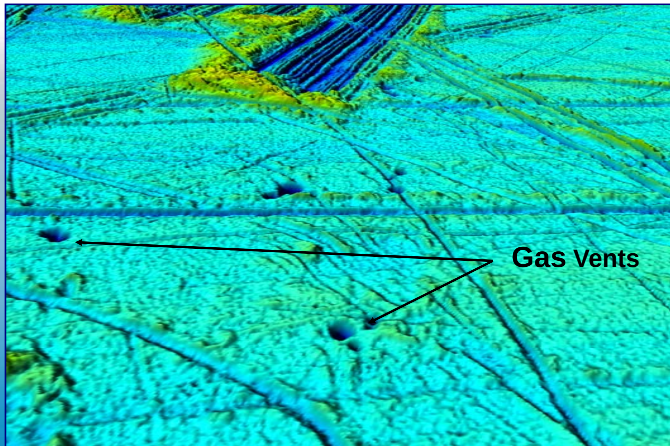
Mud Volcanoes





Garry Knolls: Mud Volcano Alley





Seabed Geoenvironmental Constraints

- seabed scouring by pressure ridge ice keels
- foundation conditions for drilling and production structures
- bottom sediment mobility
- shallow gas/faults
- subsea permafrost
- ecologically sensitive benthic habitats

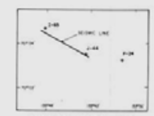
Natural Resources Canada Ressources naturelles Canada Canada

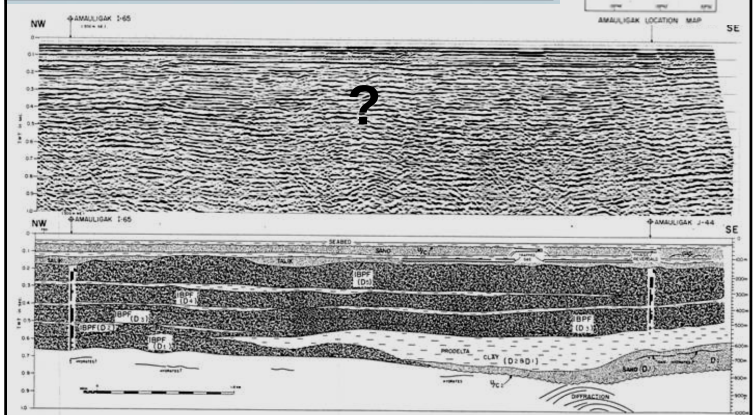
subsea Permafrost

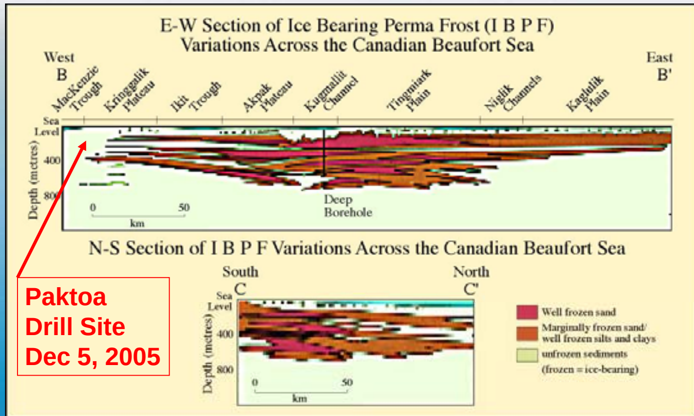
To Depths of 700m

Natural Resources Canada Ressources naturelles Canada Canada

Geohazard Detection in Ice-Bearing Sediments



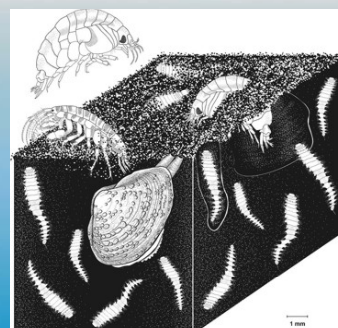




Seabed Geoenvironmental Constraints

- seabed scouring by pressure ridge ice keels
- foundation conditions for drilling and production structures
- bottom sediment mobility
- shallow gas
- subsea permafrost
- ecologically significant benthic habitats

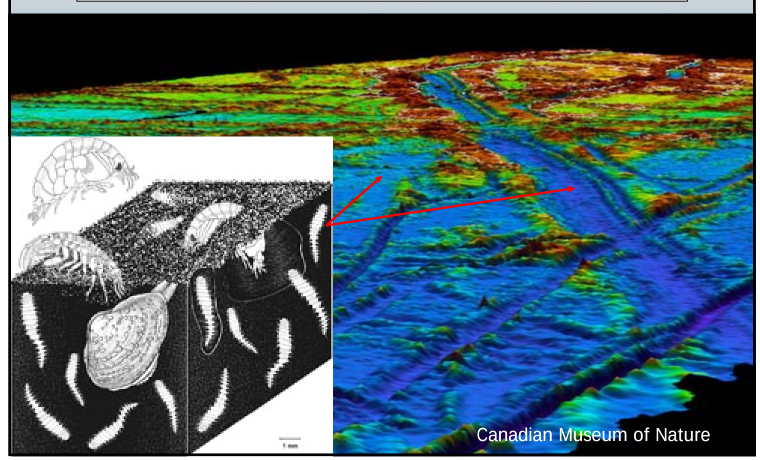
Benthic Community Visualization
Kathy Conlan CMN, DFO



Static

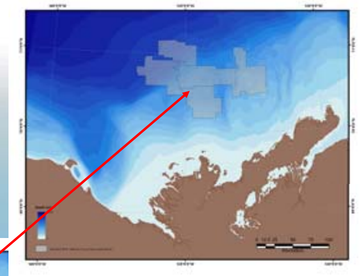
Dynamic!

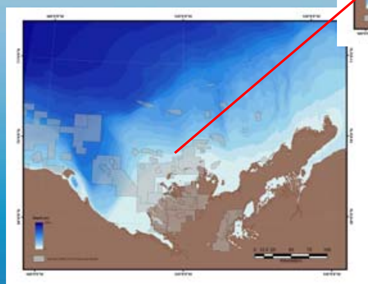
Seabed Disturbance by Bottom Founded Structures



Future:

Shift to Deep Water





2007-08

Oil Industry
Lease Blocks

Future
Seabed Geoenvironmental Research
Regional Framework

- seabed scouring by pressure ridge ice keels
- foundation conditions for drilling and production structures
- bottom sediment mobility
- shallow gas/faults
- subsea permafrost
- ecologically sensitive benthic habitats

Partnerships
Past Present Future

- Government Depts (INAC, DFO, EC NRC, NRCan, NWT)
- Industry
- Inuvialuit
- ArcticNet

The Arctic Marine Environment

My Kids Will Appreciate it!

Protecting a Sensitive Ecosystem
By Preventing Oil Spills

Thank You

The Web

5.6.2 Waves and Sediment Mobility in the Southeastern Beaufort Sea,

S.M. Solomon, G. Lintern, A. Hoque, D. Whalen, W. Perrie, B. Toulany, R. Mulligan, K.A. Jenner

[1] Coastal Geologist, Natural Resources Canada, Geological Survey of Canada, Dartmouth, NS. Email: SSolomon@nrcan.gc.ca

Nearshore hydrodynamics and their impacts on the coast and seabed are a concern for hydrocarbon exploration and development in the Mackenzie Delta region of the Beaufort Sea. Development scenarios under consideration include increased ship and barge traffic, potential dredging to improve access to facilities and exploration areas, pipelines and artificial island construction. Movement of sediment may directly affect these activities through possible adverse environmental impacts related to construction and increasing project costs. This project focuses on the investigation of processes that influence sediment movement in the shallow nearshore region of Beaufort-Mackenzie coast in both open water and ice-covered seasons.

Thirty kilometres seaward of the Mackenzie River Delta, water depths are less than five metres. These shallow depths and low gradients present a variety of challenges for data collection and modeling. During the open water season periodic storms from the northwest raise water levels and generate waves and currents capable of entraining and transporting the seabed sediments. Mapping of the morphology and texture of the seabed in this region is coupled with the measurement of wave, current and suspended sediment concentration in order to improve our understanding of the processes that control sediment movement. Initial results from swath-type mapping and sidescan sonar suggest that seabed ice scour and strudel scour are common occurrences that can persist for several years. Variations in acoustic backscatter suggest that fluid mud may cover portions of the seabed. Numerical models of wave generation and transformation, hydrodynamics and sediment transport are being implemented and validated using these observations. Initial results are promising; however we anticipate that the models may have some difficulty in realistically simulating wave transformation over the low gradient, muddy foreshore.

Researching seabed mobility during the ice-covered winter and spring seasons is constrained by challenging weather and ice conditions. While winter is generally thought to be a quiescent time in terms of sediment dynamics, storm surges are known to occur beneath the ice and are accompanied by movement of the landfast ice sheet and overflow onto the ice surface. These observations suggest that the significant water volumes and current velocities associated with the surges could have an impact on the seabed, especially where sea-ice thickness has constrained the capacity of under-ice channels. During the spring breakup when increased discharge from northerly draining rivers occurs prior to sea-ice melting, extensive overflow onto the ice surface is accompanied by energetic upwelling and strudel drainage. No measurements of current velocity or seabed erosion (other then strudel scour) have been made during these events.

The current project is funded until 2011 at which time we plan to have implemented and validated numerical models for aspects of nearshore hydrodynamics and sediment transport and developed conceptual models for under-ice and spring breakup processes. Given the role of extreme events in shaping the coastal and nearshore environments in this region, long-term observation systems need to designed and implemented to ensure that models are providing realistic outputs under the full range of present and future (climate change induced) conditions.

~~Waves and Sediment Mobility in the Southeastern Beaufort Sea~~

Understanding Sediment Dynamics in the Southeastern Beaufort Sea

S.M. Solomon, G. Lintern, A. Hoque, D. Whalen, W. Perrie, B. Toulany, R. Mulligan, K.A. Jenner, Chris Stevens, Brian Morman

Geological Survey of Canada – Natural Resources Canada
Department of Fisheries and Oceans
University of Calgary

Acknowledgements

- Program for Energy Research and Development (PERD)
  - Northern Program 2007-2011 - Waves and sediment mobility in the Beaufort Sea
  - Pipeline Program 2008-2011 - Geohazards for Pipelines from Ice-Related Nearshore and River-Mouth Processes in the Mackenzie Delta Region
- Northern Energy Development MC (2005-2009/10)
- International Polar Year (2007-2009)
- Polar Continental Shelf Project
- Aurora Research Institute
- MGMEnergy, Shell Canada, Chevron Canada – logistic support and data
- Partners and contractors: University of Calgary, University of Alberta, C-CORE, Aquatics Environmental, Tumichiat Outfitters

Driver

- Onshore gas production will lead to offshore exploration and exploitation of known offshore discoveries (pipelines)
- Assessment of risk to pipelines, navigation channels and infrastructure due to nearshore geohazards
  - Ice-seabed interaction – scours, shallow subsea permafrost
  - Magnitude, extent and mechanisms of nearshore erosion and deposition
    - Strudel scour
    - Currents in ice-covered waters – under-ice flow regime
    - Open water – waves, currents, wind driven circulation and storm surges

Policy Objective

- Information to support decision-making
  - Regulators (eg. NEB, FJMC/DFO, EC, Parks Canada, JRP)
  - Industry
  - Communities

Scientific Objective and Planned Outputs

Improved understanding of nearshore hydrodynamics and sedimentary processes (e.g. strudel and current scour, sediment mobility)

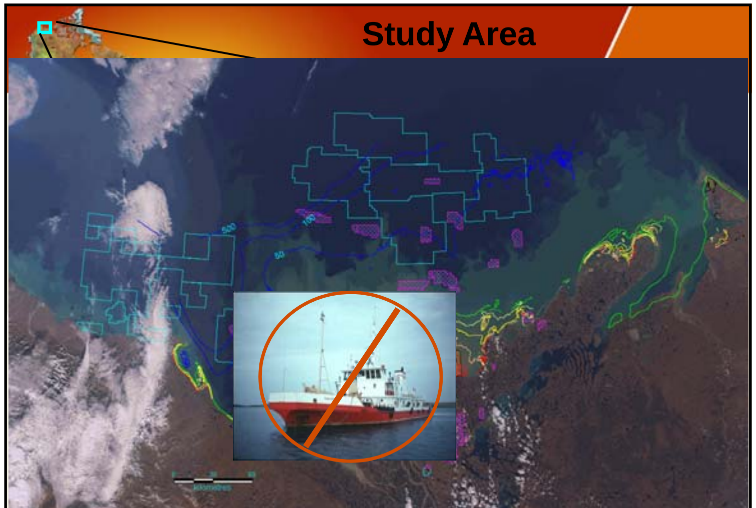
- Mapping seabed morphology and shallow stratigraphy in terms of their impact on shallow water seabed processes.
- Observations of nearshore hydrodynamics and sediment transport based on field observations.
- Modelling of shallow water hydrodynamic for fine-resolution simulations of Beaufort Sea storms in the nearshore.

Outline

- Background
- Methods
- Bottomfast ice – role, mapping
- Recent results
- Summary gaps and future directions

Natural Resources Canada Ressources naturelles Canada Canada

Study Area



Natural Resources Canada Ressources naturelles Canada Canada

Seasonality of processes

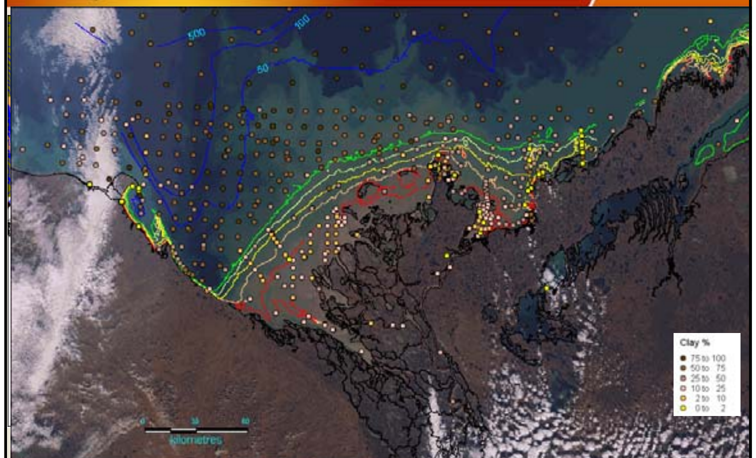
- Open water – Late June to October
  - Waves (4m, 8-10s), storm surge flooding/currents, up/downwelling, upstream rainfall events, sediment resuspension and redistribution, coastal erosion
- Freeze-up and formation of landfast ice – Oct-Dec
  - Frazil entrainment, pressure ridging-ice scour
- Winter – landfast ice – Dec-May
  - Low river discharge, under-ice surge events, bottomfast ice development
- River breakup – May-June
  - Overflow/underflow, potential enhanced currents, strudel scour, flooding, rapid increase in discharge and sediment delivery
- Sea ice break up – late June
  - Meltpool formation and ice advection or melting in place

Natural Resources Canada Ressources naturelles Canada Canada

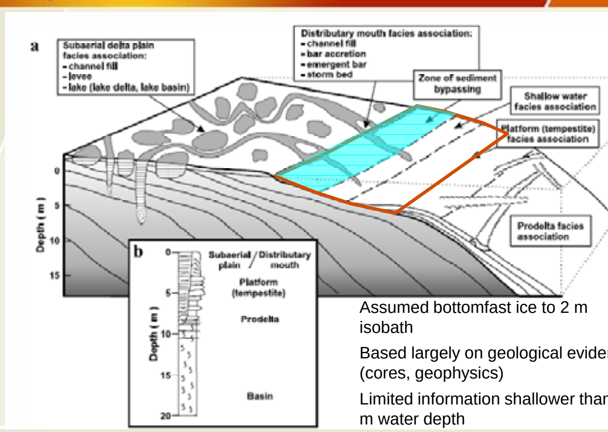
Sources of Sediment: Mackenzie River

- Largest sediment delivery to Arctic Basin
- Sediment delivered to Beaufort Sea – mostly suspended - 85 Mt (Carson et al 1999)
- >99% clay-sized sediment in during early summer is flocculated (Droppo et al 1998)

Surface Texture – Clay content



Previous work – Hill et al 2001



Assumed bottomfast ice to 2 m isobath

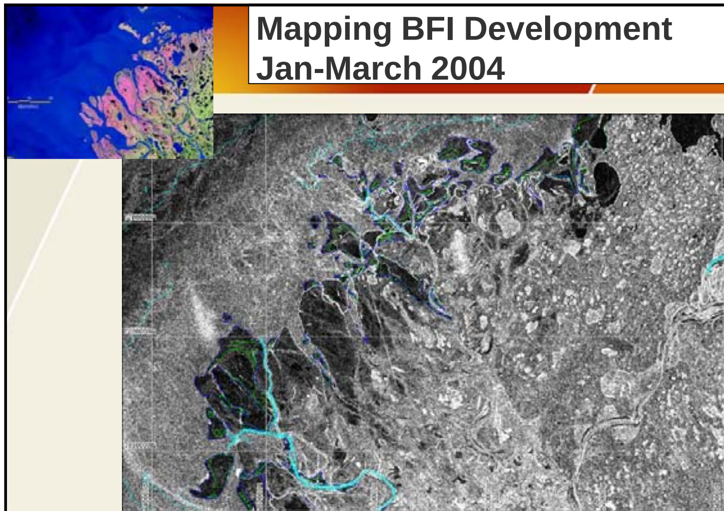
Based largely on geological evidence (cores, geophysics)

Limited information shallower than 4-5 m water depth

New investigations Seasonal Observations - Methods

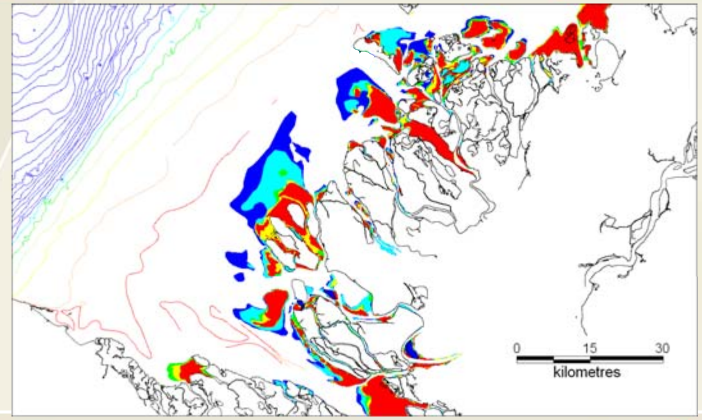
- Focus on oceanographic/fluvial processes/interactions and seabed mapping inside 4-6 m water depth
- Year-round surveillance using SAR and MODIS/MERIS satellite imagery
- Winter (March-April) operations from sea ice – GPR sampling/coring, sub-ice currents from the ice – supported by oil exploration logistics and helicopter
- Spring breakup – helicopter reconnaissance, under-ice current and turbidity measurements, overflood depth and timing measurements
- Summer – seabed mapping (sidescan, swath bathy, sub-bottom), sampling, in situ geotech, moorings (wave, current, T/S, turbidity)
- Numerical and physical modeling – nearshore hydrodynamics, strudel scour

Mapping BFI Development Jan-March 2004

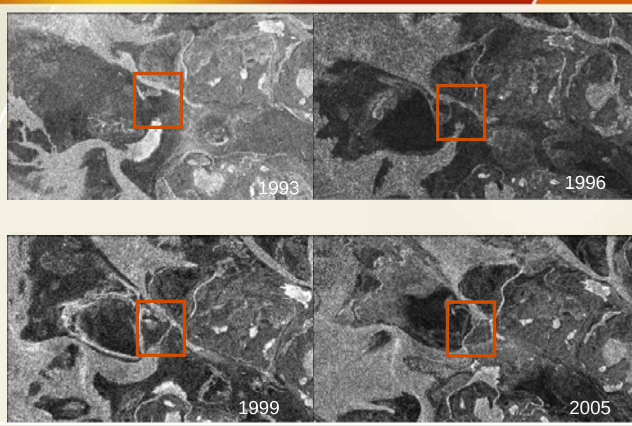


Grid 20 km

Nearshore morphology and maximum BFI extent: Proxy bathymetry



Channel Incision

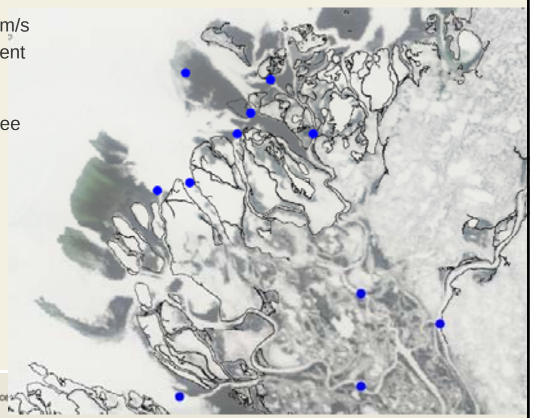


Spring breakup 2008

May 7, 18, 20, 22, 23, 24, 25, 30, June 4, 7, 11

Under ice currents, suspended sediments and temperature – 2008 snapshot

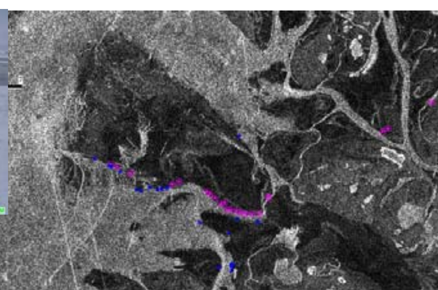
- At channel mouths and offshore
  - Currents 10-100 cm/s
  - Suspended sediment > 1 g/l
  - Temperatures generally < 1 degree

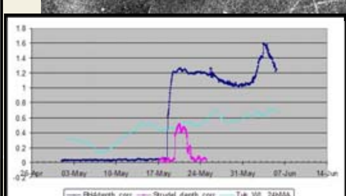


Overflow – sediment concentration

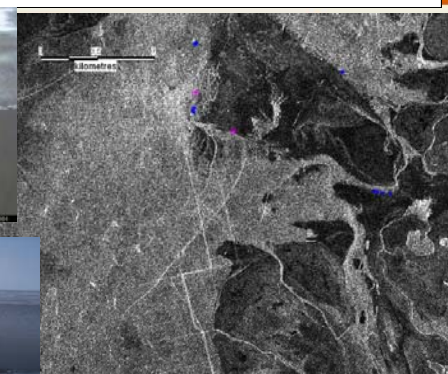
- Overflow waters – variable sediment concentrations

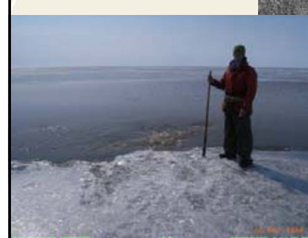
Overflow and upwelling May 21-22



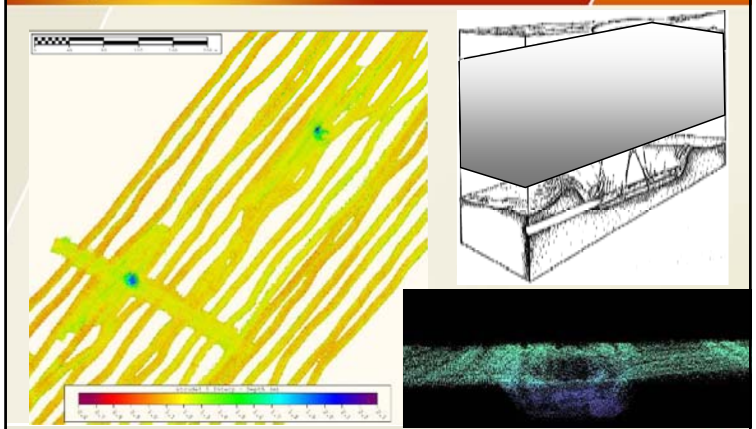


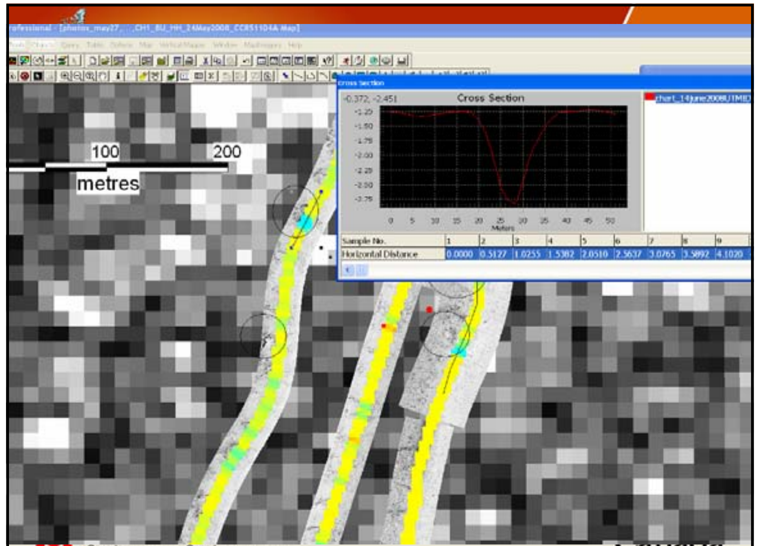
Strudel Drainage





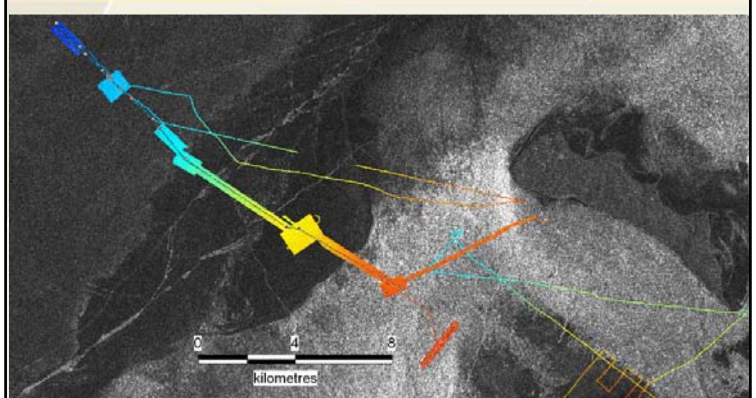
Strudel Scours August 2007





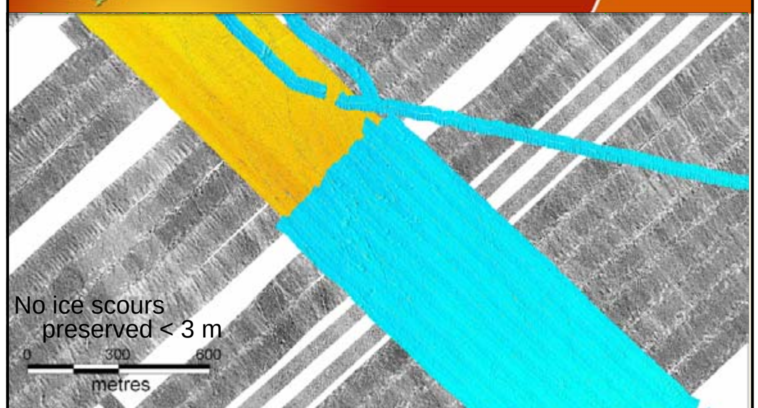
Canada Canada
Canada

Seabed Mapping



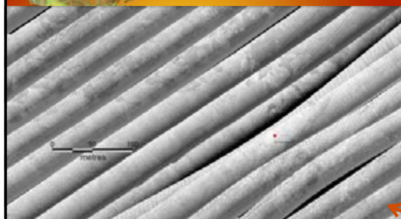
Natural Resources Canada Ressources naturelles Canada
Canada

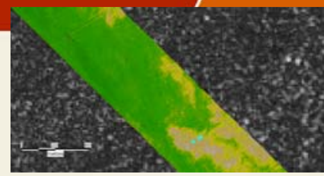
Ice Scour in shallow (5 m) water

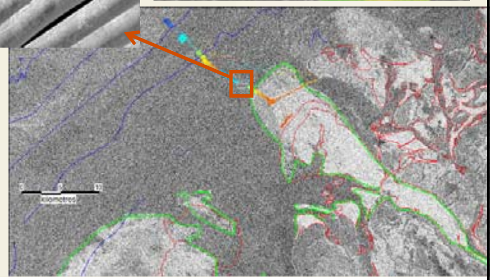


Natural Resources Canada Ressources naturelles Canada
Canada

Variable Textures – fluid mud?

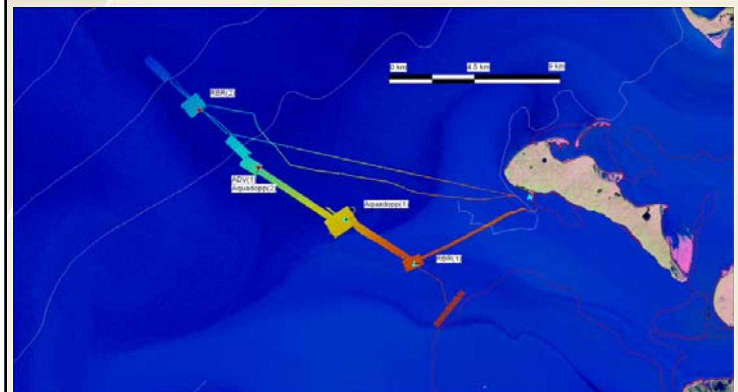




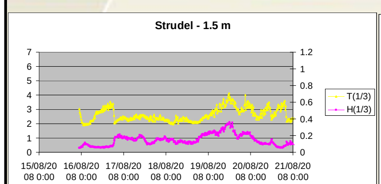


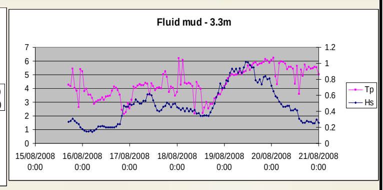
3 m WD

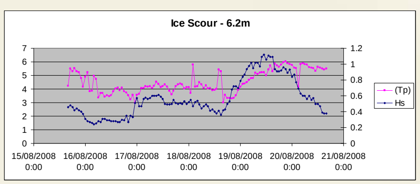
Oceanography and sediment dynamics – 2007-08 deployments



Wave attenuation 2008

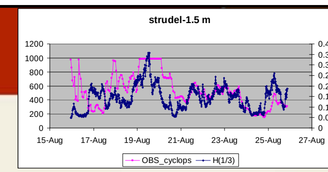


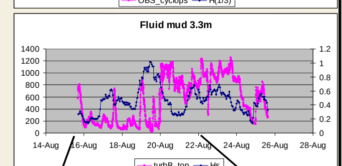


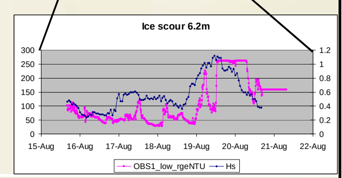


Waves and Turbidity-2008 deployments

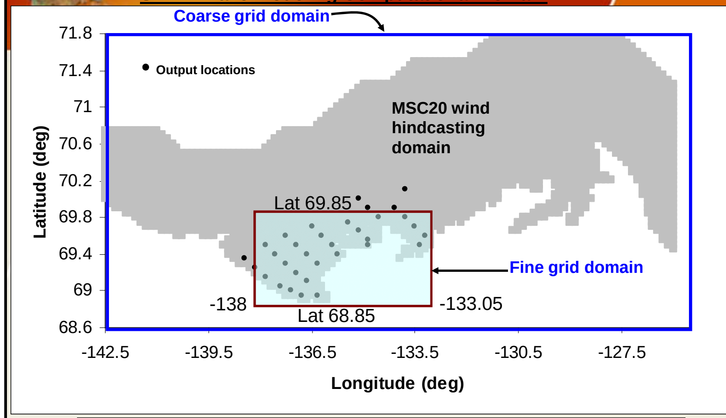
Note delayed response and continued turbidity at 3.3 m





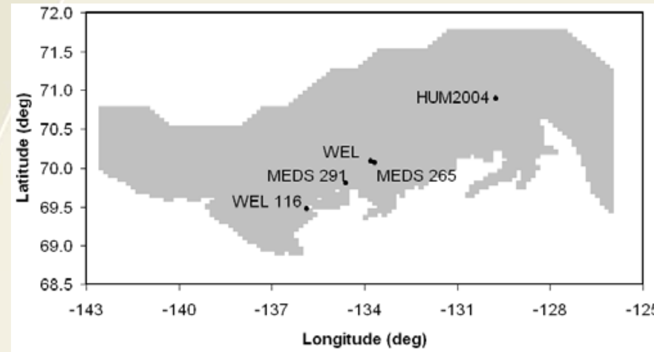


SWAN Wave modeling Computational Domain



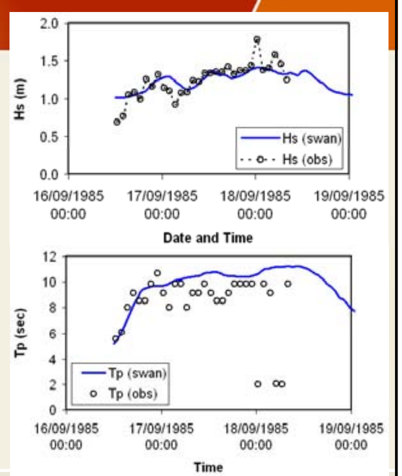
Grid	Latitude, λ	Longitude, φ	Δ_λ	Δ_φ	nλ	nφ	Δt (min)
Coarse	-142.5º ~ -126º	68.9º~71.75º	0.15º	0.05º	111	58	5
Fine	-138º ~ -133.05º	68.9º-69.85º	0.03º	0.01º	331	191	5

Location of available wave measurement buoys Data from MEDS

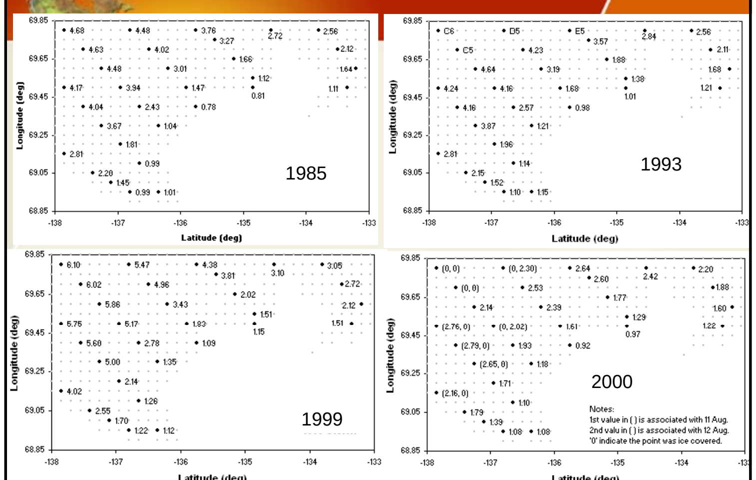


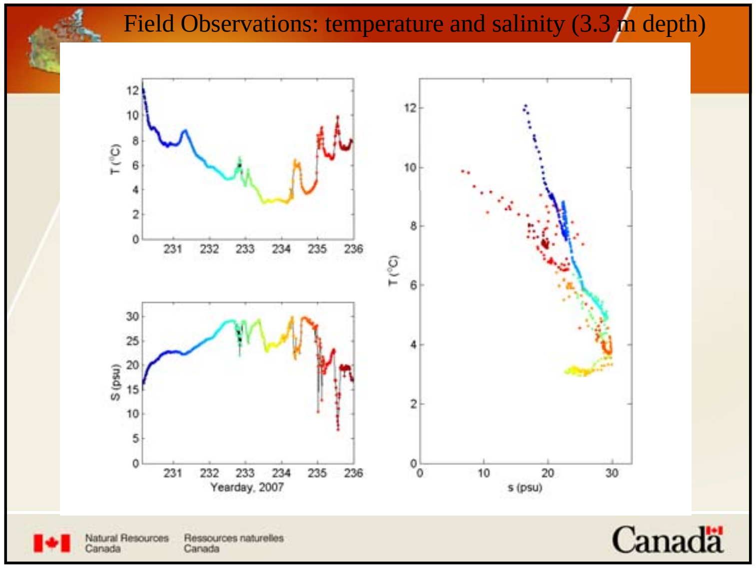
Comparison between observations and model prediction- WEL116

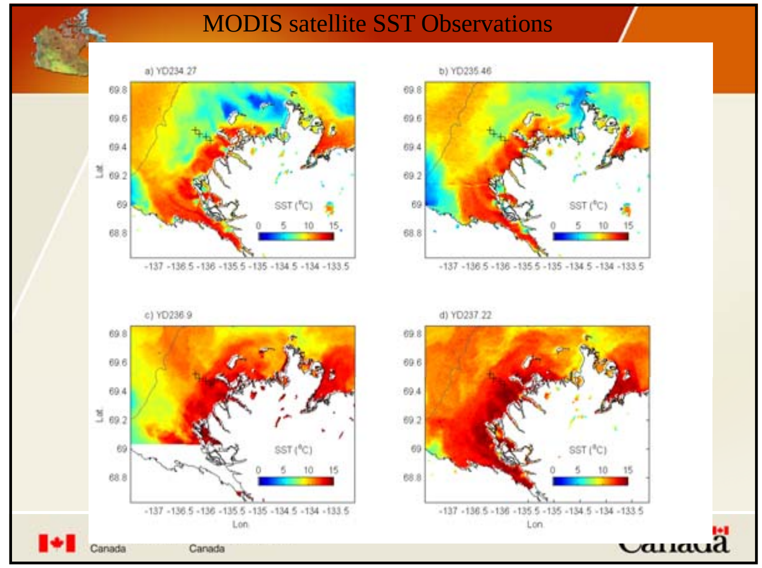
2.2 m water depth



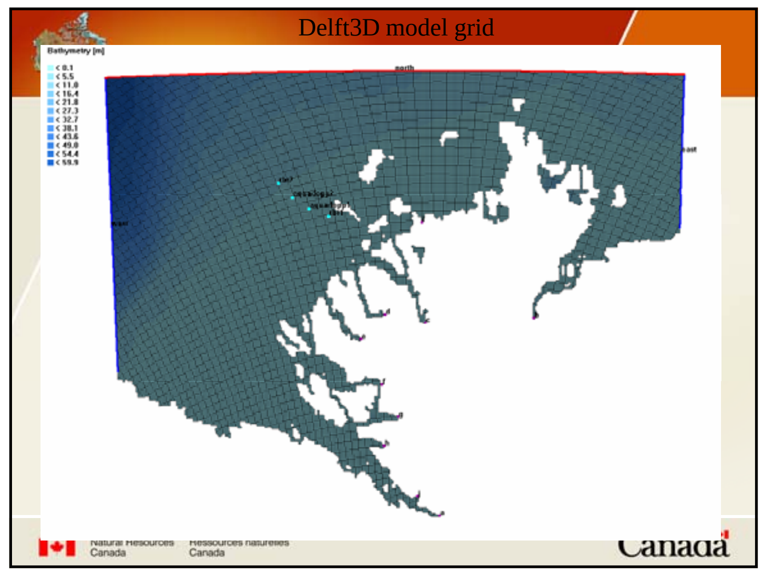
Peak wave height during four severe storms



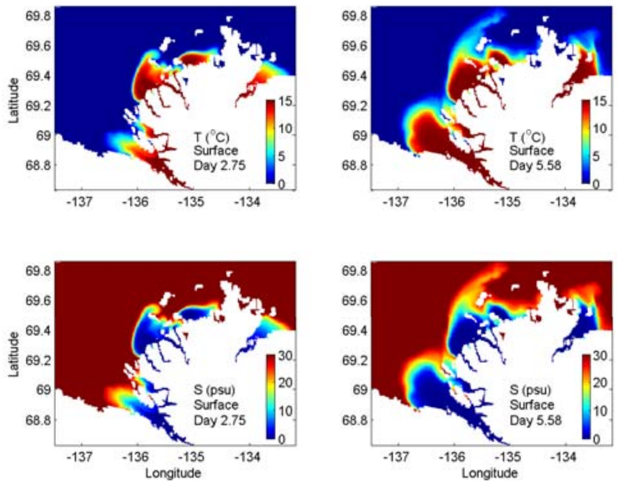

Field Observations: temperature and salinity (3.3 m depth)
T (°C)
S (psu)
Yearday, 2007
T (°C)
s (psu)
Natural Resources Canada
Ressources naturelles Canada
Canada


MODIS satellite SST Observations
a) YD234.27
b) YD235.46
c) YD236.9
d) YD237.22
SST (°C)
Lat
Lon

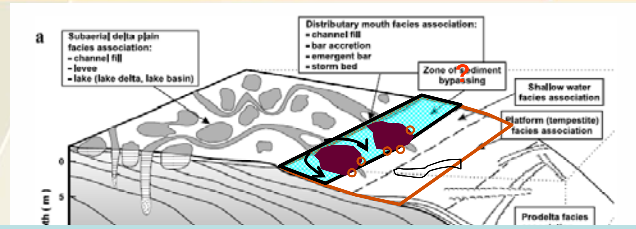

Upwelling?


Delft3D model grid
Bathymetry [m]

Delft3D model test: river plumes



Emerging models and new questions



- Ample capacity for under ice discharge in winter, but not during spring freshet or winter surges – potential enhanced under-ice velocity, upwelling and erosion
- Distributary mouth bar shoals extend well out onto the inner shelf and control permafrost distribution and spring overflood locations
- Ice scours extend into 3 m water depth – related to landfast ice formation?
- Strudel scours occur – frequency and magnitude uncertain – location related to bottomfast ice
- Evidence for a "fluid mud" phase during spring and wave-induced resuspension events

Future - Challenges

- Development of instrument moorings to make measurements under ice throughout breakup
- Use of remote sensing (esp SAR) operationally to monitor for extreme events
- Continued observations to support and validate wave and hydrodynamic models in very shallow water
- Role of fluid mud as a depositional process
- Use of AUVs for shallow water mapping
- Better linkages between fluvial and offshore models

END

5.6.3 Automated Lagrangian Water Quality Assessment System (ALWAS),

Robert Shuchman, Guy Meadows, Liza Jenkins, Chuck Hatt, John Payne

1 Michigan Tech Research Institute

[2] University of Michigan, Marine Hydrodynamics Laboratory

[3]North Slope Science Initiative

ALWAS (Automated Lagrangian Water Quality Assessment System) is a relatively inexpensive, helicopter-deployable, free-floating, water quality measuring and watershed evaluation system. It is capable of making a wide range of measurement every minute, transmitting the data in real-time as well as storing the data (up to eight hours) for later retrieval and analysis. The ALWAS water quality observations are calibrated and quality controlled during data collection and the results are displayed in a geographic information system (GIS) which greatly facilitates the interpretation.

The ALWAS system includes the buoy, water quality sensors, a microprocessor and recording device, GIS interface software, and a decision support system (DSS) that generates real-time water quality maps based on the measurements. The buoy, as presently configured, measures these parameters at a user-selectable sampling rate. The following parameters are recorded: GPS data, including geographic location (latitude and longitude), speed and heading, GPS signal quality metric, number of visible satellites, time, and date; water properties, including temperature, depth, conductivity, salinity, total dissolved solids, pH, dissolved oxygen, turbidity, chlorophyll-a, oxidation reduction potential, nitrate, ammonium, chloride, and blue-green algae; and ancillary data, including barometric pressure, battery voltage, and remaining memory.

Three ALWAS systems, and its cousin BathyBoat (only in 2008), were successfully deployed on the North Slope of Alaska during the summers of 2006 and 2008. In the 2006 deployment, 16 lakes and the Colville River were sampled over a five data period generating over 3,570 successful observations. The results of the 2006 collection are summarized in ALWAS Water Quality Sampling of Alaskan North Slope Lakes (can be found at www.northslope.org). In addition to providing the baseline water quality characterization for North Slope lakes, ALWAS data has also been used to provide control and algorithm validation points for satellite remote sensing of the extensive North Slope region. Specifically, water depths from ALWAS and BathyBoat have been used in an electro-optic-based water depth algorithm to produce bathymetry and volume of lakes within the National Petroleum Reserve Alaska (NPRA) region of the North Slope. Additionally, in situ data from the ALWAS buoys have been used to tune and validate satellite methods to then extend estimate of turbidity, chlorophyll, and salinity (expressed in alterations of aquatic vegetation and shoreline communities) to lakes that have not been directly sampled. These observations can then be linked to trophic index, saltwater intrusion, and vegetation in the North Slope region.

MichiganTech Research Institute

Automated Lagrangian Water Quality Assessment System (ALWAS)

Presented by: Robert Shuchman shuchman@mtu.edu

United States and Canada Northern Oil and Gas Research Forum
October 30, 2008

Robert Shuchman, MTRI
Liza Jenkins, MTRI
Chuck Hatt, MTRI
John Payne, NSSI
Guy Meadows, UofM

www.mtri.org

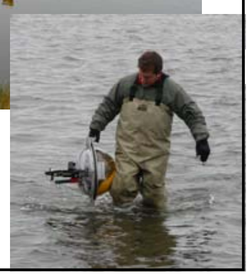
Program Objectives

- Technology demonstration of helicopter deployed autonomous water quality and bathymetry mapping robotic instruments

- Scientific Questions:
  - Baseline characterization of NPRA lakes
  - Change in water properties of lakes over time
  - Documentation of salt water intrusion in lakes near coast
  - Water quality parameters specific to yellow billed loon presence
  - In situ water depth to initialize and validate remote sensing bathymetry
  - Contrasting water quality parameter of lakes near Barrow with lakes near Inigok and Alpine

ALWAS

- Standard sensors:
  - Depth
  - Temperature
  - Conductivity
  - Salinity
  - Total dissolved solids
  - pH
  - Oxidation-reduction potential
- Optical sensors:
  - Dissolved oxygen
  - Turbidity
  - Chlorophyll-a
  - Blue green algae
- ISE sensors:
  - Nitrates
  - Ammonium
  - Chlorides



Description of the ALWAS buoy

- Inexpensive, with easily replaceable components
- Free-floating, sail-powered, or jet-driven
- Capable of measuring a data point with multiple parameters as rapidly as every 40 seconds.
- Data is transmitted for real-time viewing and is stored for future retrieval and analysis.
- Stored data is easily downloaded into a geographic database (ESRI shapefile) and spreadsheet formats.
- ALWAS uses state-of-the-art sensors to measure water quality parameters and GPS data.
- Currently, three different ALWAS buoys exist:
  - Senior standard configuration (sail powered)
  - Senior experimental configuration (remote controlled water jet driven)
  - Junior (sail powered)

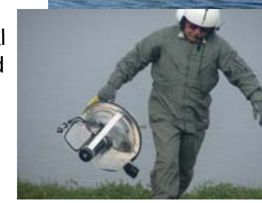
BathyBoat

- Vessel equipped with:
  - High-resolution GPS unit
  - Precision depth sounder
  - Water temperature, conductivity, and salinity sensors

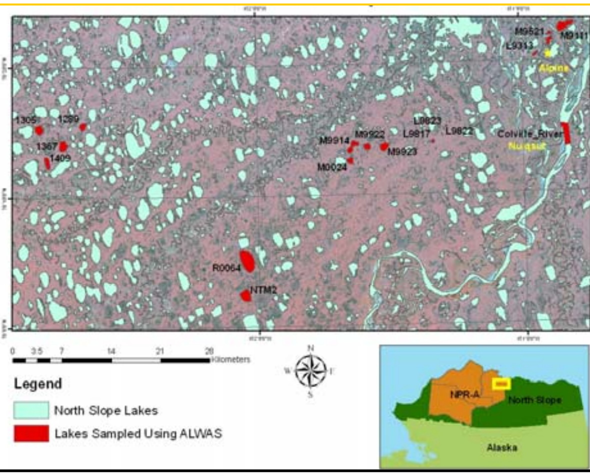
  - Data recording and storage device
  - Radio communication package

Summer 2006 Field Collection

- Five day engineering test of new buoys staged out of ConocoPhillips Alpine facility
- 16 North Slope lakes and Coleville River sampled
- Over 3,570 individual data values collected



2006 ALWAS North Slope Lakes



2006 Summary Statistics

	pH				DO				Specific Conductivity				Turb				TDS				Temp			
Name	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
NTM2	8.41	8.88	8.72	0.09	10.24	12.32	10.79	0.48	0.412	0.496	0.436	0.017	0.4	39.4	6.6	9.4	306.21	366.10	323.58	12.33	9.18	14.96	12.28	1.38
NTM1	8.45	8.52	8.48	0.01	10.08	10.44	10.18	0.06	0.340	0.440	0.384	0.012	0.0	39.5	0.6	1.8	254.90	326.10	286.60	8.59	13.04	14.55	13.69	0.43
M9923	8.36	8.41	8.39	0.01	10.06	10.39	10.24	0.05	0.370	0.373	0.371	0.001	0.1	19.1	1.1	3.0	276.30	277.80	277.52	0.46	12.66	13.08	12.83	0.12
M9922	7.66	8.06	7.99	0.04	9.08	9.87	9.63	0.08	0.276	0.281	0.278	0.001	0.8	23.5	2.6	2.3	209.38	212.94	211.02	0.74	14.90	16.01	15.76	0.25
M9914	7.64	7.94	7.71	0.05	9.87	10.39	9.93	0.08	0.135	0.136	0.135	0.000	0.9	2.7	0.1	0.4	109.00	109.70	109.18	0.32	10.53	13.32	12.98	0.69
M0024	7.89	8.18	7.96	0.04	9.89	10.40	10.17	0.10	0.186	0.189	0.187	0.001	0.0	8.9	0.2	0.7	145.30	147.44	145.69	0.39	14.04	14.63	14.17	0.14
L9823	7.60	8.07	7.66	0.06	8.82	9.81	9.57	0.10	0.134	0.135	0.134	0.000	0.0	6.5	0.3	0.7	108.28	108.99	108.29	0.11	16.52	16.67	16.59	0.03
L9817	7.79	7.97	7.87	0.03	9.16	9.98	9.31	0.10	0.409	0.412	0.410	0.001	0.5	3.5	1.3	0.6	304.40	306.20	304.00	0.44	16.35	16.68	16.51	0.11
FWS1409	8.16	8.43	8.26	0.07	9.89	10.47	10.11	0.12	0.213	0.217	0.215	0.001	0.0	22.8	0.8	2.7	164.52	167.37	166.32	0.58	12.54	14.97	13.62	0.67
FWS1367	8.39	8.48	8.47	0.02	10.43	10.75	10.47	0.05	0.287	0.290	0.288	0.001	0.0	0.1	0.0	0.1	217.21	219.34	218.40	0.40	11.41	12.86	12.57	0.37
FWS1305	8.04	8.31	8.15	0.06	9.70	10.15	9.93	0.12	0.277	0.281	0.278	0.001	0.0	1.6	0.3	0.3	210.09	212.90	210.90	0.51	14.06	15.10	14.39	0.26
FWS1289	8.38	8.42	8.40	0.01	10.34	11.16	10.48	0.15	0.263	0.277	0.264	0.002	0.0	0.4	0.1	0.1	200.13	210.09	201.21	1.61	11.70	13.22	12.98	0.39
CD1	7.30	8.04	7.96	0.11	8.90	10.08	9.98	0.14	0.299	0.304	0.303	0.001	0.0	4.0	0.1	0.5	225.70	229.30	228.40	0.48	16.62	17.57	16.93	0.23
Colville River	7.97	8.32	8.06	0.13	9.69	10.45	10.19	0.23	0.227	0.368	0.342	0.051	3.4	451.1	311.4	153.5	174.50	274.88	256.88	36.26	12.12	13.41	12.41	0.41

	ORP				Salinity				NO3				NH4				Cl			
Name	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
NTM2	157.0	177.2	163.2	3.1	0.12	0.17	0.13	0.01	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
NTM1	184.6	203.2	197.4	4.7	0.09	0.14	0.11	0.01	0.001	6.980	1.080	0.549	0.128	0.178	0.165	0.004	217.3	235.2	227.3	3.6
M9923	156.4	179.0	174.9	5.2	0.10	0.10	0.10	0.01	0.903	2.890	1.980	0.306	0.165	0.186	0.171	0.004	190.3	202.8	196.7	2.6
M9922	57.9	181.4	152.7	21.1	0.06	0.06	0.06	0.00	0.266	1.647	1.372	0.218	0.190	0.224	0.216	0.005	187.7	214.6	208.3	4.2
M9914	183.0	194.8	190.8	2.6	0*	0*	0*	0*	0.133	2.111	1.424	0.425	0.105	0.168	0.152	0.015	142.2	150.2	145.0	2.1
M0024	141.8	182.5	161.8	4.6	0.01	0.01	0.01	0.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
L9823	91.4	135.4	120.3	10.3	0*	0*	0*	0*	0.026	1.115	0.847	0.202	0.086	0.150	0.139	0.014	129.4	147.9	144.2	2.9
L9817	104.0	144.4	127.8	11.9	0.13	0.14	0.13	0.00	0.331	0.562	0.451	0.077	0.150	0.230	0.211	0.017	251.9	272.8	267.6	3.5
FWS1409	84.2	200.2	171.8	25.8	0.02	0.02	0.02	0.00	0.619	0.907	0.754	0.062	0.092	0.108	0.100	0.004	128.1	137.0	132.4	1.7
FWS1367	170.9	183.4	176.6	3.7	0.05	0.06	0.05	0.00	0.810	1.260	0.920	0.088	0.121	0.166	0.131	0.008	160.1	163.8	161.9	1.1
FWS1305	144.9	172.7	164.4	5.3	0.05	0.06	0.05	0.00	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FWS1289	161.3	185.0	179.7	4.8	0.04	0.04	0.04	0.00	0.908	1.166	0.991	0.070	0.101	0.107	0.103	0.002	150.4	159.8	153.0	2.1
CD1	130.6	156.0	149.1	4.6	0.07	0.08	0.08	0.00	0.260	0.391	0.336	0.031	0.351	0.855	0.382	0.055	215.0	224.4	220.0	2.0
Colville River	107.7	171.7	152.8	16.9	0.02	0.09	0.08	0.02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

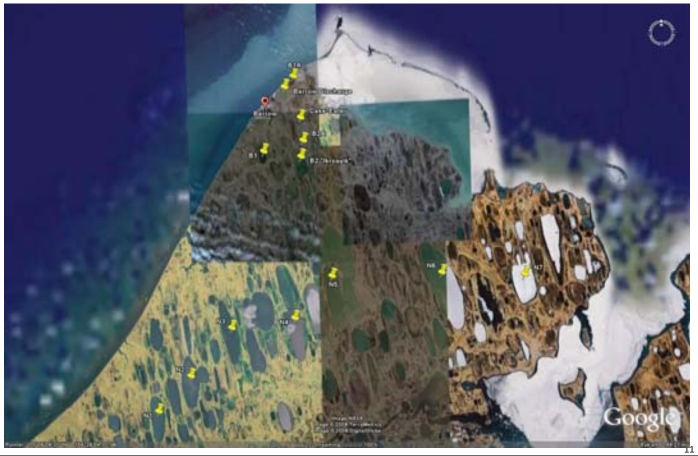
- The full set of observations is located in *ALWAS Water Quality Sampling of Alaskan North Slope Lakes -- Report on 2006 Field Activities which can be found at* *www.northslope.org*

Summer 2008 Field Collection

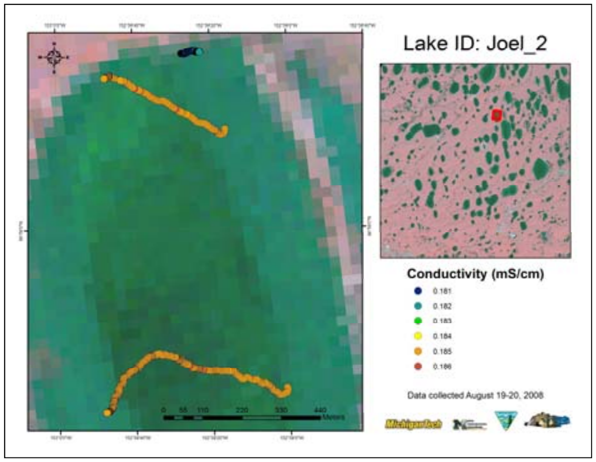
- 24 lakes within 40 miles of BLM Inigok field facility
- 13 lakes within 25 miles of Barrow

Summer 2008 Inigok Sites

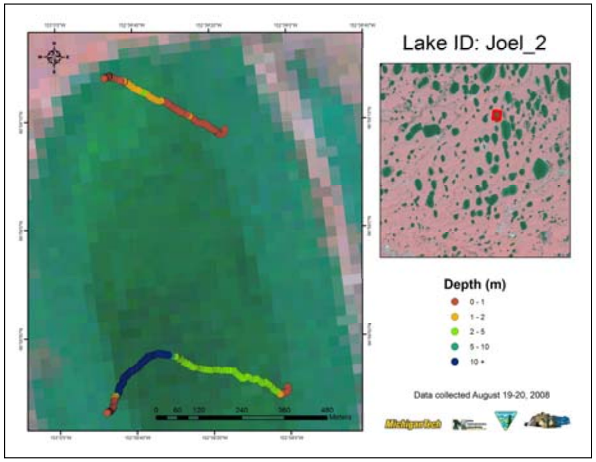
Summer 2008 Barrow Sites



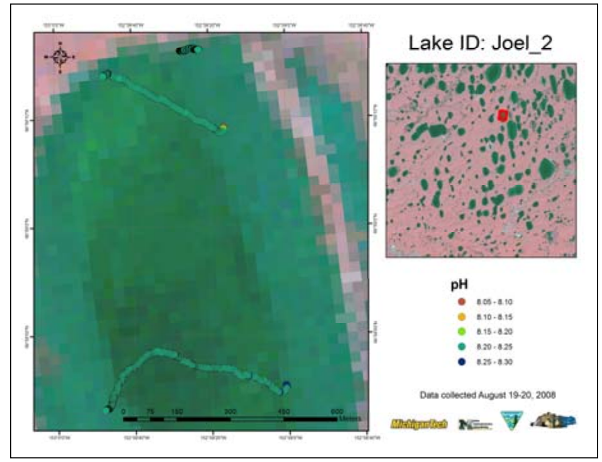
ALWAS Inigok Example: Conductivity



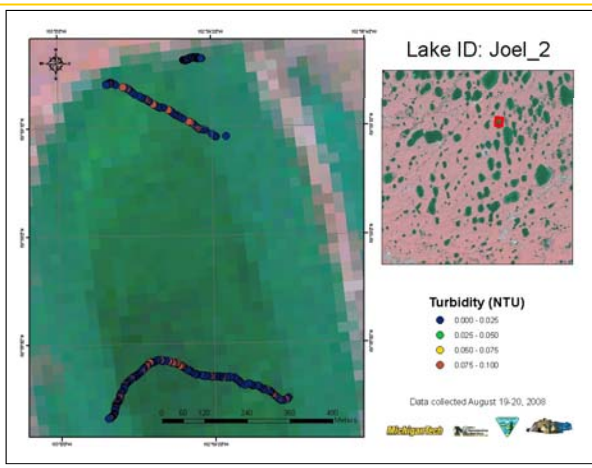
ALWAS Inigok Example: Depth



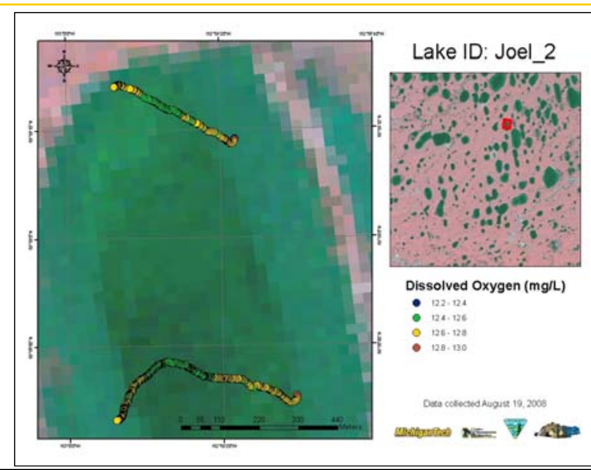
ALWAS Inigok Example: pH



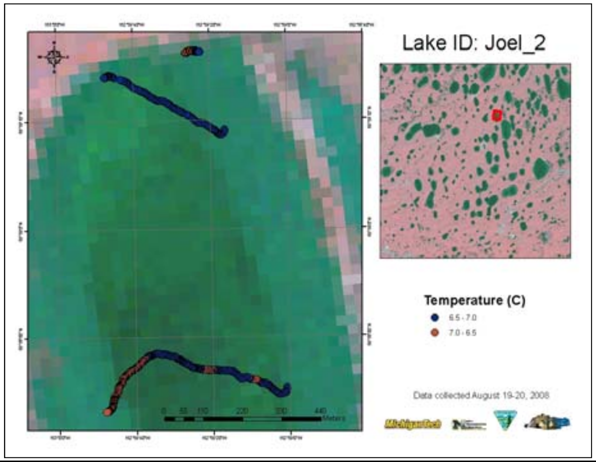
ALWAS Inigok Example: Turbidity



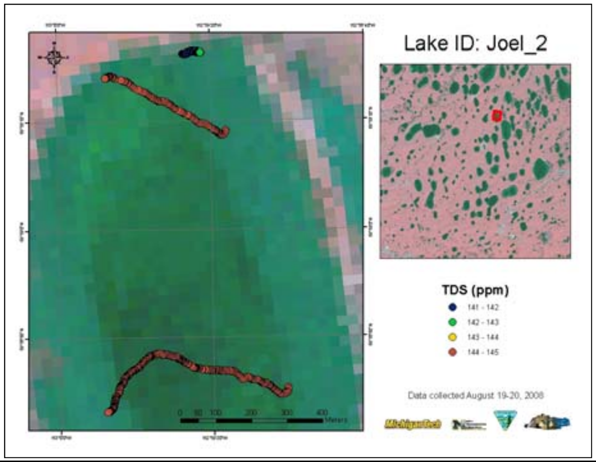
ALWAS Inigok Example: DO



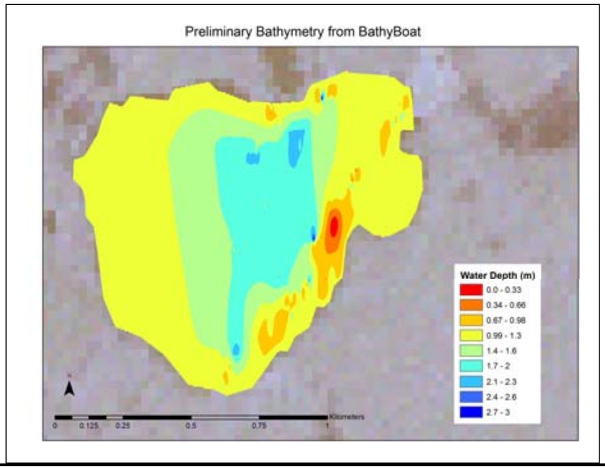
ALWAS Inigok Example: Temperature



ALWAS Inigok Example: TDS



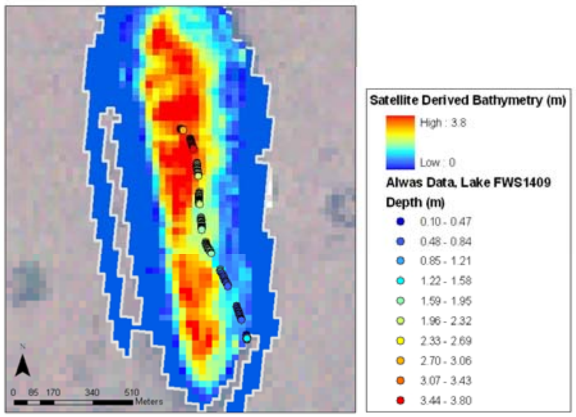
BathyBoat Inigok Example



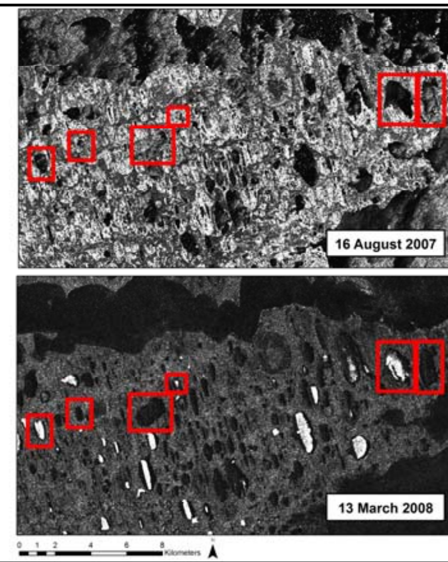
Satellite Derived Depth Via ALWAS/BathyBoat Data

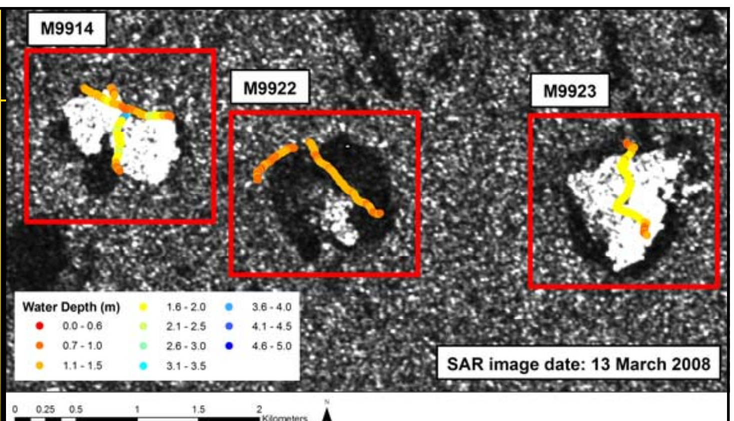
- Bathymetry maps can be created using remote sensing images from multi-spectral sensors such as Landsat and high resolution commercial satellite data such as IKONOS/QuickBird.
- North Slope lakes have ideal water properties for use with the algorithm. The satellite needs to be able to "see" the lake bottom, and North Slope lakes are generally clear and shallow.
- In-situ depth values are needed in order to calibrate the algorithm, which can be provided by ALWAS and BathyBoat.

Satellite Water Depth Example



- North Slope SAR image can be used for bathymetry analysis
- Frozen to lakebed < 2 m → low backscatter → dark
- Not frozen to lakebed → high backscatter → bright





- M9923 Min 0.0 m, Max 2.1 m (not frozen in SAR)
- M9922 Min 0.0 m, Max 2.0 m (frozen in SAR)
- M9914 Min 0.0 m, Max 4.5 m (not frozen in SAR)

Some Preliminary Observations

- Water quality of lakes sampled in NPRA is good (no values outside of published acceptable ranges).
- Water quality at M9914, M9922, and M9923 has changed little between 2006 and 2008.
- Conductivity/salinity measurement at Teshekpuk Lake and lakes measured within 10 miles of coast may indicate slight salt water intrusion (slightly elevated conductivity).
- Pairs of loon presence/loon absence lakes sampled near Inigok indicate significant differences in depth, conductivity, pH, TDS, and temperature.

Concluding Remarks

- ALWAS and BathyBoat instruments are effective tools for rapid characterization of North Slope lake water parameters
- The buoys are highly cost effective with 5-8 lakes sampled in one day
- Merging of in situ buoy data with satellite observations can result in extended lake depth surveys
- ALWAS and BathyBoat water quality parameter characterization support wildlife habitat studies
- Continuing logistics/engineering modifications to improve field collection efficiency

5.6.4 Subsidence, Flooding, and Erosion Hazards in the Mackenzie-Beaufort Region,

Donald L. Forbes, M.R. Craymer, G.K. Manson, P. Marsh, S.M. Solomon & D. Whalen

[1] Research Scientist, Geological Survey of Canada, Natural Resources Canada. Email: dforbes@nrcan.gc.ca

Natural gas discoveries in the Mackenzie Delta spurred development of the Mackenzie Gas Pipeline to deliver gas to southern markets via a route up the Mackenzie Valley to Alberta. Construction of the pipeline would enable production from the Taglu and Niglintgak gas fields in the delta and other discoveries. This study was undertaken in response to concern about sources and rates of subsidence in the delta and implications for flooding and erosion hazards, including impacts on nesting bird habitat. The project addresses design constraints and environmental impacts of development for the information of regulators, industry, and Inuvialuit communities.

Little is known about sources of subsidence in major Arctic deltas such as the Mackenzie. Permafrost with varying conditions of ice-bonding extends to >600 m beneath the margins of the delta and to lesser depths (<100 m) beneath the Holocene delta plain. A vast network of lakes and channels covers the delta plain: many are <2 m deep and freeze to the bottom in winter, maintaining sub-zero temperatures in underlying deposits; others are deeper, do not freeze to the bottom, and create taliks in underlying sediments. The result is a frozen surface layer punctuated by numerous thaw bulbs and pipes in which sediment compaction can proceed unimpeded by ice bonding and through which gas venting can occur. Other sources of subsidence include postglacial isostatic adjustment, crustal response to long-term delta loading, tectonics, and deepening of the surface active layer inducing thaw of shallow excess ice. Several linear features (channels, lakes, and the eastern edge of the delta along the Caribou Hills escarpment) may be the surface expression of underlying faults.

Rates of subsidence in the Mackenzie Delta are being determined using a range of techniques, including geophysical models, the tide-gauge record at Tuktoyaktuk, continuous and episodic GPS, and InSAR. The low-relief delta plain topography is being mapped using airborne LiDAR to create a digital elevation model with vertical resolution of ±0.2 m. Coastal erosion across the region has been measured by repetitive surveys and digital photogrammetry with QuickBird imagery. Preliminary results indicate variable rates of subsidence reaching 11 mm/yr or more. With regional isostatic subsidence of ~2 mm/yr, this implies delta compaction+loading at rates as high as 9 mm/yr, which seems high for an ice-bonded delta, perhaps pointing to a tectonic component. In addition to subsidence, other factors relevant to flood risk in the outer delta include relative sea level rise (3.5±1.2 mm/yr at Tuktoyaktuk), storm surges, changes in spring freshet affecting breakup flooding, other climate factors in the Mackenzie drainage basin, and any differential tilting across the delta.

This work has been supported by Natural Resources Canada (PERD, GSC, PCSP), Indian and Northern Affairs Canada (Northern Oil and Gas Research Initiative and IPY funding), Environment Canada, ArcticNet and the Networks of Centres of Excellence, Aurora Research Institute, Chevron Canada Resources, and MGM Energy Corporation, among others, and guided through annual consultation with Inuvialuit communities. Field support from JC Lavergne has been critical to the success of this project.

Subsidence, flooding, and erosion hazards in the Mackenzie-Beaufort region

Don Forbes[1], Mike Craymer[2], Gavin Manson[1], Phil Marsh[3], Steve Solomon[1], Dustin Whalen[1]

[1]Geological Survey of Canada, Natural Resources Canada, Dartmouth, NS
[2]Geodetic Survey Division, Natural Resources Canada, Ottawa
[3]National Water Research Institute, Environment Canada, Saskatoon, SK

Some issues relevant to production onshore in the Mackenzie Delta

- Flooding hazards
  e.g. habitat inundation in KIBS;
  design freeboard for production facilities
- Breakup and storm-surge flooding
- Sea-level rise
- Multiple sources of subsidence
  - glacio-isostatic adjustment, loading, compaction, thaw consolidation, and future production-induced subsidence, tectonics,
- Permafrost, ice-content, and other geotechnical properties affecting foundations and compaction processes in delta deposits
- Shoreline erosion

Mackenzie Delta subsidence & flooding hazards

Robust projections of inundation and flooding in the Mackenzie Delta require

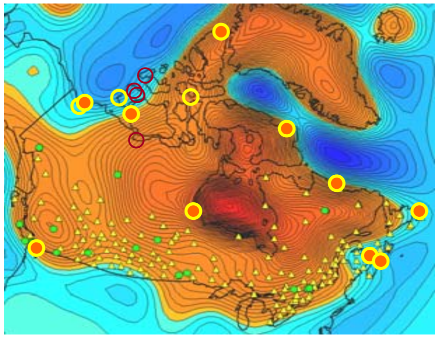
- knowledge of regional trends in vertical motion & sea levels
- improved estimates of delta loading, compaction, and future production-induced subsidence
- improved understanding of tectonic setting

Regional vertical motion and SLR

Partnership with Geodetic Survey (NRCan) and Canadian Hydrographic Service (DFO)

*from Andrews (1989)

ICE-4G model of present vertical motion

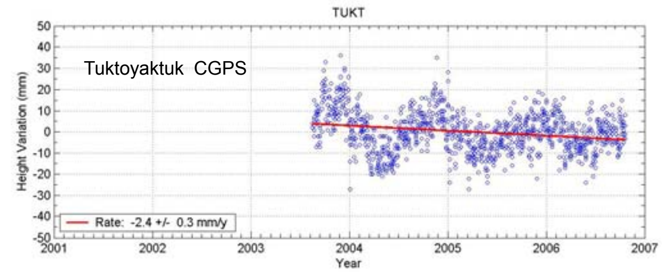


Canadian Spatial Reference System *(NRCan/ESS)* & vertical velocity from ICE-4G *(W.R. Peltier University of Toronto)*

co-located GPS and tide gauge

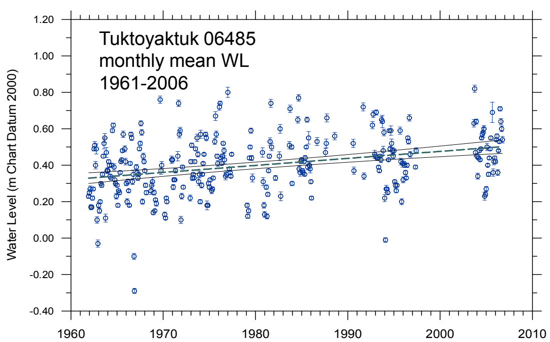
Continuous GPS observations co-located with tide gauges at Tuktoyaktuk and Ulukhaktok in western Arctic

Preliminary analysis using PPP provides vertical motion estimate consistent with geological and WL evidence



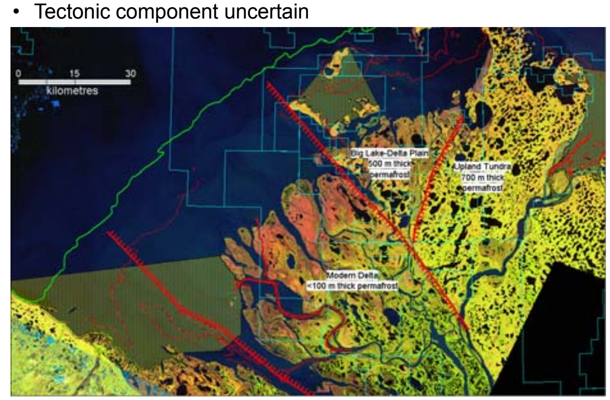
Tide-gauge record at Tuktoyaktuk

45-year rising trend (1961-2006) +3.5 ± 1.2 mm/yr



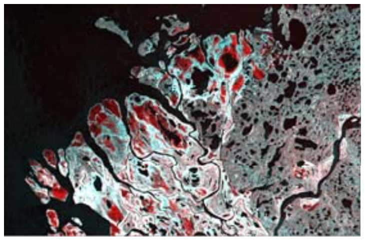
Subsidence in the Mackenzie Delta

- Long-term subsidence due to sediment loading is a component of vertical motion on the outer delta plain
- Tectonic component uncertain

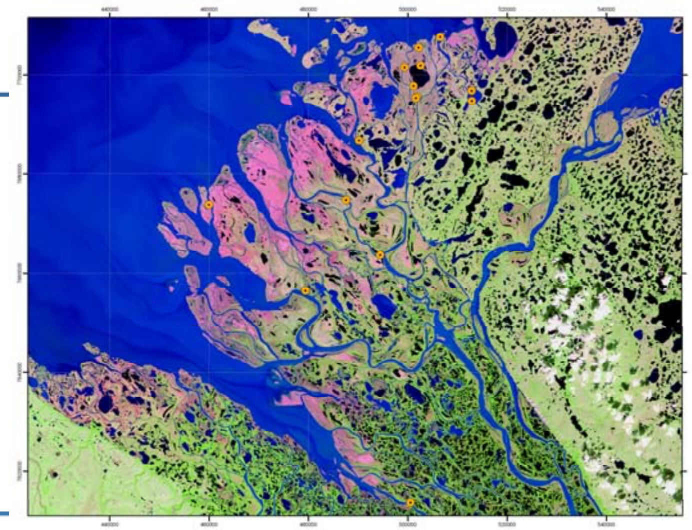


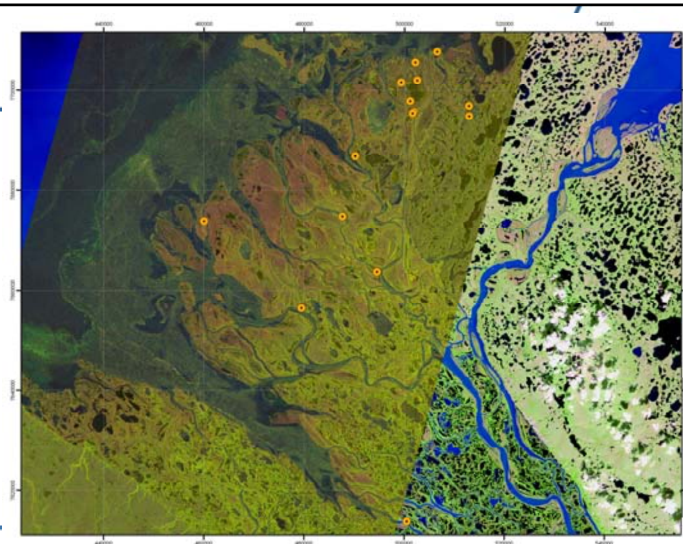
Compaction

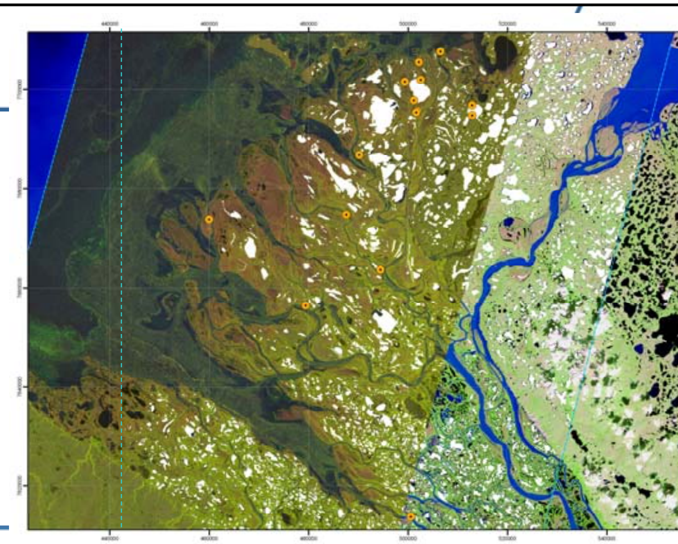
Compaction in the upper part of the modern delta is limited by permafrost and ice-bonding, but may continue at greater depth and in thaw taliks below lakes and channels

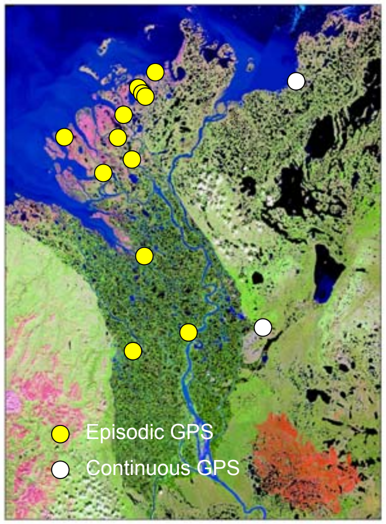


Induced subsidence due to reservoir compaction expected once natural gas production begins









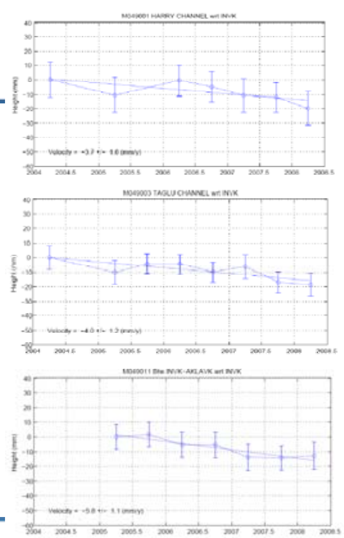
Measuring Mackenzie Delta subsidence

- 9 episodic sites established in the Mackenzie Delta in 2004 and 2005
- Monitor natural subsidence prior to gas production
- Network densified in 2007-2008.
- Now 12 + 5 sites across Delta

Occupations (≥3 days) twice per year

M049001
Harry Channel near mouth

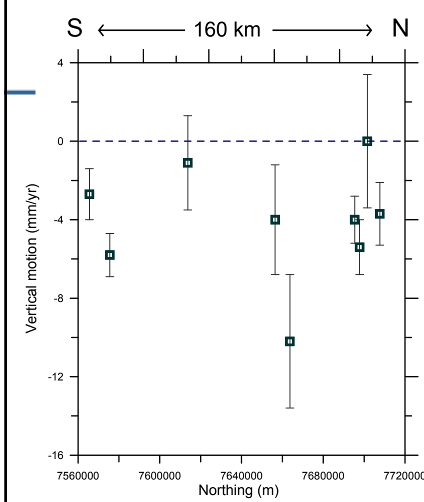
M049010
Peel Channel above Aklavik



Time series for three epoch sites on the Mackenzie Delta

All sites are in ice-bonded or partially ice-bonded deposits and vertical motion is considered representative of the upper 30 m of sediment.

Rates with respect to Inuvik (~0 mm/yr)

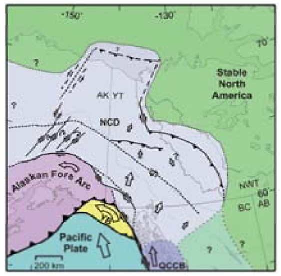


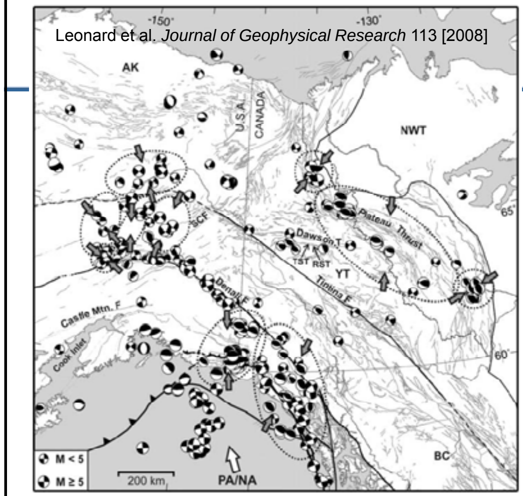
GPS epoch rates for Mackenzie Delta

- Variable subsidence rates
- Mean -4 mm/yr
- Max -10.2 ± 3.4 mm/yr
- No systematic pattern
- Very high rates for compaction and loading of ice-bonded deposits …
- Is there a tectonic component?

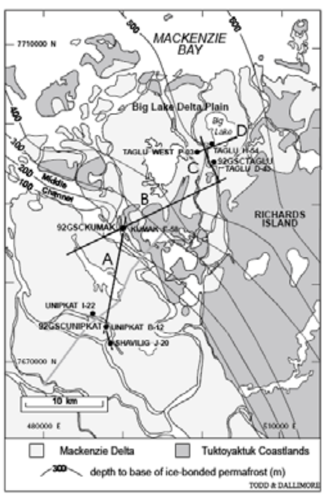
The Mackenzie-Beaufort region may be a currently active thrust front

- The potential for severe thrust earthquakes and tsunamis may warrant some examination (pers. comm. Roy Hyndman, PGC, 2008).
- The rate of convergence is slow ~3-5 mm/yr, so the frequency of great thrust events is probably low.
- There should be an ongoing small horizontal and vertical deformation signal of the strain build up.



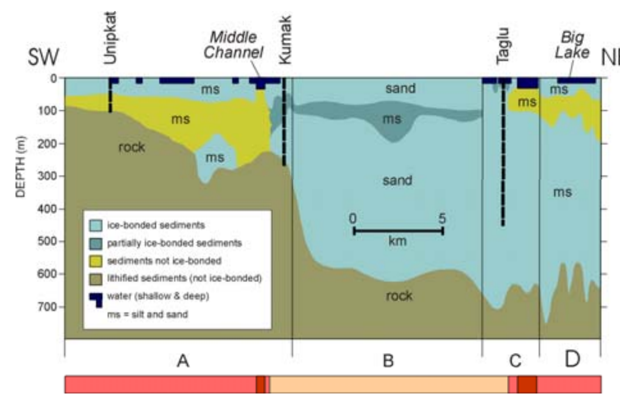


Leonard et al. *Journal of Geophysical Research* 113 [2008]



The challenge of estimating compaction rates

- Large differences in depth of permafrost
- No established basis for modelling in a delta section with ice-bonded and partially ice-bonded sediments



- Interpreted EM profile shown on previous slide (modified from Todd and Dallimore, 1997).
- Colour bar below is shows compaction potential (qualitative). Darker red implies more rapid compaction.

GPS occupation on MGM et al. Aput C-43 well casing
August 2008

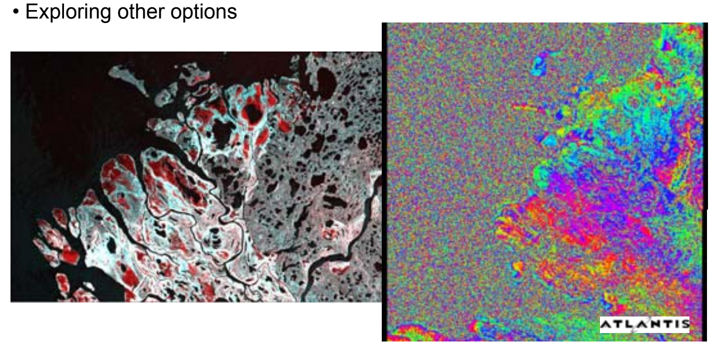
depth = 2101 m

69°02'02.5" N
135°41'48.6" W

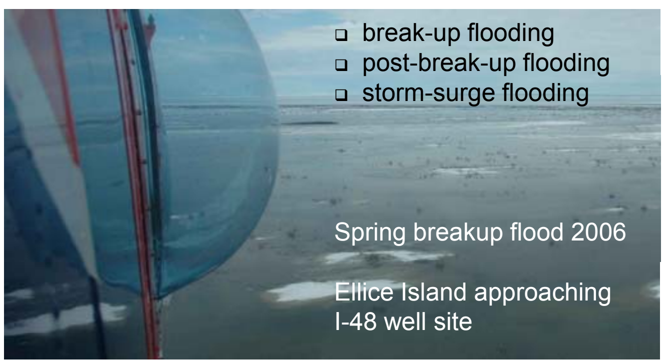
First deep monument occupied.

InSAR to densify estimates of differential vertical motion in the Mackenzie Delta

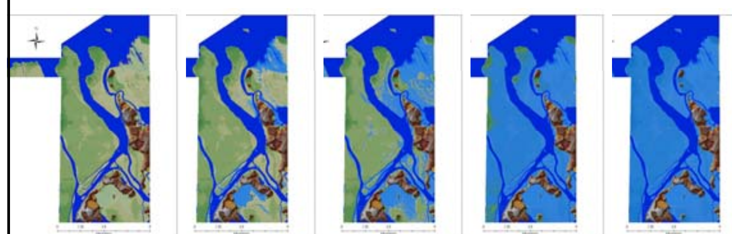
- Using permanent scatterer technique with reflectors
- Exploring other options



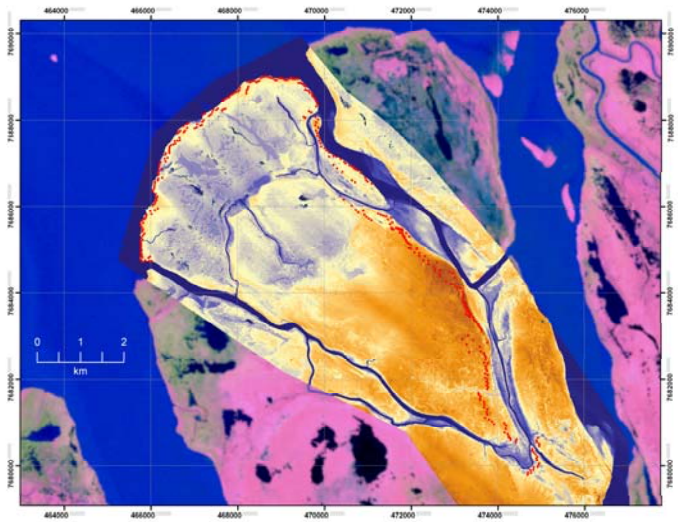
Flooding in the Mackenzie Delta today

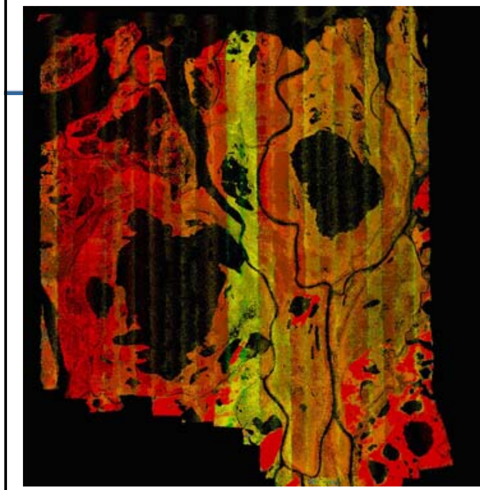


Storm surge flooding at Harry Channel

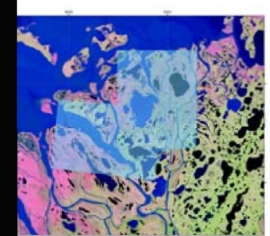


WL	0.00 m	+0.50 m 12% flooded	+0.75 m 33% flooded	+1.0 m 78% flooded	+2.1 m 85% flooded





2008 LiDAR
Taglu- Big Lake
backscatter
(unprocessed)



Projecting future changes in the frequency of flooding in the outer Delta

- Past water levels at existing WSC stations
- Computed channel slopes and how they vary
- Compared to known elevations and DEM from LiDAR (where available)

Assessments of surface hydrology and habitat impacts on the outer Mackenzie Delta

- Using hydrologic models to compute snowmelt, runoff and flood routing across delta land surface.

Conclusions

Mackenzie Delta subsidence & flooding hazards

Robust projections of inundation and flooding in the Mackenzie Delta require

- knowledge of regional trends in vertical motion & sea levels; better knowledge of storm surges and surface hydrology
- improved estimates of delta loading, compaction, and future production-induced subsidence
- Improved understanding of tectonic setting

Conclusions

Mackenzie Delta subsidence & flooding hazards - 1

Regional trends in vertical motion and sea levels:

- Western Arctic coastal plain is subsiding and relative sea level is rising
- ICE-5G estimate is approximately -2 mm/yr
- RSL at Tuktoyaktuk +3.5 ± 1.2 mm/yr (1961-2006)
- RSL on Delta could be up 1-7 mm/yr faster (i.e. another 5-35 cm in 50 years)

Conclusions

Mackenzie Delta subsidence & flooding hazards - 2

Storm surges and surface hydrology

- LiDAR (airborne laser altimetry) provides surface topography with decimetre resolution as required for flood modelling and surface flow routing.
- Large areas of outer delta flooded in spring freshet and again in storm surges through summer and fall.

Conclusions

Mackenzie Delta subsidence & flooding hazards - 3

Geotechnical properties and compaction of delta sediments:

- Shallow ice content highly variable and determined using GPR and cores.
- Depth and strength of ice-bonding is spatially variable and challenging to map.
- Modelling compaction in ‘swiss-cheese’ permafrost remains a challenge.

Conclusions

Mackenzie Delta subsidence & flooding hazards - 4

Management and regulatory implications:

- Preliminary measurements of baseline subsidence now available … Sources of subsidence not fully understood.
- Break-up and storm-surge flood dynamics and flow routing require more work … Need to complete hi-res digital elevation model (LiDAR)
- Tectonic hazards may require further attention.

Subsidence, flooding, and erosion hazards in the outer Mackenzie Delta

This work has been supported by:

- Natural Resources Canada (PERD, GSC, PCSP) ,
- Indian and Northern Affairs Canada (Northern Oil & Gas Research Initiative, GoC IPY funding),
- Environment Canada,
- ArcticNet and Networks of Centres of Excellence (Canada),
- Aurora Research Institute,
- Chevron Canada Resources,
- MGM Energy Corporation,
- University partners (Calgary, Memorial, &c).

Guided by annual consultation with Inuvialuit communities.

Field support by JC Lavergne was critical to success, as was support from numerous other colleagues and partners

Thank you !

5.6.5 Enhancement of Permafrost Monitoring in the Mackenzie Valley, *Sharon Smith*

Ph.D., Permafrost Research Scientist, Geological Survey of Canada, Natural Resources Canada.
Email: ssmith@nrcan.gc.ca

Permafrost is an important feature of the landscape of the Mackenzie Valley and Delta that has impacts on both the natural and socio-economic environments of the region. Permafrost and its associated ground ice can influence ecosystems through its influence on drainage patterns and ground stability as well as present challenges to northern development. Permafrost may warm and thaw in response to climate warming or disturbance to the ground surface such as that due to clearance of vegetation associated with development. Thawing of permafrost can lead to landscape instability, thermokarst development and ground subsidence which has important implications for northern infrastructure, hydrological processes, ecosystems and northern lifestyles. Knowledge of permafrost conditions, including thermal state and ground ice conditions, and their spatial and temporal variations is critical for engineering design of infrastructure in northern Canada, the assessment of environmental impacts and the characterization of the impacts of climate change. Ongoing monitoring of permafrost conditions is essential to understand how these conditions may change over time, to assess impacts on northern development, and to develop strategies to mitigate these changes.

Since the mid 1980's, the Geological Survey of Canada has maintained a permafrost monitoring network in the Mackenzie Valley including a suite of sites along the Norman Wells to Zama pipeline corridor. This network has generated information that has facilitated quantification of the rate of increase in permafrost temperatures over the last two decades as well as characterization of changes in thaw depth. The response of permafrost terrain to both pipeline development and climate change has also been characterized. The network has provided key information that supports environmental management of existing infrastructure and also the design and environmental assessment of future projects. There were, however, extensive gaps in the network including the region north of Norman Wells and the sensitive and dynamic environments of the Mackenzie Delta region. Funding acquired in 2004, through a Northern Energy Development Memorandum to Cabinet, enabled a collaborative field program to address gaps in baseline permafrost knowledge through drilling of over 50 boreholes, collection of samples for determination of geotechnical properties, and the installation of instrumentation for ground temperature monitoring.

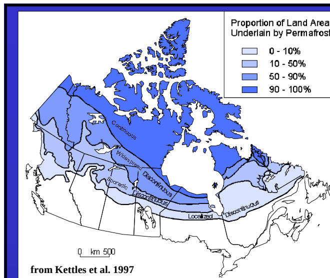
New information has been generated on the physical properties of the soils in representative terrain types throughout the region. Initial ground temperature data has been acquired and this has facilitated a characterization of the thermal state of permafrost in areas where little recent information was available. These data can be utilized in the engineering design of future projects and the associated regulatory processes. The provision of improved information on permafrost conditions also provides a baseline against which change can be measured forming a key component of future environmental effects monitoring and management programs. The enhanced permafrost monitoring network can also contribute to future monitoring programs associated with hydrocarbon and other development in the Mackenzie corridor.

Enhancement of Permafrost Monitoring in the Mackenzie Valley

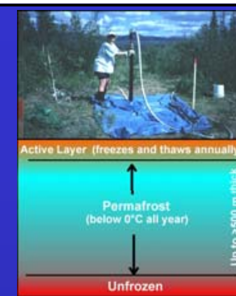
Sharon Smith
Geological Survey of Canada
Natural Resources Canada

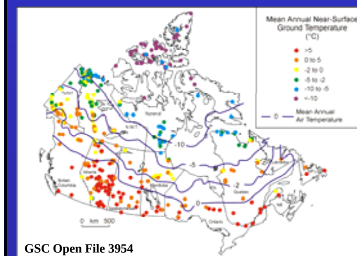
Anchorage – October 30, 2008

Natural Resources Canada Ressources naturelles Canada



from Kettles et al. 1997





GSC Open File 3954

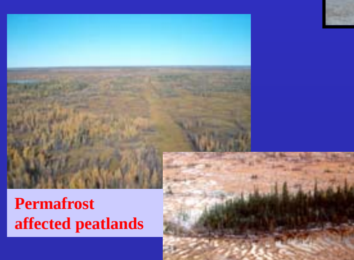
Permafrost is soil or rock that remains below 0°C throughout the year

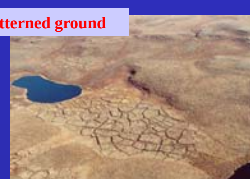
- **the permafrost region covers more than half of the Canadian landmass**
- **a significant portion of the permafrost region is underlain by permafrost warmer than -2°C**

Permafrost is an important feature of the northern landscape


Pingo


Massive ice

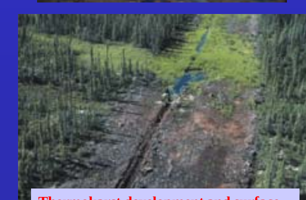

Permafrost affected peatlands


Patterned ground

Permafrost presents challenges to northern development

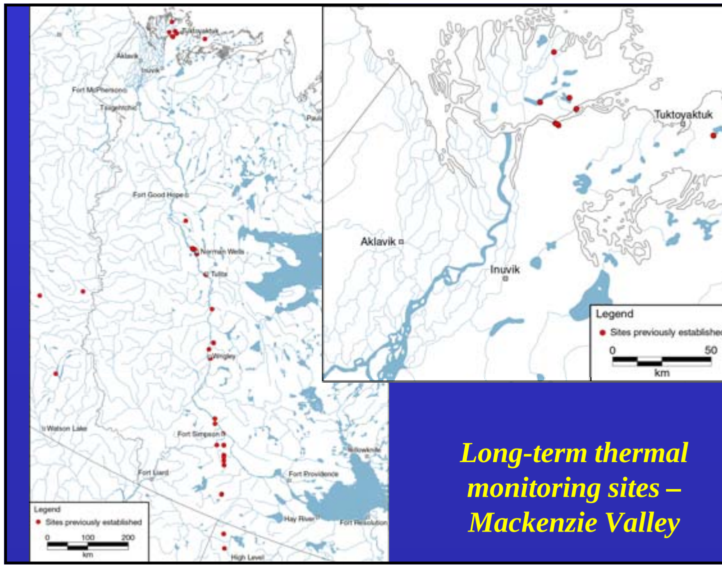

Unstable ground


Adaptation techniques


Thermokarst development and surface settlement

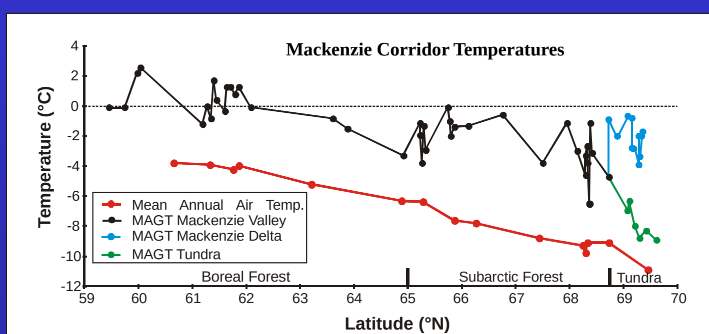
Knowledge of permafrost thermal state and ground ice conditions are required for:

- engineering design of northern infrastructure
- landuse planning
- assessment of environmental impacts associated with northern development and development of mitigation techniques
- assessment of impacts of climate change on natural and human systems

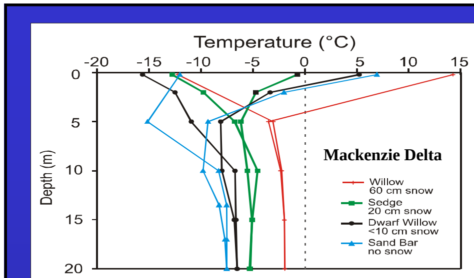


Long-term thermal monitoring sites – Mackenzie Valley

Data generated from monitoring network and historical data facilitated characterization of ground thermal regime within the Mackenzie corridor

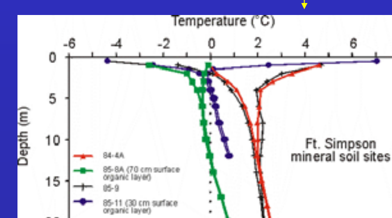


Relationship Between Air Temperature and Ground Temperature (MAGT) and Latitude in Mackenzie corridor



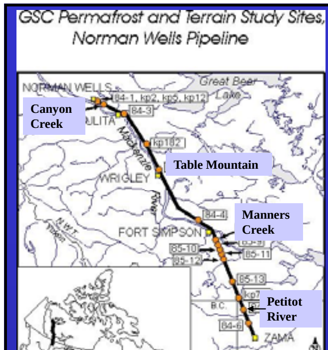
Effect of snow cover

Effect of organic layer

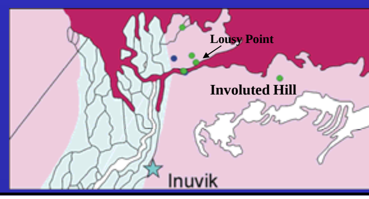


Characterization of ground thermal regime for various terrain types and microclimatic conditions

Long-term Thermal Monitoring Sites



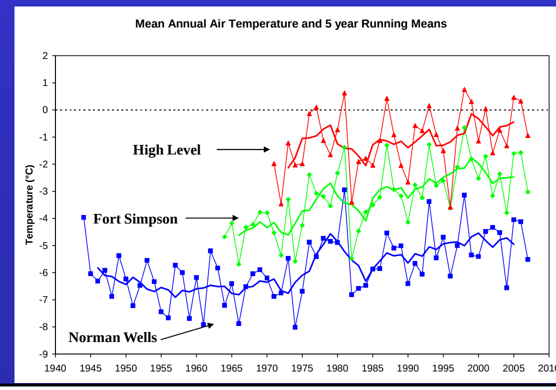
- network of thermal monitoring sites along Norman Wells pipeline corridor
  - *sites established off pipeline right-of-way contribute to national network*
  - *temperatures measured to 20 m depth*
  - *network in operation for over 20 years*
- GSC has maintained a permafrost thermal monitoring network in the Mackenzie Delta region since 1989



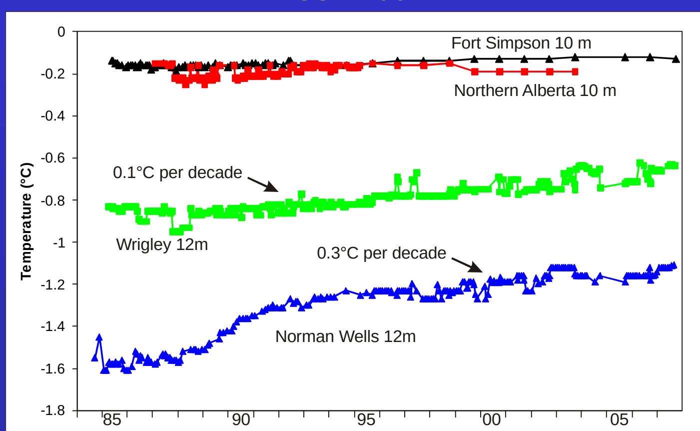
Air Temperature Trends Mackenzie Valley

Climate Normals – Mean annual air temperature

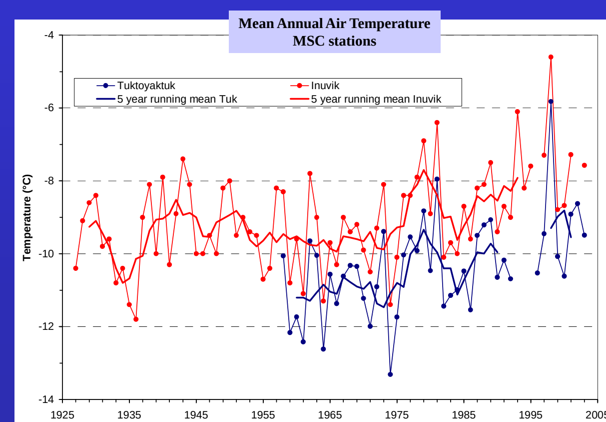
Station	1951-1980	1961-1990	1971-2000
Norman Wells	-6.4	-6.0	-5.5
Fort Simpson	-4.2	-3.7	-3.2
High Level	-2.0	NA	-1.3



Trends in Permafrost Temperature Central and Southern Mackenzie Valley 1984-2007

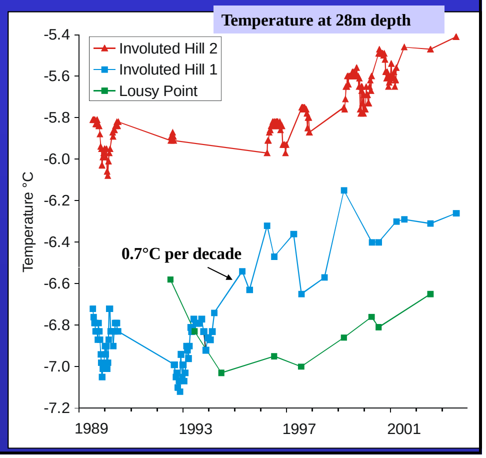


Air Temperature Trends Mackenzie Delta Region



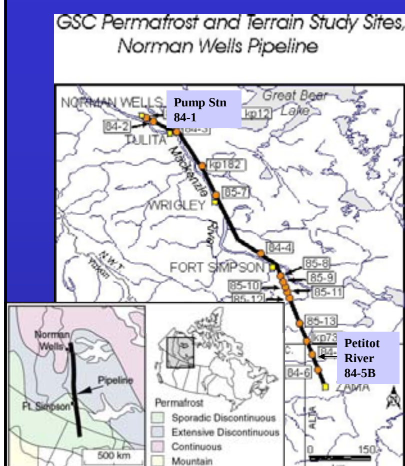
Mackenzie Delta Region

- Cold thick permafrost
- Warming of permafrost at depth since early 1990s

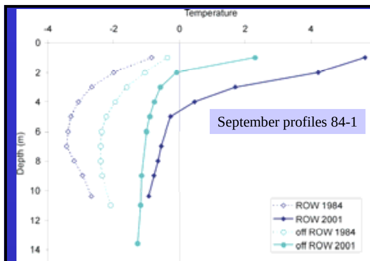


Norman Wells Pipeline Permafrost and Terrain Research and Monitoring

- **Collaborative effort between government and Enbridge (formerly IPL) to develop and implement monitoring program to:**
  - *assess impact prediction*
  - *improve impact evaluation and mitigation on NW pipeline and future projects*
- **Establishment of 23 instrumented sites provided unique opportunity to:**
  - *examine thermal and terrain conditions*
  - *investigate long-term change in permafrost conditions at undisturbed sites*
  - *investigate impact of disturbance on permafrost terrain*

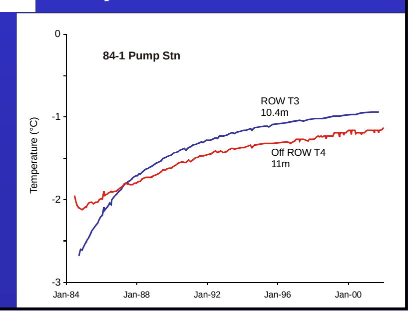


- **thermal monitoring sites established on and off pipeline right-of-way (ROW)**
- **temperatures measured to 20 m depth**
- **thaw settlement measured**
- **in operation for 20+ years**



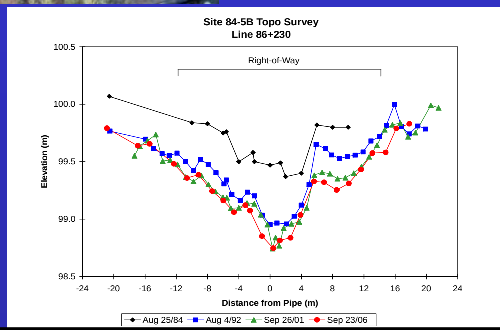
Comparison of ground thermal regime on and off ROW

Greater increase in ground temperature and thaw penetration on ROW



84-5B, KP 783
Peatland Site

Monitoring surface settlement resulting from thaw of ice-rich permafrost

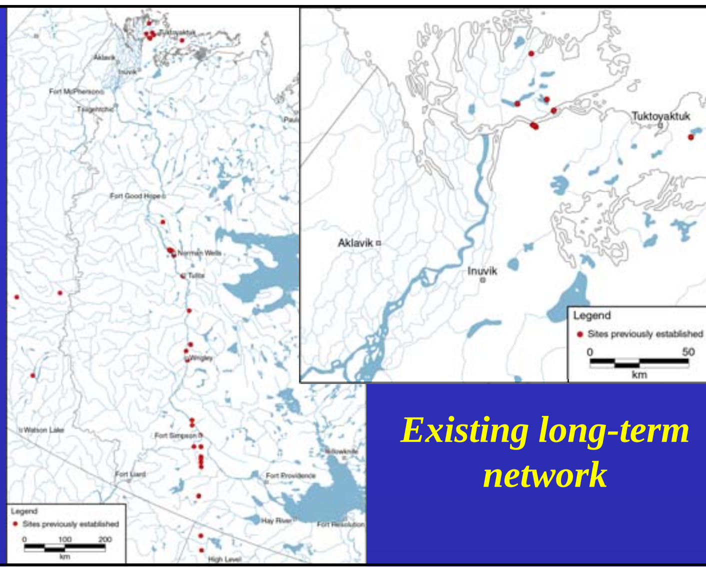


Information generated from existing network has supported:

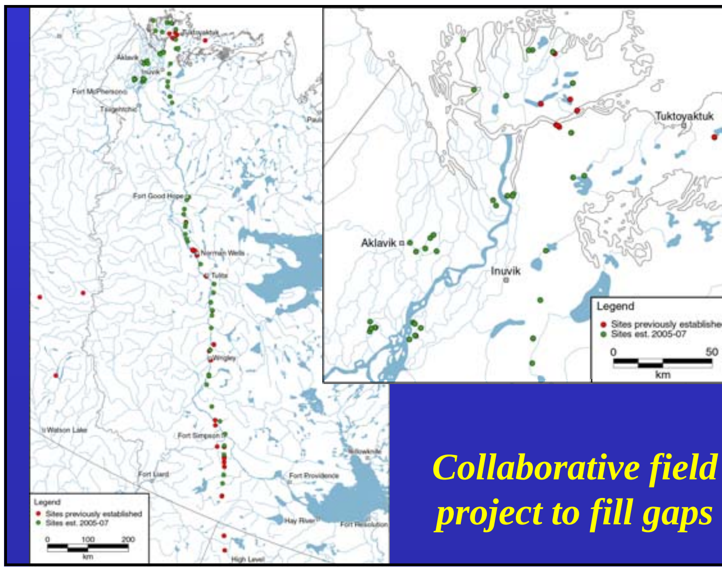
- **environmental assessment and regulatory process associated with proposed pipeline project**
- **preliminary pipeline design**

Existing network had regional gaps

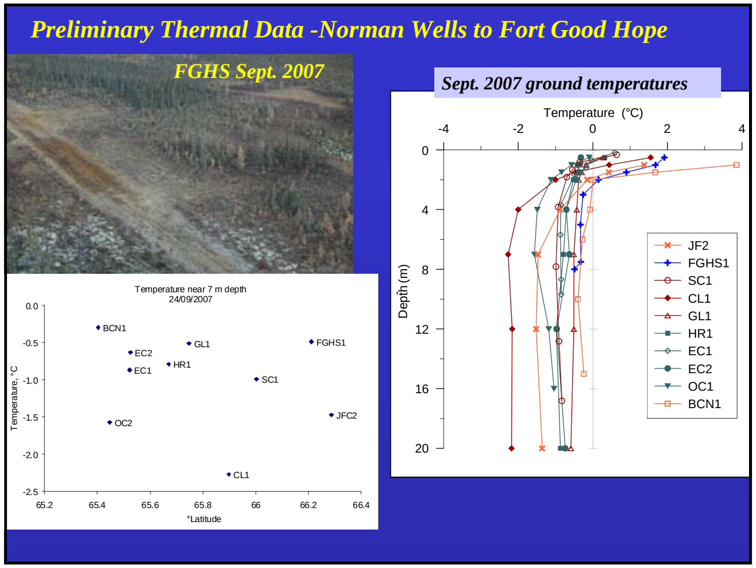
- **major field project undertaken to address gaps in baseline knowledge of permafrost conditions**
- **collaboration with government partners and stakeholders**
- **50 new monitoring sites established**

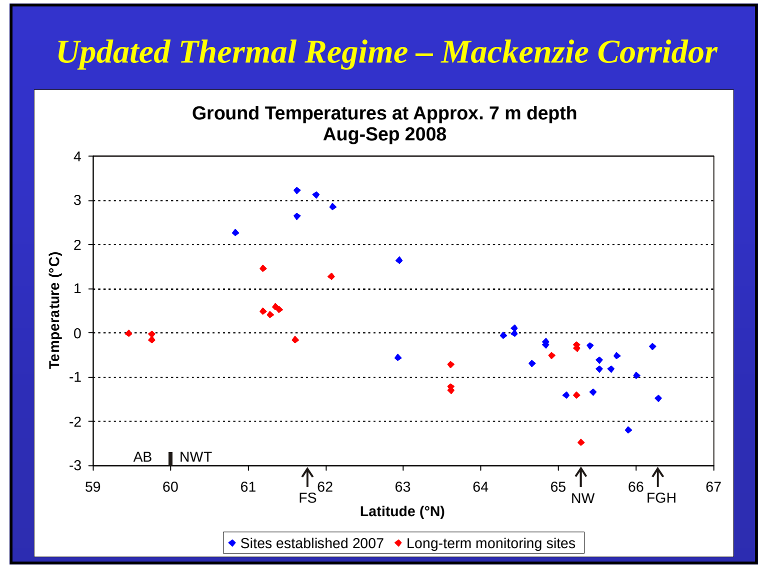


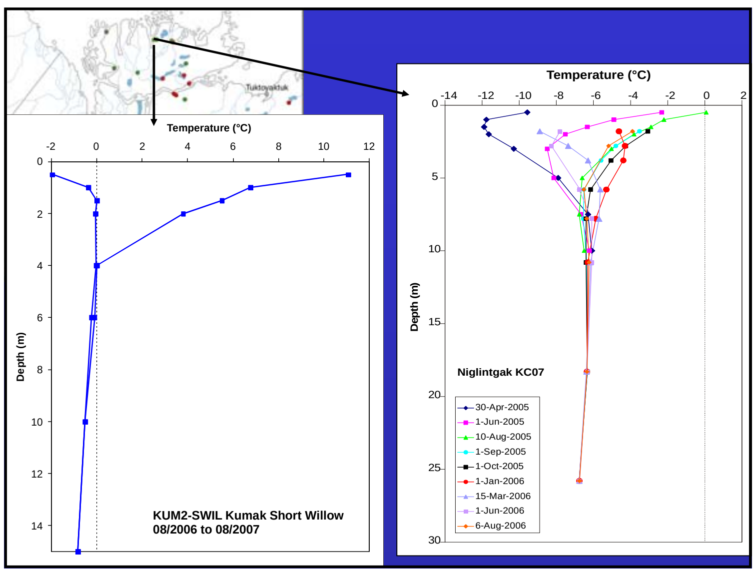
Existing long-term network

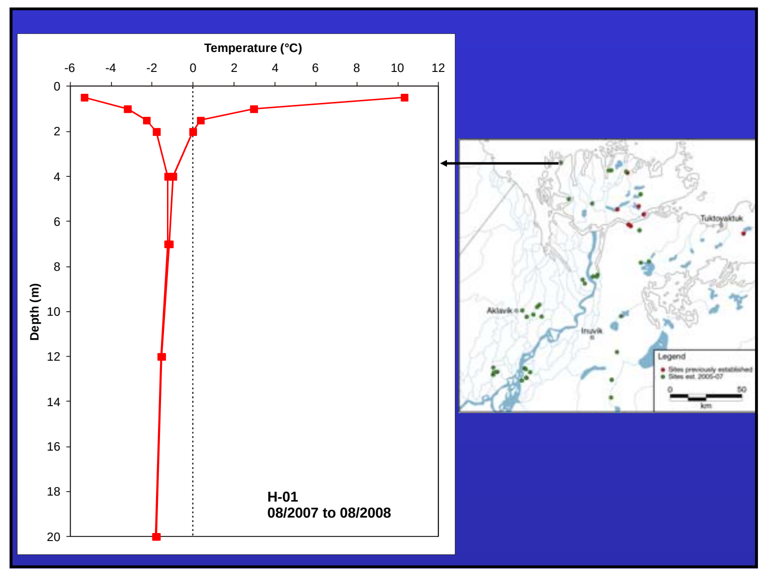


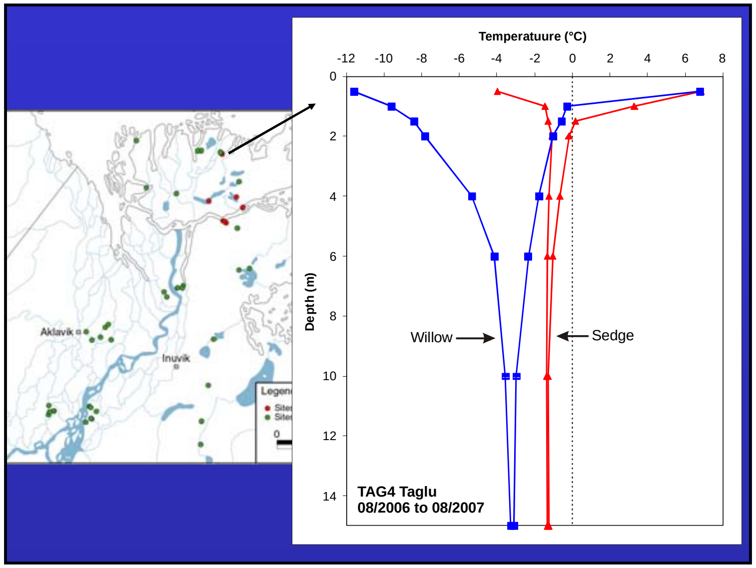
Collaborative field project to fill gaps


Preliminary Thermal Data -Norman Wells to Fort Good Hope
FGHS Sept. 2007
Sept. 2007 ground temperatures
Temperature (°C)
Depth (m)
JF2
FGHS1
SC1
CL1
GL1
HR1
EC1
EC2
OC1
BCN1
Temperature near 7 m depth
24/09/2007
Temperature, °C
°Latitude
BCN1
GL1
FGHS1
EC2
HR1
EC1
SC1
JFC2
OC2
CL1

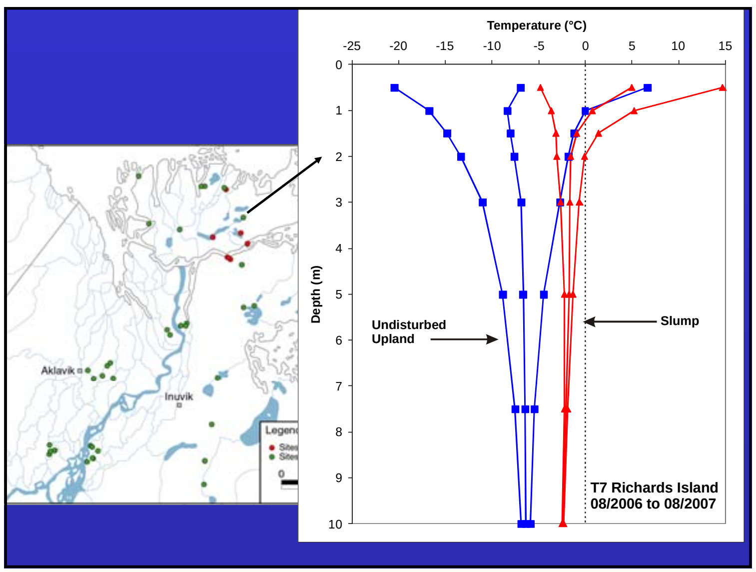

Updated Thermal Regime – Mackenzie Corridor
Ground Temperatures at Approx. 7 m depth
Aug-Sep 2008
Temperature (°C)
Latitude (°N)
AB
NWT
FS
NW
FGH
Sites established 2007
Long-term monitoring sites

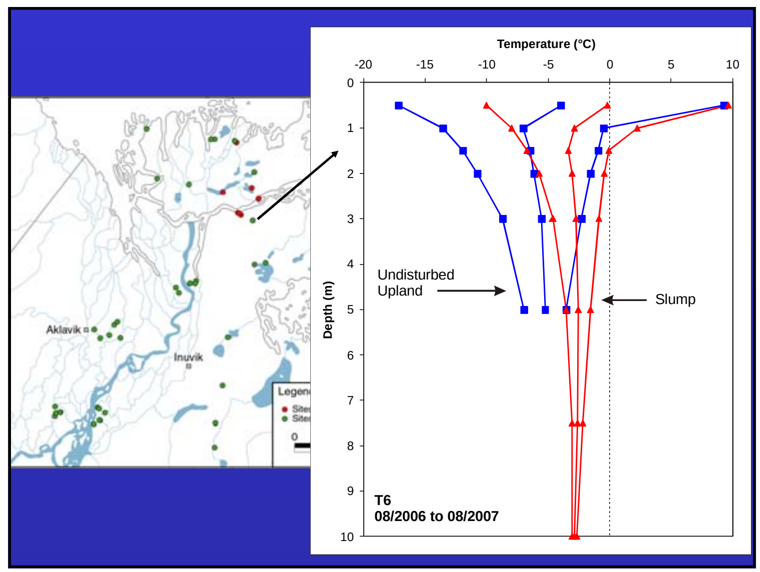

Tuktoyaktuk
Temperature (°C)
Depth (m)
KUM2-SWIL Kumak Short Willow
08/2006 to 08/2007
Temperature (°C)
Depth (m)
Niglintgak KC07
30-Apr-2005
1-Jun-2005
10-Aug-2005
1-Sep-2005
1-Oct-2005
1-Jan-2006
15-Mar-2006
1-Jun-2006
6-Aug-2006

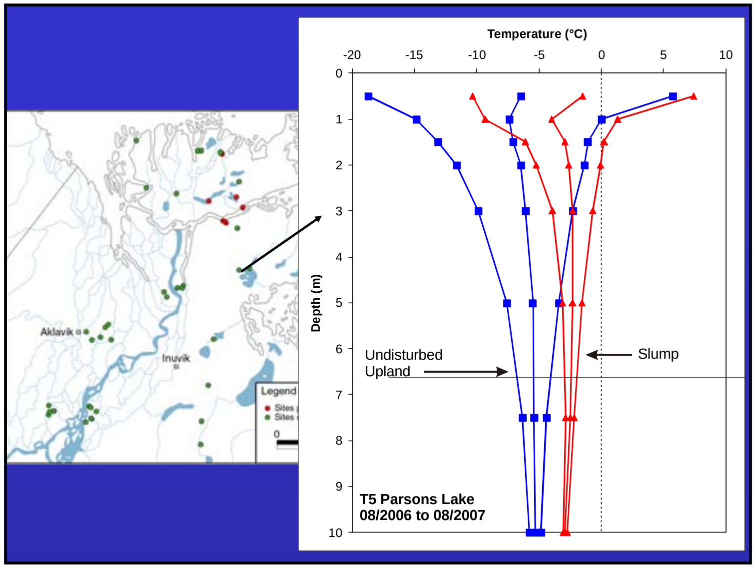

Temperature (°C)
Depth (m)
H-01
08/2007 to 08/2008
Tuktoyaktuk
Aklavik
Inuvik
Legend



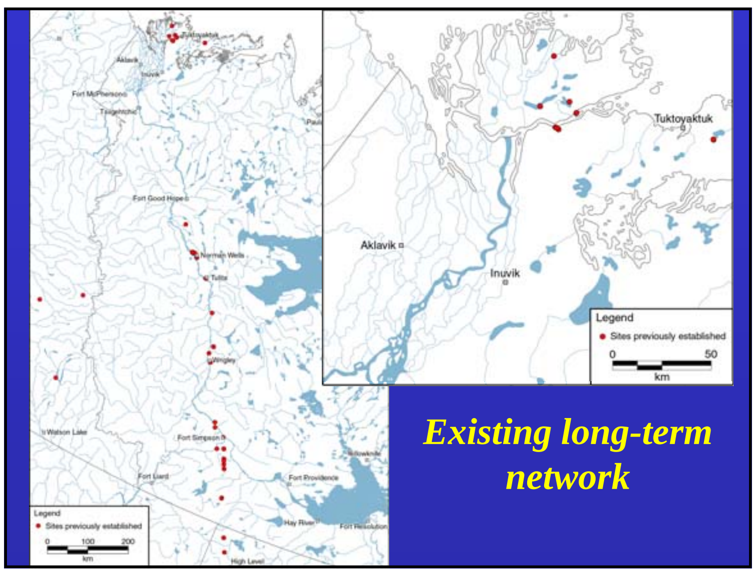
Impact of disturbance due to slumping

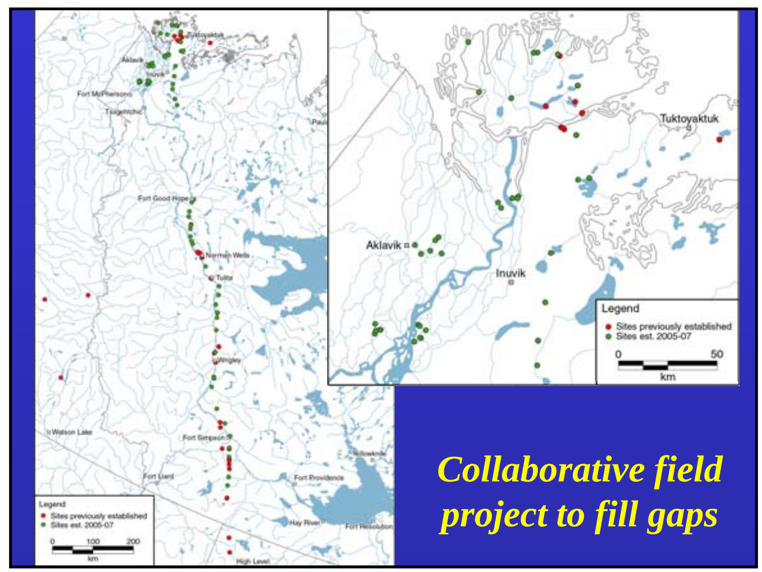


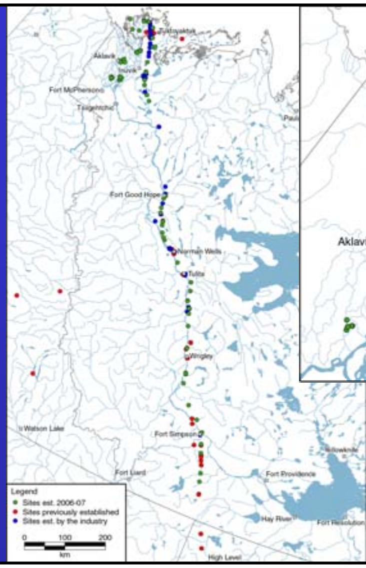


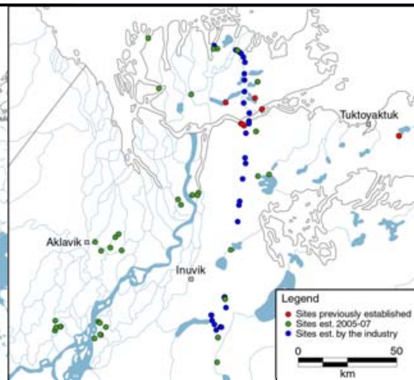

Temperature (°C)
-20 -15 -10 -5 0 5 10
Depth (m)
0 1 2 3 4 5 6 7 8 9 10
Undisturbed Upland
Slump
T5 Parsons Lake
08/2006 to 08/2007
Aklavik
Inuvik
Legend


Characterization of sediment properties


Existing long-term network
Tuktoyaktuk
Aklavik
Inuvik
Legend
Sites previously established
0 50
km


Collaborative field project to fill gaps
Tuktoyaktuk
Aklavik
Inuvik
Legend
Sites previously established
Sites est. 2005-07
0 50
km





Industry sites may contribute to network

Summary

- **major collaborative field project has resulted in enhanced permafrost monitoring network**
  – improved baseline knowledge of permafrost conditions
- **updated characterization of thermal regime throughout corridor**
- **generation of baseline information to support:**
  – design of future development projects in the region
  – environmental assessment and regulatory processes
  – landuse planning decisions

Support provided by:

- **Geological Survey of Canada, Natural Resources Canada**
- **Northern Energy Development MC**
- **Panel on Energy Research and Development (PERD)**
- **Enbridge Pipelines**
- **Imperial Oil Resource Venture Limited**
- **Department of Indian and Northern Affairs**
- **Federal Government's Climate Change Action Plan 2000**
- **Polar Continental Shelf Project**
- **Numerous colleagues who have contributed to data collection and analysis**

5.6.6 Characterization and Water Use of Alaskan North Slope Lakes,

Michael R. Lilly & Daniel White

[1] President, Research Hydrologist, Geo-Watersheds Scientific. Email: mlilly@gwscientific.com

[2] Ph.D., Director, Institute of Northern Engineering, University of Alaska Fairbanks. Email: ffdmw@uaf.edu

Oil and gas development on Alaska's North Slope depends on lakes and reservoirs for all phases of development. Exploration uses ice roads, pads, and runways to help reduce environmental impacts. Water available during the winter tundra-travel season mainly comes from lakes, as most streams and rivers either have no available water, or are providing critical overwintering fish habitat. Both lake ice and under-ice water are used for construction and maintenance of arctic-transportation networks. These same water sources also serve development and operations phases during construction of pipelines, camps and processing facilities.

Early development of oil and gas on the North Slope took place in the central portion of the coastal plain, which also has the highest density of natural lakes. Management approaches for lakes and reservoirs were developed to meet current needs, usually with a lack of basic supporting information. Recent exploration and development has spread into areas with fewer lakes and terrain requiring greater amounts of water for transportation purposes. A study began in 2002 to define hydrology and chemical characteristics of lakes and potential impacts of winter water use. This study was expanded in 2005 to investigate lakes and reservoirs, overall water use, and to develop tools to better understand and manage water resources. One of the key management criteria for Arctic lakes is the preservation of overwintering habitat for fisheries resources. Understanding and developing management tools for estimating potential lake recharge, methods for defining available water volumes within permit practices, and understanding and simulating dissolved oxygen for overwintering fish habitat were some of the key project objectives. In a cooperative project with industry, resource agencies, and environmental groups, we investigated a series of lakes and reservoirs from 2002 through spring 2008. Coordination with industry partners and their water use activities was a key component of our efforts.

Lakes and reservoirs are recharged primarily during snowmelt, but summer precipitation and lake evaporation are important parts of the annual water balance. Defining contributing watersheds, outlet elevations, accurate bathymetry, the permitting differences between surface ice removal and under-ice water removal, and improved estimates of seasonal ice growth were identified as important management information. Study lakes were used to help identify these issues, along with new water management methods. Natural chemistry variation in the study lakes was measured, along with an evaluation of potential water-use impacts. We did not find significant differences in water chemistry due to water use. A model was developed to help simulate dissolved-oxygen concentrations in lakes and take into account water use. In study lakes and reservoirs, within the North Slope coastal plain, the model is able to define winter reductions and vertical profiles of dissolved oxygen. Water volumes permitted on the North Slope are higher than amounts actually used. Current North Slope water-use practices and management have been conservative. Resulting improvements in understanding lake watershed hydrology and management tools will help meet future challenges for increased water demands on existing oil and gas fields, as well as new water-poor areas on the North Slope.

US/Canadian Northern Oil and Gas Research Forum, 2008

Characterization and Water Use of Alaskan North Slope Lakes

Michael R. Lilly
Geo-Watersheds Scientific

Daniel M. White
University of Alaska Fairbanks

October 30, 2008

Water and Environmental Research Center

Project Partners

- DOE/NETL/Arctic Energy Office – UAF/AETDL
- UAF Water and Environmental Research Center
- BP Exploration
- ConocoPhillips Alaska
- Bureau of Land Management
- North Slope Borough
- Northern Alaska Environmental Center
- The Nature Conservancy
- National Weather Service
- Alaska Department of Natural Resources
- Alaska Department of Transportation and Public Facilities
- Mineral Management Service
- International Arctic Research Center

Phase 1 - Physical and Chemical Characteristics of Arctic Lakes, and Variations Due To Water Use

2002 – 2005 Objectives

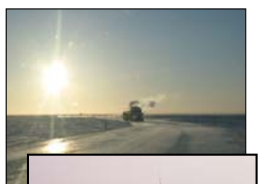
- Characterize & quantify potential effects from mid-winter pumping of arctic lakes
- Improve permitting efforts

Potential Effects of Pumping?

- Altering lake water balances
- Impacting aquatic lake ecosystems
- Influencing baseline water chemistry

Other Dynamics?

- Immediate and/or Cumulative Impact son lakes, Changing climates?
- Interactions with adjacent rivers?



Phase 2 - Operational Watershed Modeling Tools to Support North Slope Field Operations

2005 – 2008 Objectives

- Cooperative data-collection network - - weather, tundra-travel objectives
- Operational modeling tools to improve estimates of available water assets and usage risks, annual and seasonal use
- Solutions for transportation, field development, operations
- Modeling tools, improved understanding of DO in arctic lakes and reservoirs
- Cooperative environment

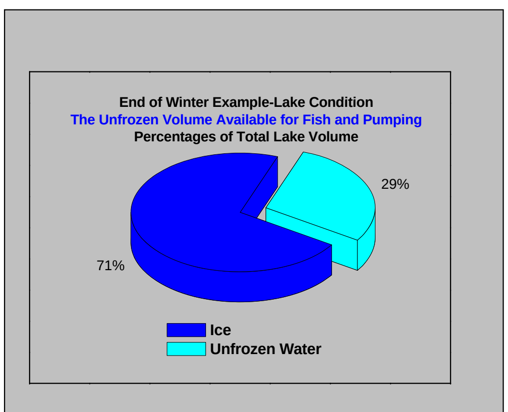
Water Use

- **Road, Pad Infrastructure**
  - Exploration, Largest User
    - Road construction speed is highest priority
  - Operations and Maintenance of pipelines
  - Short/Long-term use
- **Facilities**
  - Mud and drilling support operations
  - Enhanced recovery
  - Processing facilities
  - Main camp operations and potable water
  - Long-term use

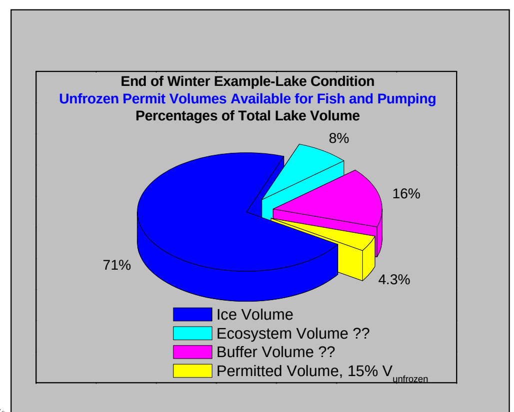
Arctic Lake Hydrology

- **Different lakes will respond to pumping in different ways**
  - Single lake watersheds
  - Multiple lake watersheds, one lake recharges downstream lakes
  - Lakes recharged by adjacent surface-water overflow during snowmelt or storm events
  - Borrow (gravel) pits, used as reservoirs
  - Lakes near coast versus away from coast
  - Shallow vs. deep
  - Temporal water variability

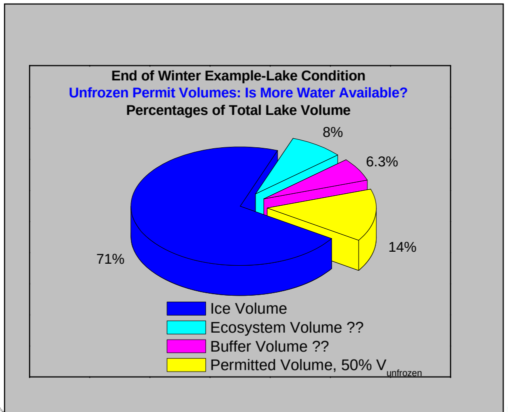
Lake Water Volumes and Uses



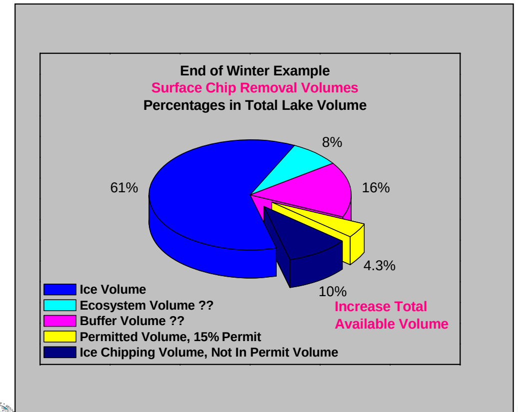
Lake Water Volumes and Uses



Lake Water Volumes and Uses



Lake Water Volumes and Uses



Hydrologic Management Tools: Bathymetry

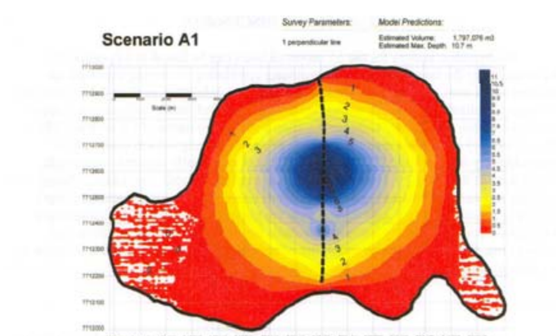


Figure 3. Scenario A1: Minimal sampling effort consisting of one vertical transect.

Cott and others, 2005

Hydrologic Management Tools: Bathymetry

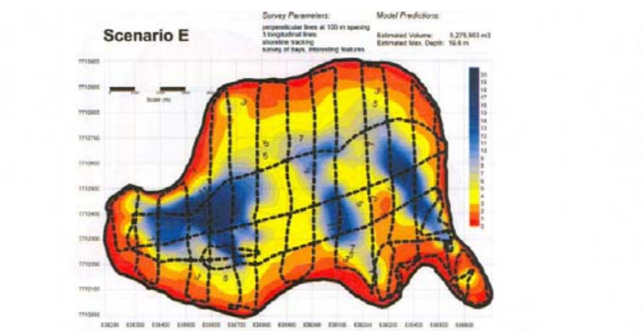
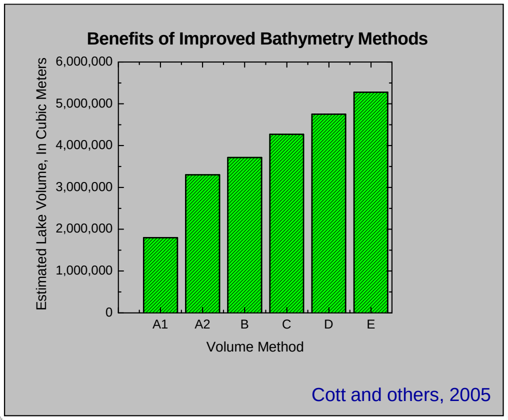


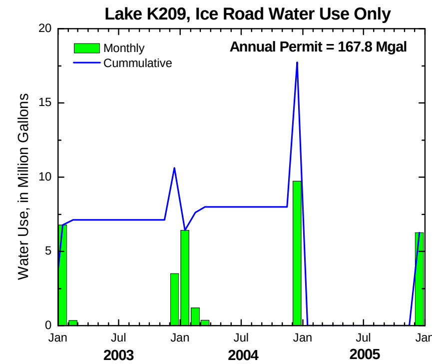
Figure 8. Scenario E: Depicts the gain in resolution, and correspondingly increased water volume estimate, achieved by decreasing the spacing of vertical transects to 100m, conducting 3 horizontal transects, incorporating shoreline tracking, and surveying bays and interesting features.

Cott and others, 2005

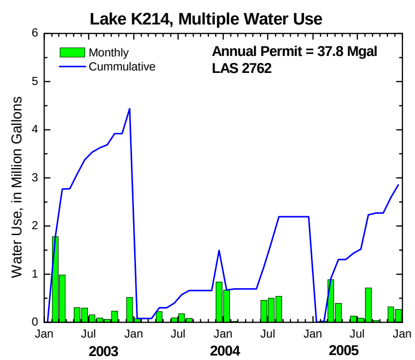
Hydrologic Management Tools: Bathymetry



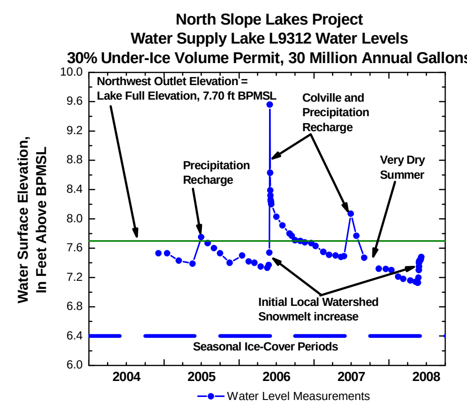
Permitting, Water Use, Hydrologic Cycles



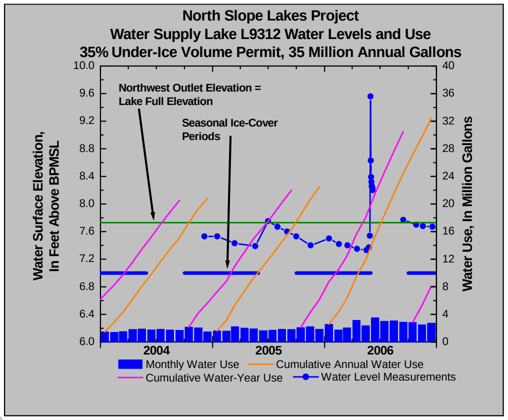
Permitting, Water Use, Hydrologic Cycles



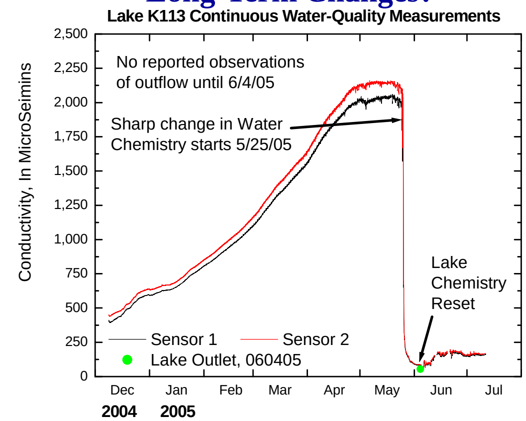
Permitting, Water Use, Hydrologic Cycles

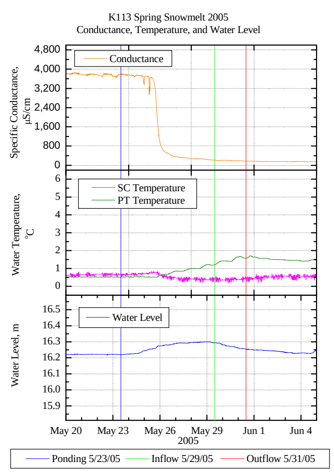


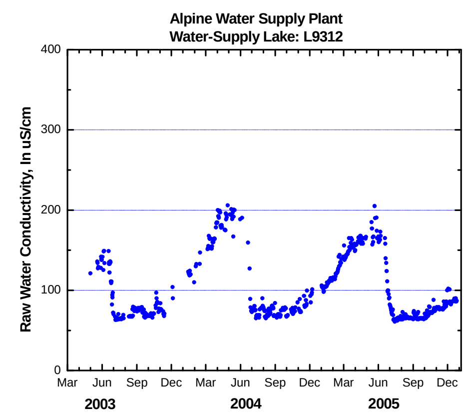
Permitting, Water Use, Hydrologic Cycles



Long-Term Changes?

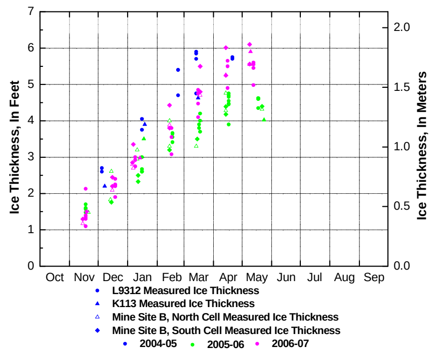






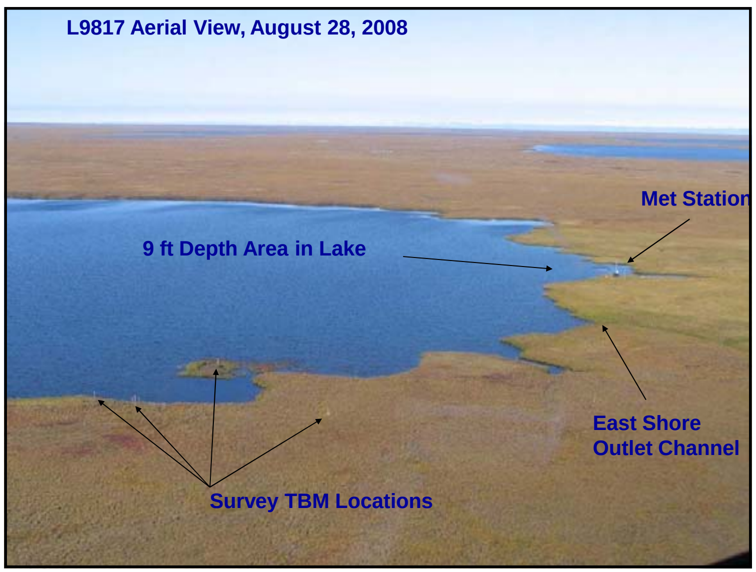
Alaskan North Slope Lakes and Water Use

How Thick Does Lake Ice Grow?

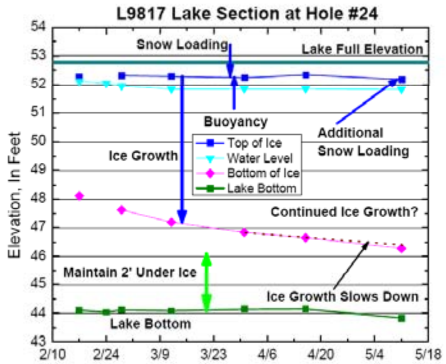


Alaskan North Slope Lakes and Water Use

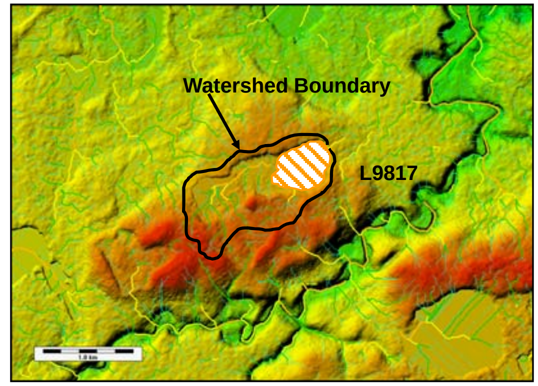
- *L9817 Used New Permit Approach for Winter Water Use*
  - *Indicated what needed to be left at end of winter*
  - *More direct approach to meet objectives of permit goals*
  - *Requires use of more information for managing water use*
  - *Resulted in increased water availability*



Alaskan North Slope Lakes and Water Use



Watershed Approaches to Water Use



Watershed Approaches to Water Use

$V_R = (A_{LW}-A_L) * (P_a - ET_a) + (A_L*(P_a - E_L))$

Where,
A_L = Lake Area
A_{LW} = Lake-Watershed Area
ET_a = Annual Evapotranspiration
E_L = Lake Evaporation
P_a = Annual Precipitation
V_R = **Potential Recharge**

Reservoir Example

- **Mine Site B**
  - Old Gravel Site
  - 2 cells
  - Connected to stream
  - ~25-30 feet deep
  - Facility water supply
  - Drilling water supply
  - Overwintering habitat

Reservoir Benefits

- **Mine Site B**
  - Deeper
  - Higher DO profiles
  - Overwintering Habitat
  - Better recharge control

Need for an Oxygen Depletion Model

Permits require that fisheries be protected

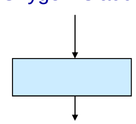
1. Overwinter habitat on the slope is limited.
2. Fish require adequate levels of oxygen to survive.
3. Current permits are based on a volume removal limit to preserve oxygen levels in lakes. This is not based on a measured or predicted oxygen concentration in the lake.
   ---increases risk

Our objective was to build an oxygen model for arctic lakes that:

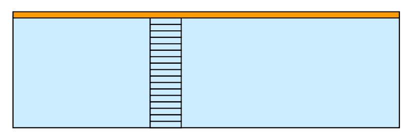
- Models oxygen concentration throughout the water column, throughout the winter
- Includes an algorithm for ice growth and the effects of snow cover
- Requires a minimum number of input variables
- Can account for the effects of pumping
- Can be easily used, emailed, modified

Water column is divided into cells, 1m x 1m x d/20m

Oxygen entering cell
- At beginning of ice cover, all cells are saturated with oxygen
- Oxygen is added to the top cell by ice exclusion

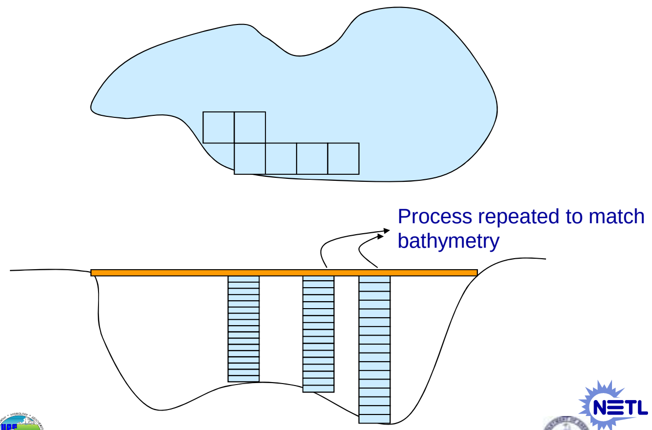


Processes in cell
- Water column oxygen consumption
- Diffusion across cell (function of gradient)
- Mixing
- Benthic consumption from bottom cell only

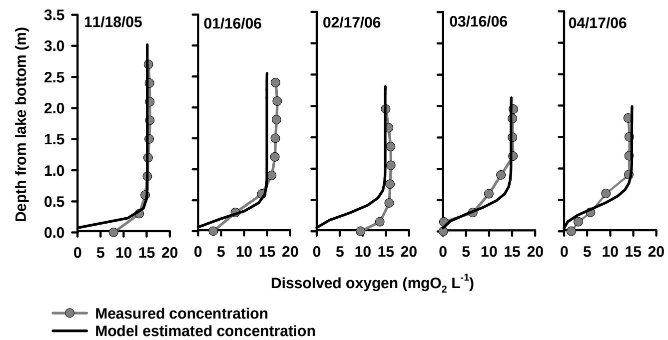


Lake Boundary

Accounting for bathymetry…sort of



Lake L9312 Model fitting



Lake	L9312		
Start Year	2005	yyyy	
Initial Depth	11.48	ft	
Minimum DO	4	mg/L	
Temperature	Climatology		

Pumping Events		Units	gal/d
Continuous Pumping			
	Start(mm/dd/yyyy)	End	Amount
1	1/1/2006	3/15/2006	500000
2	3/16/2006	4/1/2006	100000
3			
4			
5			

Discrete Pumping Events		
	Date	Amount
1	2/1/2006	10000000
2	3/1/2006	10000000
3		
4		
5		

Permitted Under-Ice Fraction (%)	30	%
Maximum Ice Method	Assume 7 ft	ft
Pumping Volume Prior to Sep 1		gal

Simulation Options

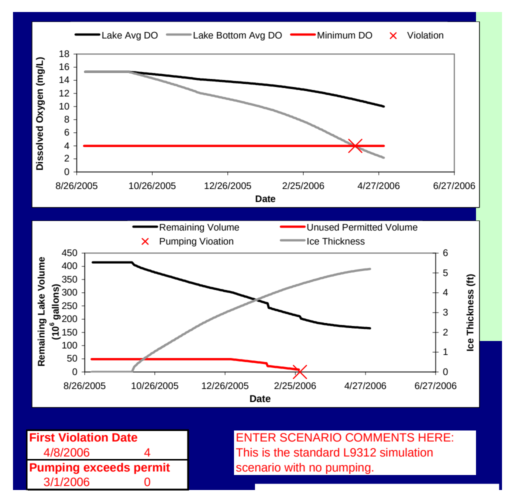
- Run Simulation
- Save Output

Scenario Name

Default L9312

Scenario Options

- Load Scenario
- Save New Scenario
- Add New Lake
- Clear Input Fields
- Delete Lake/Scenario
- Export



DO Model Summary

- **Model requires limited input**
- **Model can be emailed**
- **Model is better, on average, than other empirical models**
- **It is the only model that takes into account ice growth**
- **Model was built on arctic lakes**
- **Model is easily modified**

Reporting, Meetings, and Outreach

- **Reports, Papers**
  - Project reports available on-line at http://www.uaf.edu/water/projects/nsl/reports.html
    - Project and Data Reports, Hydrologic Notes
  - AWRA Featured Collection, Apr 2008 http://www3.interscience.wiley.com/journal/119414234/issue
  - Joint US/Canadian Effort
  - Invited Selection of 7 papers, free access to Dec 08
  - New AWRA DO paper accepted
- **Multiple Meeting and Workshops**

Alaskan North Slope Lakes and Water Use

Phase 1 Project Recommendations

- Uniform reporting of basic lake, permitting, and water use information
  - **Improve the overall understanding of lake systems and water use**
- Permitting periods based on water year
  - **October through September**
- Separate reporting of land-fast ice from under-ice water-use permit volumes
  - **Increase available ice-chip volumes**

Alaskan North Slope Lakes and Water Use

Phase 2 Project Recommendations

- Develop Permit and Management Tools
  - **Use of Excess Water**
  - **Summer versus Winter use Permitting**
  - **Outlet Elevations tied to Permit Volumes (when needed)**
  - **Reservoirs Managed Differently from Lakes (All reservoirs high DO)**
- Improve Understanding of DO Uptake, Use
  - **Relate to regional soils, geology**
  - **Species threshold limits for DO**

Alaskan North Slope Lakes and Water Use

Project Recommendations In Action!

- Gravel mine sites - cumulative volume permitting to support single point of extraction
- Surface-Ice Removal Treated Separately
- Annual Water-Use Permitting Moving to Water Year (selected new lakes)
- Ice Harvesting used this winter to address low snow
- *Use of Actual Ice Thicknesses in Discussion*
- *Alpine Water Supply Lake (L9312) permit improved to allow "Excess Water"*
- *L9817 2007/08 test permit approach under consideration*
- ***Cumulative Tools In Action!***

Alaskan North Slope Lakes and Water Use

Ongoing Projects

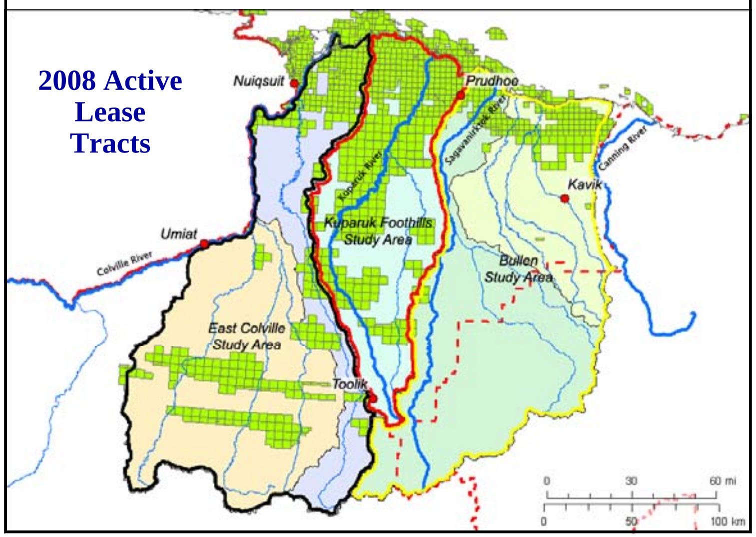
- Bullen and Sagavanirktok River Hydrology
  - **Sagavanirktok River to Canning River**
  - **Watershed Hydrology**
  - **Lake and Reservoir Surveys, Water Use**
- Kuparuk Foothills Hydrology
  - **Kuparuk River Watershed, Coastal Area**
  - **Watershed Hydrology**
  - **Lake and Reservoir Surveys, Water Use**

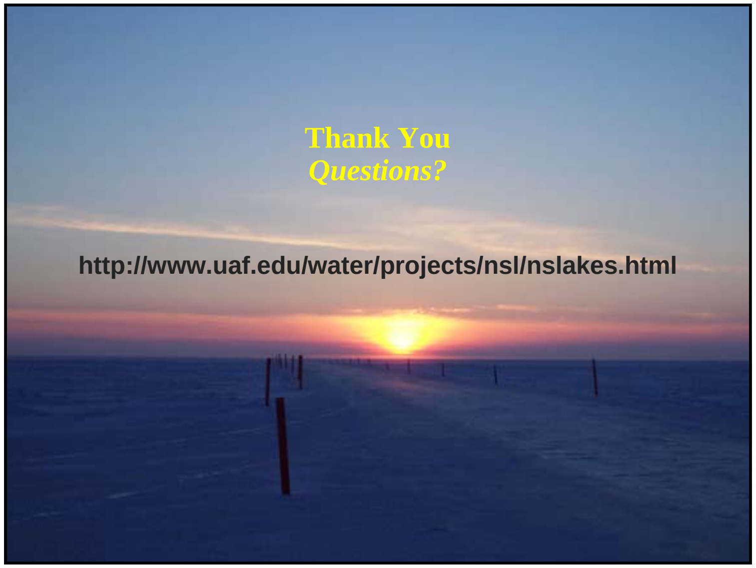
Alaskan North Slope Lakes and Water Use

Ongoing/New Projects

- MMS Support for Climate Stations
- DOE Project on Management Tools
- DOE Project on Application of Snow Fences
- Continued Coordination and Support with BLM, ADNR, ADOT, BP, ConocoPhillips and other US and Canadian Partners

2008 Active Lease Tracts




Thank You
Questions?
http://www.uaf.edu/water/projects/nsl/nslakes.html

5.6.7 Hydrology of the Mackenzie Delta Region,

Philip Marsh, M. Russell, C. Onclin, H. Haywood, S. Pohl, D. Forbes, S. Solomon

[1]Project Chief and Research Scientist, National Hydrology Research Centre, Environment Canada.

Email: philip.marsh@ec.gc.ca

The proposed Mackenzie Gas Project (MGP) will carry natural gas from three gas fields in the Mackenzie Delta area. This proposed development project has raised a number of concerns, including: (i) the impact of natural gas extraction subsidence on the flooding of bird habitat in the Mackenzie Delta, and (ii) the potential hazard posed by rapidly draining lakes in the uplands to the east of the Delta. This study, was undertaken to consider both of these concerns.

The outer Mackenzie Delta is dominated by lakes, channels, and low lying terrestrial areas. Due to the importance of the bird habitat in this area, the Kendall Island Bird Sanctuary (KIBS) was established in 1961. Since two anchor fields of the MGP are located in KIBS, and since the timing of bird nesting is affected by flooding, there is concern about the effect of natural gas extraction induced subsidence on flood frequency and magnitude of KIBS. Unfortunately, the hydrology of the outer Mackenzie Delta is not well understood at present, a factor that introduces large uncertainties in estimating the impact of the proposed MGP on flooding and bird habitat. The hydrology of the outer Mackenzie Delta is controlled by a number of factors, including discharge from the Mackenzie and Peel Rivers, storm surges on the Beaufort Sea, river ice, tides, near-shore sea ice, and natural subsidence and deposition for example. Lidar is being used to provide a high resolution digital elevation model, which when combined with detailed water level measurements and hydraulic modelling carried out in a related International Polar Year Project will allow an improved understanding of the relationship between water level and flooding. This talk will describe preliminary analysis that has improved our understanding of the spatial and temporal variability in flooding in this region, and allowed an improved consideration of the relative importance of various processes controlling water levels.

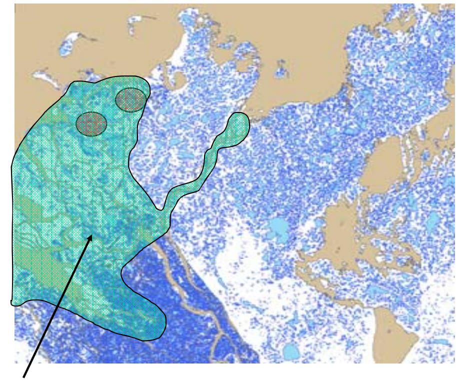
The uplands to the east of the Mackenzie Delta are lake rich, and have high concentrations of ground ice. These lakes are prone to rapid drainage, with lakes disappearing in less than one day. The basins left after a lake has drained is often referred to as a Drained Thaw Lake Basin (DTLB). Analysis of DTLBs has shown that 41 lakes drained in the study area between 1950 and 2000, and that the rate of lake drainage has been decreasing over this 50 year period. This decline in lake drainage events is likely related to a warming climate. Rapidly draining thaw lakes pose a hazard to proposed pipelines, as they often result the melting of drainage channels 5 m in depth, 10 m wide, and up to a few hundred meters in length. The development of these enlarged drainage channels is due primarily to the melting of ground ice. Maximum discharge during a drainage event can be orders of magnitude larger than maximum discharge from snowmelt or rainfall. This study has also identified the physiographic areas with the highest risk of lake drainage. These projects have been supported by Environment Canada, Natural Resources Canada (PERD, PCSP), Indian and Northern Affairs Canada (Northern Oil and Gas Research Initiative and IPY), and Aurora Research Institute.

Flooding and surface hydrology in the Mackenzie Delta region

Phil Marsh & partners

National Water Research Institute,
Environment Canada, Saskatoon, SK

Mid- to outer Mackenzie Delta



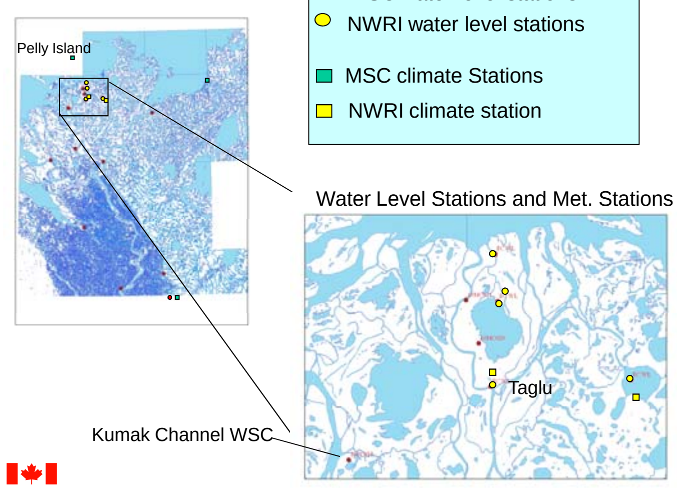
Lower subaerial plain. Area with tidal influence (Lewis, 1988)

Water levels controlled by

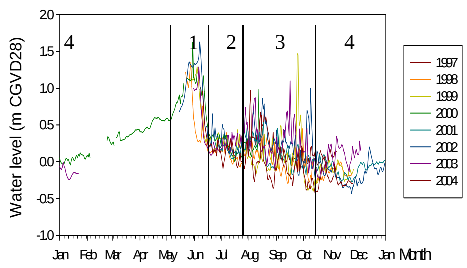
- Mackenzie River discharge,
- ice confinement at the delta front,
- ice jams in the main channels of the delta,
- tides,
- storm surges, and
- local runoff

Hydrological Data Sets

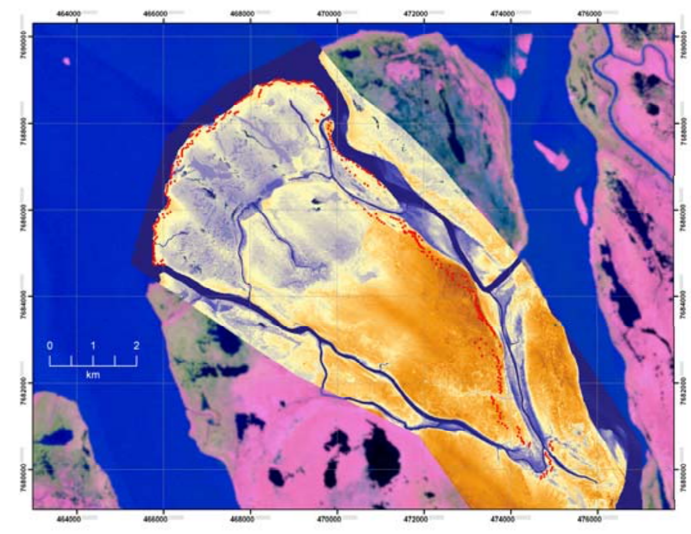
- WSC water level stations
- NWRI water level stations
- MSC climate Stations
- NWRI climate station

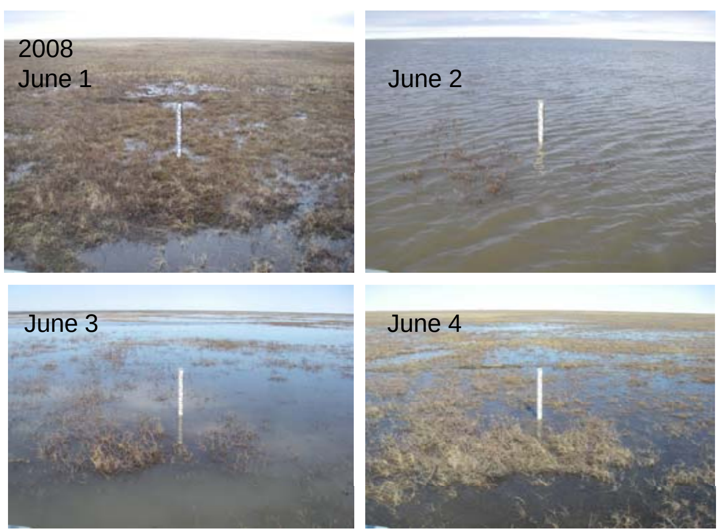


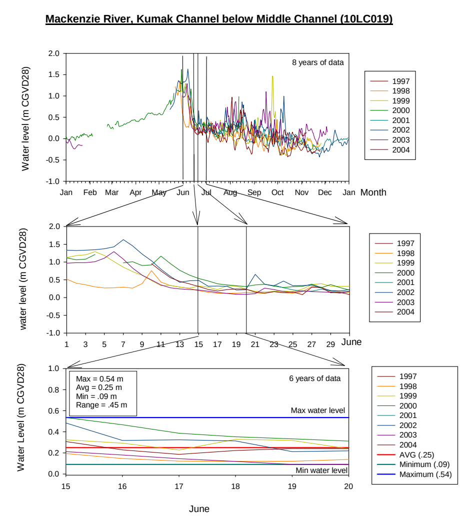
Typical channel water level for Kumak Channel



1 – spring breakup and recession
2 – period of relatively low variability… pre storm surges?
3 – summer, with large variability due to both storm surges and discharge
4 – winter







Critical water levels

Reference period is critical. Bird nesting window is June 15-20, after spring flooding.

Other key periods? We will be negligent if we design a program only to look at the nesting period.

Percentage of the area flooded at any point in time is a key issue. This requires detailed knowledge of water levels vs. land elevation.

Projecting future changes in the frequency of flooding in the outer Delta

- Past water levels at existing WSC stations
- Compute channel slopes and how they vary
- Compare to known elevations and DEM from LiDAR (where available)
- Build in estimates of subsidence and current sea-level rise
- Incorporate effects of accelerated SLR under CC

Assessments of surface hydrology and habitat impacts on the outer Mackenzie Delta

- Use hydrologic models to compute runoff from delta land surface

---

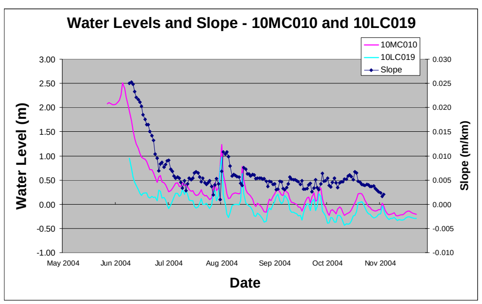
Outer Mackenzie Delta WSC Level Stations

- Each station has geodetic benchmark
- All historical water levels converted to both CGVD28 and CGG05 orthometric height

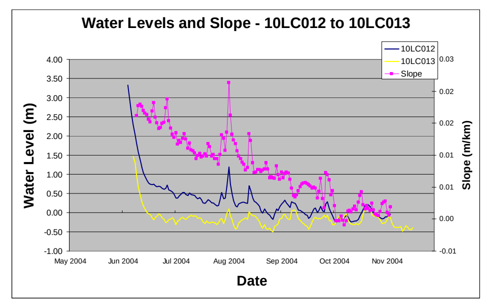
Analysis of channel water levels

- Compare WLs at 3 stations
  10LC012
  10LC013
  10MC010
  10LC019
- Calculated water slope between each of these stations
- First attempt to compare water level between these stations using CGG05 heights

---



- Water slopes vary from 0.025 m/km shortly after spring breakup to a relatively constant 0.005 m/km during the summer
- During one event in August 2004, the slope decreased to near zero
- This is an expected storm-surge backwater response



- Slopes diminish from 0.02 m/km shortly after spring breakup to nearly zero at the end of summer
- During the same August 2004 event, the slope increased to >0.025 m/km - very different response to outer delta on west side of Richards Island.

New water level stations in the Big Lake area

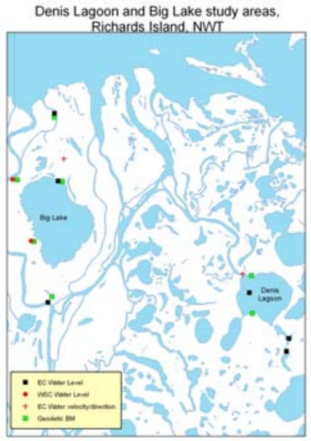
EC/WSC installed two new stations in 2007

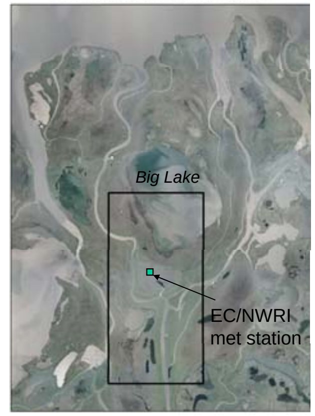
- Big Lake (SW end of lake)
- Kuluarpak Channel

EC/NWRI also installed three stations in 2007

- Kuluarpak Channel upstream
- Big Lake (north end of lake)
- small channel north of Big Lake (near coast)

Benchmarks were installed and surveyed in 2007





Surface hydrology & topography

- Combine hydrological models (RiverTools and Topoflow) with
- LiDAR DEM
- to estimate topographic slope, runoff pathways and flooding under existing topography, and topography after subsidence.
- GPR surveys to measure shallow ground ice including polygonal ice wedges (University of Calgary M.Sc.) to estimate potential thaw subsidence with active-layer thickening

5.6.8 Wind and Wave Hindcasts for the Beaufort Sea, *Val R. Swail*

Chief, Climate Data and Analysis Section, Climate Research Division, Environment Canada.

Email: Val.Swail@ec.gc.ca

The study reported here adopts the approach of hindcasting a multi-decadal "continuous" period for the Canadian Beaufort Sea, thereby producing a database from which both operational and extreme metocean statistics may be derived.

For accurate extremes, it was still found to be necessary to apply intensive reanalysis of the wind fields for a subset of storms that drives the extreme wave conditions. For the continuous periods outside the major storm events, statistical corrections were applied to the NCEP/NCAR Global Reanalysis (NRA) winds. Weekly dynamic updates of ice edge information for wave modeling were based on high-resolution Canadian Ice Service data. Application of Oceanweather's (OWI) 3rd generation shallow water wave model was made on a 28 km grid covering much of the open waters of the Arctic and nested to a 5 km grid within the Canadian Beaufort. Extensive validation using a series of MEDS wave measurements in water depths from 11 to 87 m water depth was performed. The hindcast compares well against available wave measurements not only in terms of bias and scatter, but over the entire frequency distribution out to and beyond the 99th percentiles of waves.

The Beaufort hindcast was run for the continuous period of 1970 to 2007 (38 years) and produced an hourly archive of wind and wave parameters at all points as well as wave spectra at select points archived over the fine domain model. Hindcast output was then subjected to extremal analysis and computation of a wind and wave atlas (http://www.oceanweather.net/MSC50WaveAtlas/). These derivative products, along with the point-sorted archive of model output, were combined into a single USB drive of hindcast products.

The database of high-quality continuous wind and wave hindcasts has already been used by industry in several Beaufort offshore projects. In addition, the wind and wave hindcast results were used as a contribution to the Beaufort Sea Regional Annex to the International Standard ISO/DIS 19901-1: *Petroleum and natural gas industries – specific requirements for offshore structures: Part I: Metocean design and operating considerations*. The results also provide an important input to shoreline erosion studies such as those reported by Solomon earlier in this Symposium.

All work for the MSC Beaufort project was funded by the Climate Research Division of Environment Canada and the Federal Program of Energy Research and Development.

The MSC Beaufort Wind and Wave Reanalysis

Val Swail
Environment Canada

Vincent Cardone, Brian Callahan, Mike Ferguson, Dan Gummer and Andrew Cox
Oceanweather Inc.
Cos Cob, CT, USA

Introduction: History of Studies leading up to the MSC-B

- •Murray and Maes (1986) extreme wave climate review of 100-year wave 4-16 m
- •1990-92: PERD hindcast of 30 severe storms for Canadian Beaufort using 2-G wave model over period 1957-88; 100-year waves varied from 2m near shore to 6m offshore; also included sensitivity to alternative probabilistic ice cover
- •1993: PERD update to include 29 storms in Canadian Beaufort as possible erosion producing storms
- •1993-2005: dormant period in Beaufort Sea interest
- •2005-08: interest in continuous hindcast of 20+ years – *this study*

25 years of wind/wave modeling expertise
oceanweather inc.
Environment Canada Environnement Canada

Introduction: Purpose of MSC-B

- •Apply the same methodology used in the MSC50 NA hindcast to the Canadian Beaufort Sea to produce a high-quality climatology
- •"Continuous" multi-decadal hindcast for both operating and extreme metocean statistics
- •Increase resolution of Beaufort basin model
- •Increase temporal resolution of archive
- •Increase accuracy to reduce uncertainty on any climate or design data statistics
- •Wind and wave databases and Beaufort Sea Atlas online

25 years of wind/wave modeling expertise
oceanweather inc.
Environment Canada Environnement Canada

Challenges

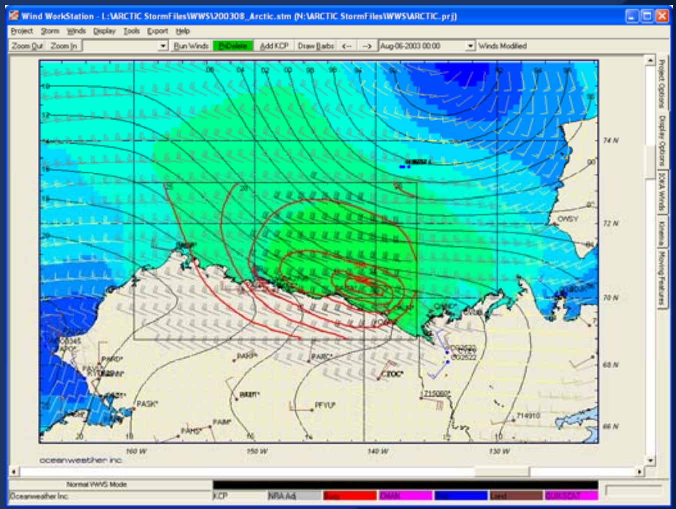
- Scarcity of in situ meteorological data
- Almost total absence of transient ship and moored weather buoy reports
- Highly variable and complex nature of sea ice cover
- Reanalysis wind fields considerably less accurate in Arctic
- Limited satellite products available even in recent years due to latitude of study area

Wind Field Methodology

- OWI Interactive Objective Kinematic Analysis still the basis for hindcast wind fields
  - QuikSCAT to correct systematic errors in NRA winds
  - adjust coastal wind measurements to effective over-water exposure using station-dependent overwater/overland transformation ratios
  - Import marine and adjusted coastal winds into WWS with adjusted winds from transient ships
  - Apply IOKA to storm periods

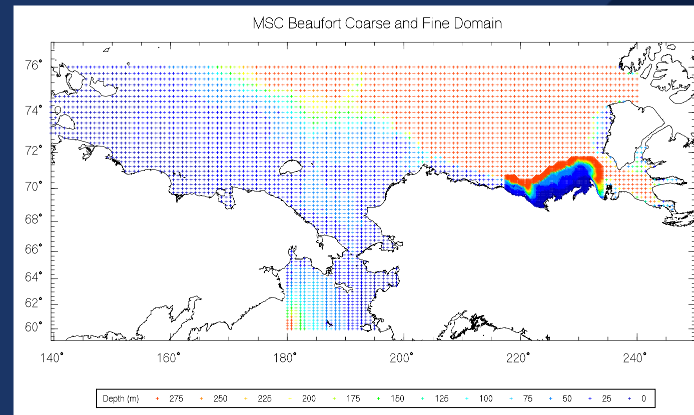
QuikSCAT/NRA Wind Correlations

- SCAT and NRA data matched for all NRA grid boxes in the Beaufort Sea - fewer than 500 comparisons per box
- NRA 6-hourly winds linearly interpolated to nearest hour of satellite observation
- Direction stratifications are 90 degree segments based on NRA direction starting with 45-135, and all directions
- Standard difference statistics and Q-Q distributions computed
- If Q-Q linear then a simple correction algorithm is applied for speed; direction adjusted by mean difference
- Result: NRA winds biased low, especially for south and east winds, so were increased

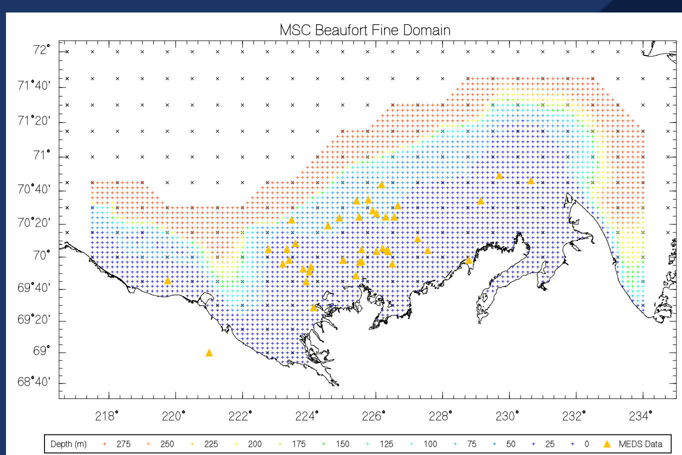


Wave Modelling Methodology

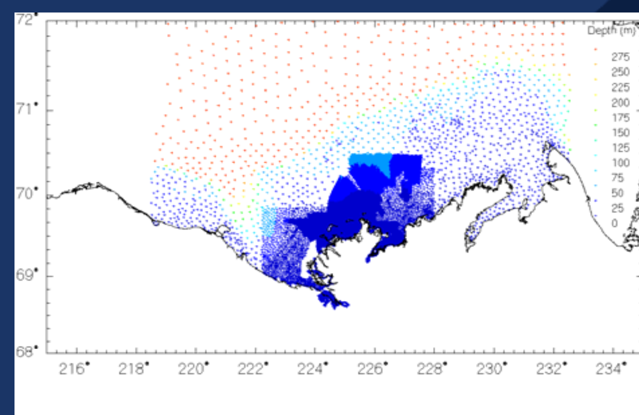
- OWI 3-G shallow water model
  - 28 km coarse grid; nested 5 km fine mesh
  - 3442 active grid points
  - Boundary spectra from OWI GROW hindcast
- Bathymetry
  - GEBCO 2003 1 minute data
  - CHS data for fine mesh area
  - Little smoothing required



25 years of wind/wave modeling expertise
oceanweather inc.
Environment Canada Environnement Canada



25 years of wind/wave modeling expertise
oceanweather inc.
Environment Canada Environnement Canada



Depth measurements provided by CHS for use in the Beaufort wave model

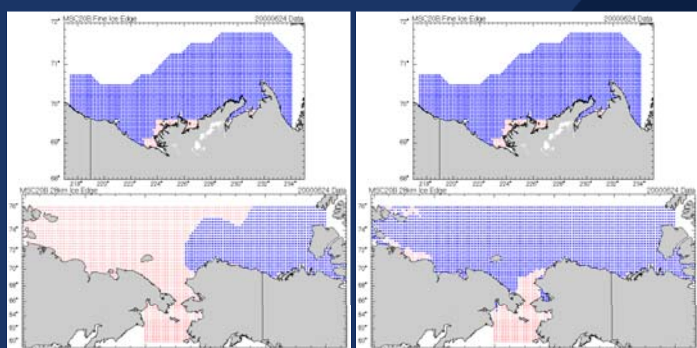
25 years of wind/wave modeling expertise
oceanweather inc.
Environment Canada Environnement Canada

Ice Edge

- In the wave model grid point locations with > 50% ice concentration are considered as land, with no wave generation or propagation
- Ice edge updated on weekly basis
- In Canadian waters CIS high resolution ice data set used
- Other areas GFSC/DMSP ice data used, with blending since CIS data did not cover the entire 28 km model domain

Ice concentration data sources

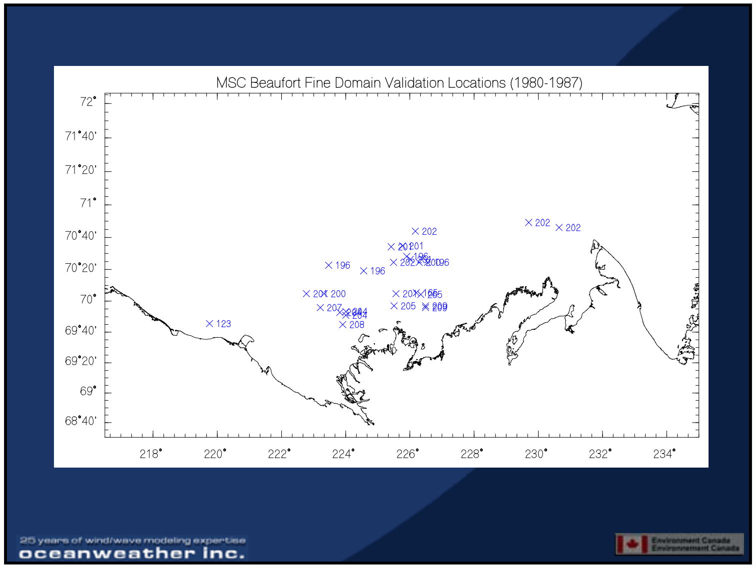
Source	Frequency	Coverage	Date Range
GSFC	Daily	Full	Nov1978-Dec 2000
DMSP	Daily	Full	Jan 2001-Present
CIS NetCDF	Weekly	Canadian Waters	Jan 1971-Present

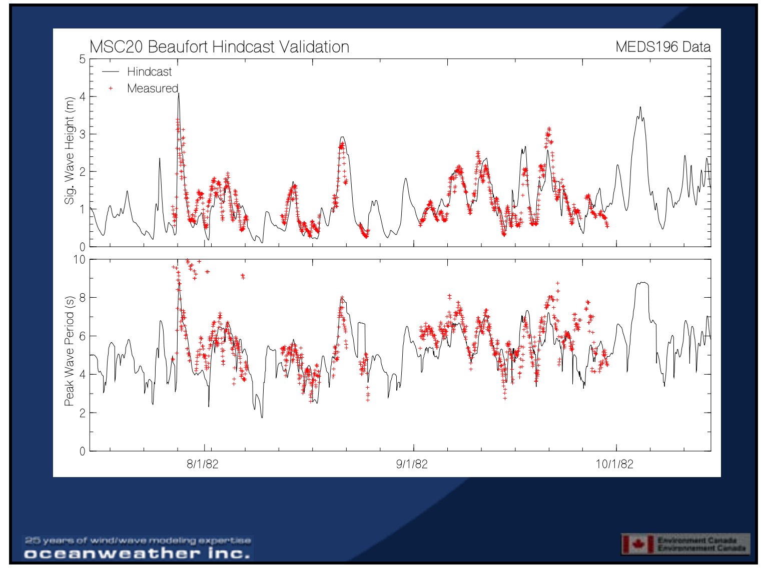


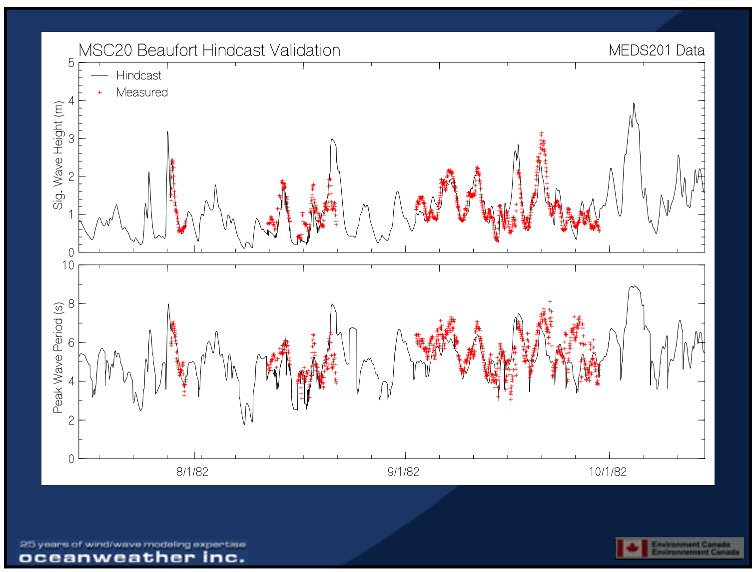
Comparison of weekly ice edge (blue represents greater than 50% concentration) valid June-24-2000 from the Canadian Ice Service (left) and final blended ice edge (right) from multiple ice data sources on the MSC Beaufort coarse and fine model domain

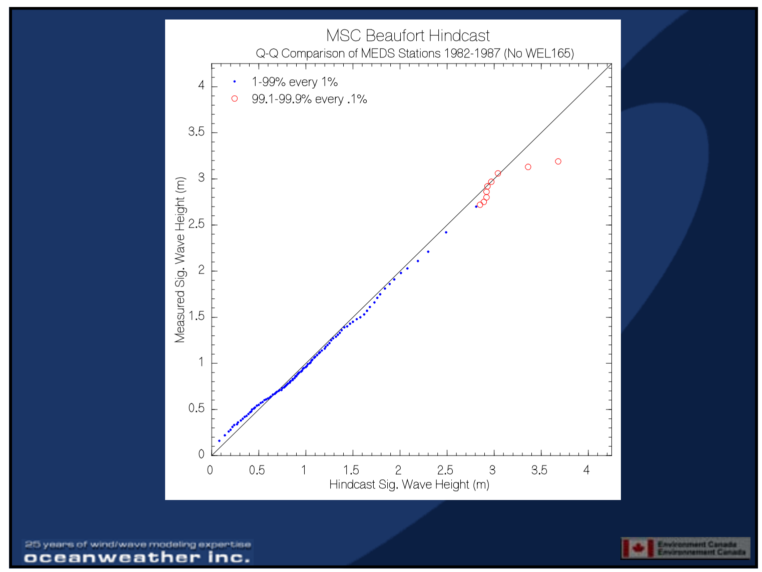
Validation

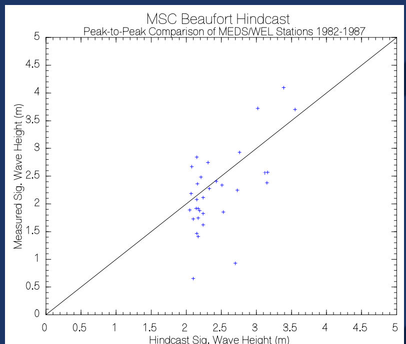
- MEDS - 12 buoys, 26 deployments in ice-free period over 1981-86
- Additional months hindcast in this period using same methodology since no in situ data in study period
- Water depths 11 to 71 m
- SI 42%, larger than MSC50 due to larger uncertainty in wind fields and low mean measurement (0.99 m)
- Q-Q plots show good agreement > 99th
- Peak-to-peak showed hindcast low bias of 22 cm and SI 23%


MSC Beaufort Fine Domain Validation Locations (1980-1987)
72°
71°40'
71°20'
71°
70°40'
70°20'
70°
69°40'
69°20'
69°
68°40'
218°
220°
222°
224°
226°
228°
230°
232°
234°
25 years of wind/wave modeling expertise
oceanweather inc.
Environment Canada
Environnement Canada


MSC20 Beaufort Hindcast Validation
MEDS196 Data
Hindcast
Measured
Sig. Wave Height (m)
Peak Wave Period (s)
8/1/82
9/1/82
10/1/82
25 years of wind/wave modeling expertise
oceanweather inc.
Environment Canada
Environnement Canada


MSC20 Beaufort Hindcast Validation
MEDS201 Data
Hindcast
Measured
Sig. Wave Height (m)
Peak Wave Period (s)
8/1/82
9/1/82
10/1/82
25 years of wind/wave modeling expertise
oceanweather inc.
Environment Canada
Environnement Canada


MSC Beaufort Hindcast
Q-Q Comparison of MEDS Stations 1982-1987 (No WEL165)
1-99% every 1%
99.1-99.9% every .1%
Measured Sig. Wave Height (m)
Hindcast Sig. Wave Height (m)
25 years of wind/wave modeling expertise
oceanweather inc.
Environment Canada
Environnement Canada



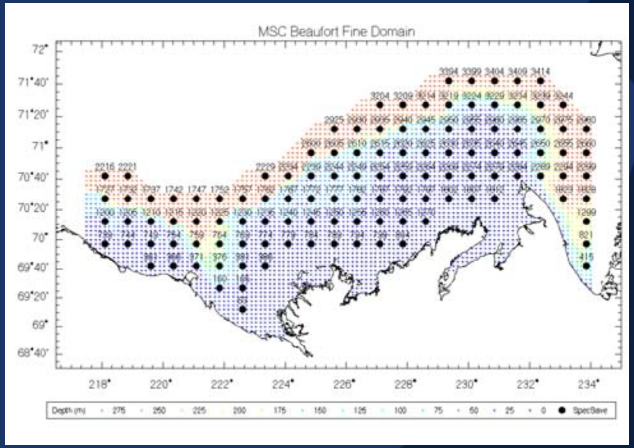
Hindcast Period : 01-JAN-1982 00:00:00 to 01-JAN-1988 00:00:00

	Station	Grid Point	Number of Pts	Mean Meas	Mean Hind	Diff (H-M)	RMS Error	Stnd Dev	Scat Index	Ratio	Corr Coeff
Sig Wave Ht (m)	MEDS196	0	9	2.61	2.54	-0.07	0.50	0.49	0.19	0.44	0.67
Wave Period (s)	MEDS196	0	9	7.33	7.06	-0.27	0.58	0.51	0.07	0.44	0.76
Sig Wave Ht (m)	MEDS201	0	7	2.35	2.21	-0.14	0.43	0.41	0.17	0.14	0.26
Wave Period (s)	MEDS201	0	7	6.90	6.53	-0.36	0.60	0.48	0.07	0.14	0.22
Sig Wave Ht (m)	MEDS204	0	4	2.34	1.79	-0.55	0.56	0.11	0.05	0.00	0.95
Wave Period (s)	MEDS204	0	4	6.87	5.92	-0.95	1.02	0.39	0.06	0.00	0.84
Sig Wave Ht (m)	MEDS265	0	5	2.47	2.41	-0.05	0.45	0.44	0.18	0.60	0.85
Wave Period (s)	MEDS265	0	5	7.09	6.94	-0.16	0.64	0.62	0.09	0.40	0.82
Sig Wave Ht (m)	Combined	0	32	2.45	2.24	-0.22	0.60	0.56	0.23	0.31	0.63
Wave Period (s)	Combined	0	32	7.66	6.61	-1.05	4.11	3.98	0.52	0.31	-0.29

Hindcast Products

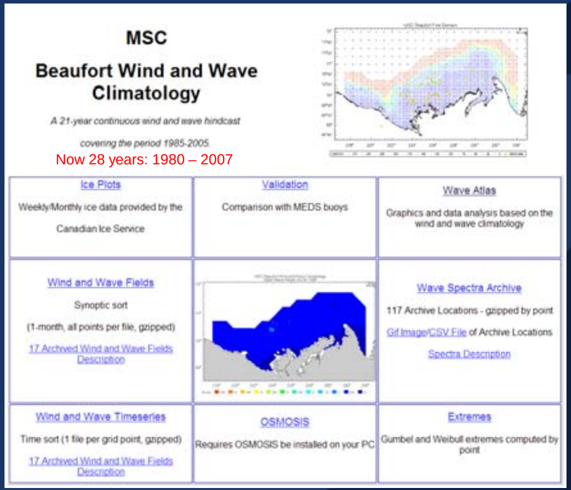
- Hourly archive 1985-2007 at all grid points in fine mesh (to be extended to Canadian domain)
- Wave spectra at selected fine mesh points
- Beaufort sea wave atlas online
  - Mean, sd, %ile, exceedance, anomaly
  - Individual and collective months, years
  - Extremal analysis at each grid point

25 years of wind/wave modeling expertise
oceanweather inc.
Environment Canada

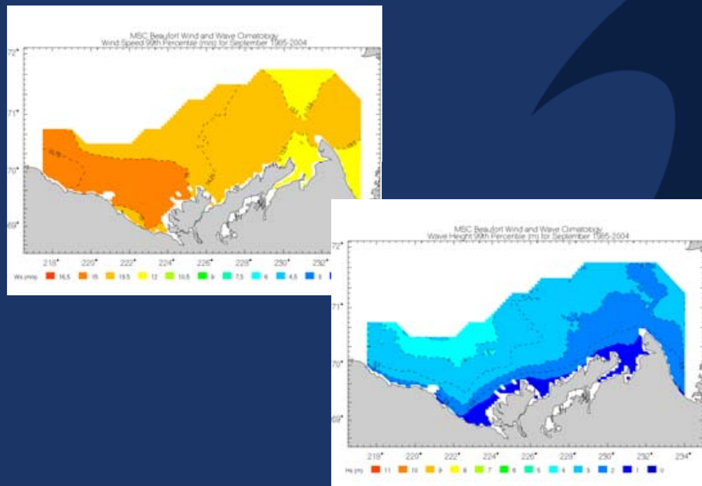


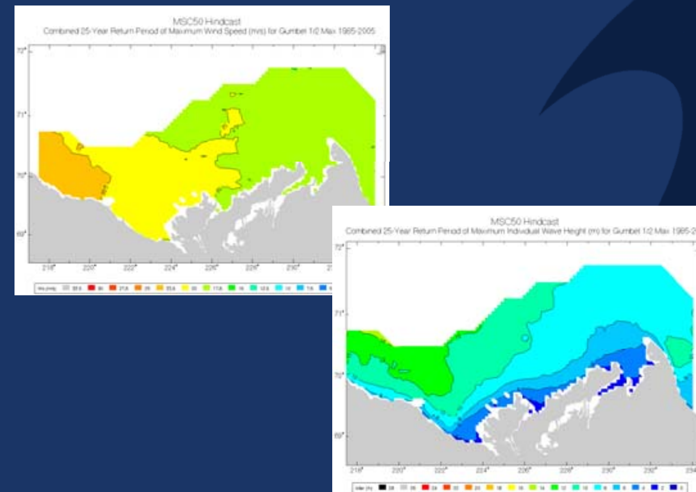
Beaufort wind and wave archive (colored by depth) and wave spectra (black) locations

25 years of wind/wave modeling expertise
oceanweather inc.
Environment Canada



25 years of wind/wave modeling expertise
oceanweather inc.
Environment Canada





25 years of wind/wave modeling expertise
oceanweather inc.
Environment Canada Environnement Canada

Summary And Future Work

- MSC-B provides a new high resolution wind and wave hindcast at higher temporal and spatial resolution than previous efforts: 28-year "continuous" hindcast with good agreement with measurements
- Hindcast data provided to
  - MSC Climate Services
  - DFO ISDM
  - International oil and gas companies and their consultants for design and planning
  - Government regulatory agencies for environmental assessment
  - Researchers, e.g. Solomon for shoreline erosion studies
- Climate information provided to Beaufort Sea Regional Annex to International Standard ISO/DIS 19901-1: *Petroleum and natural gas industries – specific requirements for offshore structures: Part I: Metocean design and operating considerations*
- Beaufort Sea wind and wave atlas (http://www.oceanweather.net/MSC50WaveAtlas/).

25 years of wind/wave modeling expertise
oceanweather inc.
Environment Canada Environnement Canada

Summary And Future Work

- Extend hindcast to 40+ years (1970-2010)
- Extend validation using earlier in situ data and recent altimeter data
- Investigate combined wind, wave, storm surge modelling for Canadian Beaufort
- Concerns involve wind field, bathymetry and land surface elevation data, sufficient high-quality validation data for wave and water levels
- Investigate use of SAR wind products for small scale variability close to coast
- Increasing requirement for improved wave-in-ice models
- Investigate similar efforts from USACE in US Beaufort

25 years of wind/wave modeling expertise
oceanweather inc.
Environment Canada Environnement Canada


THE BEAUFORT SEA AFTER CLIMATE CHANGE?
THE END

5.6.9 Regional Hydro-Climatology and its Relationship to Northern Oil and Gas Development, *Barrie Bonsal*

Ph.D., Research Scientist, Environment Canada, Saskatoon, SK, Canada. Email: Barrie.Bonsal@ec.gc.ca

Past hydro-climatic trends/variability and projected future climate change have, and will continue to have considerable effects on physical and socio-economic systems over many regions of the world. Of particular concern are high-latitude areas that are extremely sensitive to hydro-climatic variations and are expected to experience the greatest impacts from climate change. This presentation summarizes past trends and variability and projected future changes to the regional hydro-climatology of the Beaufort Sea, North Slope, and Mackenzie Delta as they relate to oil and gas exploration and development in the area.

Much of the Arctic has experienced significant trends towards warmer temperatures and increased precipitation during the instrumental record. For North America during the last 50 years, largest warming rates were observed in the Mackenzie Basin/Beaufort Sea region, with greatest increases in winter and spring. During this same period, annual precipitation has also increased. The spring warming has also been reflected in the earlier occurrence of spring melt (approximately 10 days) during the last half century. These trends, and in particular increasing temperatures, have had discernible impacts on environmental processes over the Mackenzie/Beaufort region. For example, the lake and river ice season has become significantly shorter primarily due to earlier break-up. Spring peak river flows have also become earlier mainly due to an advanced snowmelt. In terms of permafrost, there has been a northward movement in some areas of the Northwest Territories in the last few decades, and a warming of shallow permafrost temperatures in the central and northern Mackenzie region.

All future Global Climate Model (GCM) projections for the middle of this century demonstrate temperature and for the most part, precipitation increases over the Mackenzie/Beaufort region, however, there is a considerable range on both temporal and spatial scales. For temperature, autumn shows the greatest change (+1.4 to +3.3 °C), followed by winter (+1.2 to +2.6 °C), spring (+0.8 to +2.4 °C), and summer (+0.2 to +1.6 °C). Spatially, the ocean warms more than the land during the cold season. It is also noteworthy that recent temperature changes at Inuvik, NWT indicate that Beaufort-region warming is occurring faster than projected by the majority of GCMs. Future precipitation shows annual increases averaging between 4.8 and 10.7%. For extremes, climate-change projections revealed a substantial shift in the temperature distribution toward fewer very cold months and several more warm months. Extreme high monthly precipitation amounts were also projected to increase.

These past and projected changes to the hydro-climatology of the Mackenzie Basin/Beaufort Sea region suggest several key research issues with respect to future oil and gas exploration and development in the area. Examples include: 1) collection and assessment of reliable, consistent data to characterize and better understand past/current hydro-climatic variability, 2) better understanding of atmospheric circulation patterns affecting regional hydro-climatology, 3) more reliable climate projections from Global and Regional Models at the appropriate regional scale, and 4) better understanding of hydro-climatic extremes and variability which have, and will continue to have substantial impacts on the infrastructure associated with oil and gas exploration and development in the Mackenzie/Beaufort Sea region.

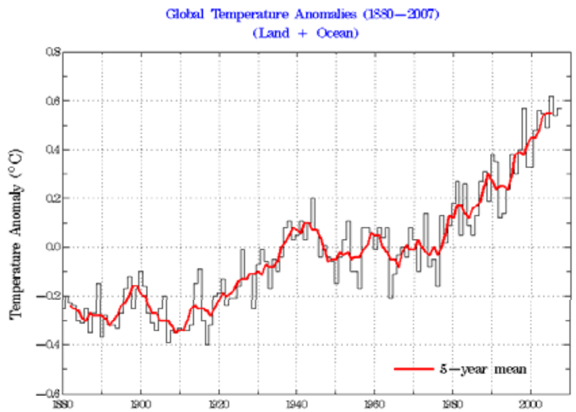
Regional Hydro-Climatology and Its Relationship to Northern Oil & Gas Development

Barrie Bonsal
Environment Canada
Saskatoon, SK

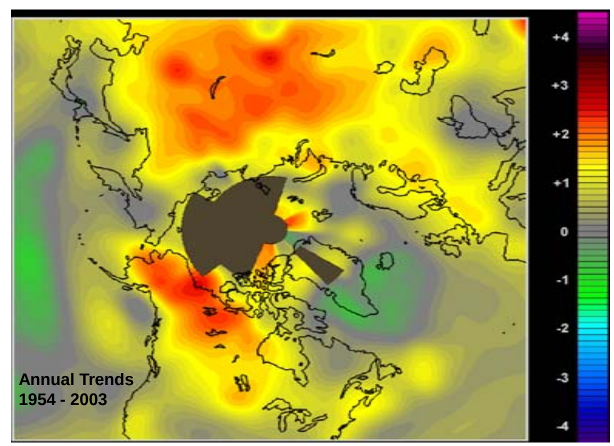
Outline

- Past Trends and Variability in Regional Hydro-Climatology – Temperature, Precipitation, Ice-Related Variables
- Future Climate – Projections, Variability, Extremes
- Summary
- Key Research Issues as they Relate to Northern Oil & Gas Development

Global surface temperatures are rising

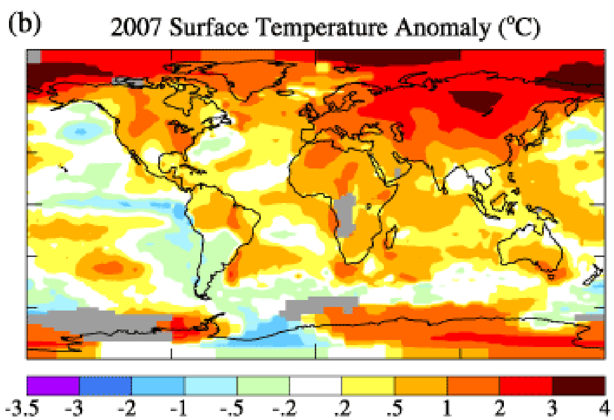


Changes in temperature are unevenly distributed



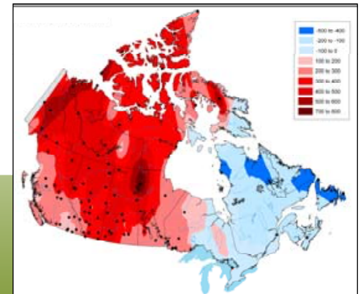
Source: http://arctic.atmos.uiuc.edu/

Changes in temperature are unevenly distributed

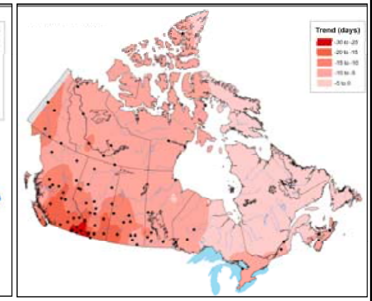


Source: NOAA

Trends in Climate-Ice Related Variables (1950-2003)

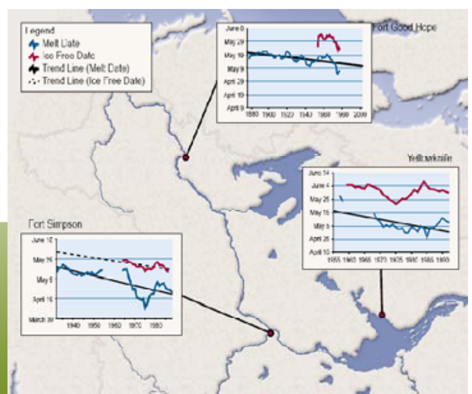


Freezing-Degree Days



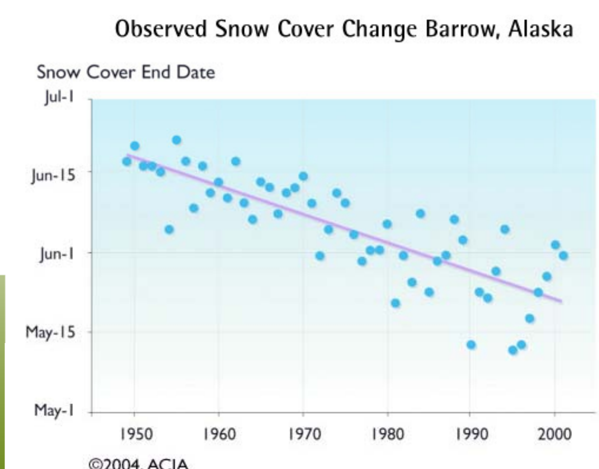
Spring 0°C Isotherm Dates

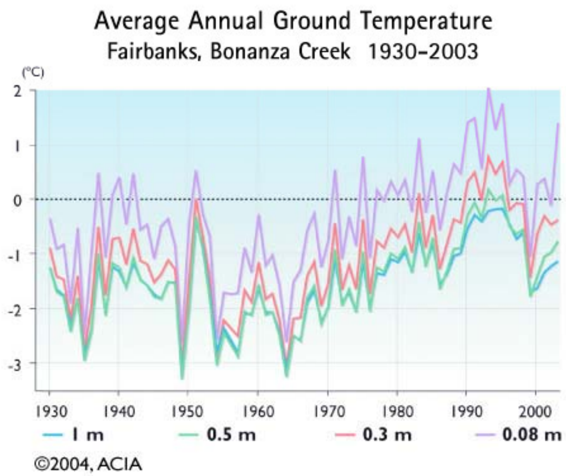
Melting of Freshwater Ice



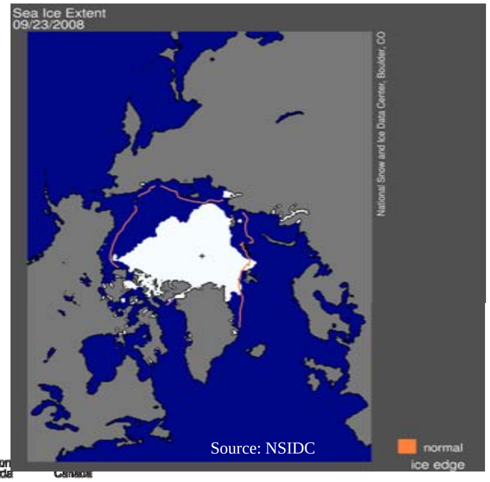
Source: Mackenzie River Basin State of the Aquatic Ecosystem Report (2003)

River and lake ice is melting earlier in the Mackenzie River Basin.

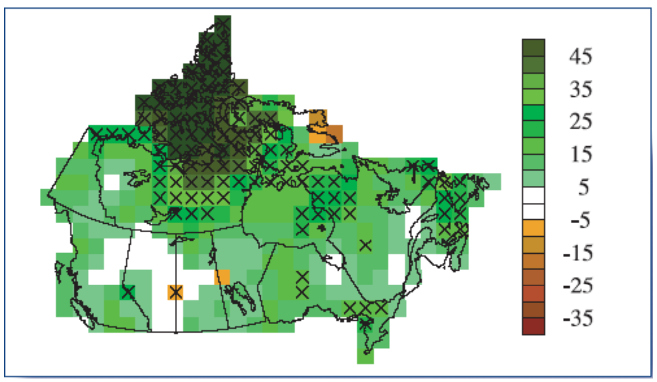




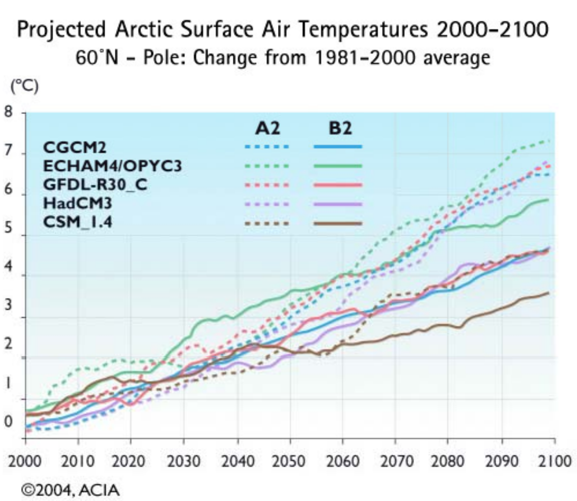
Observed Sea Ice Changes

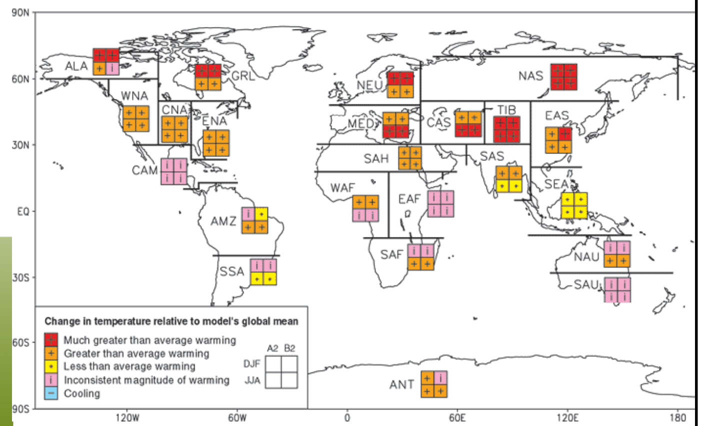


Annual Precipitation Trends (1950-2003)

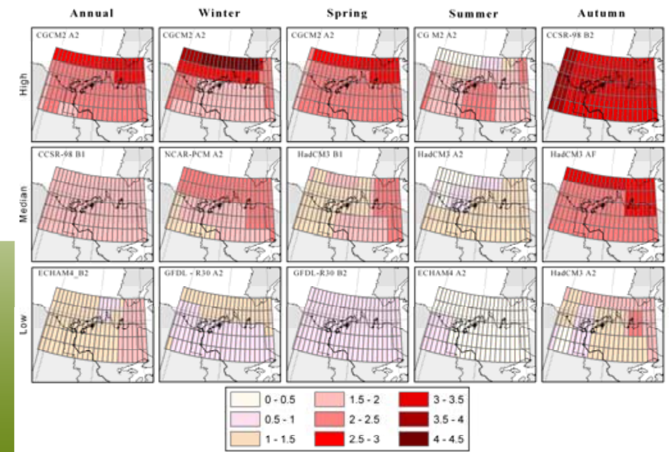


Updated From Zhang et al. (2000)

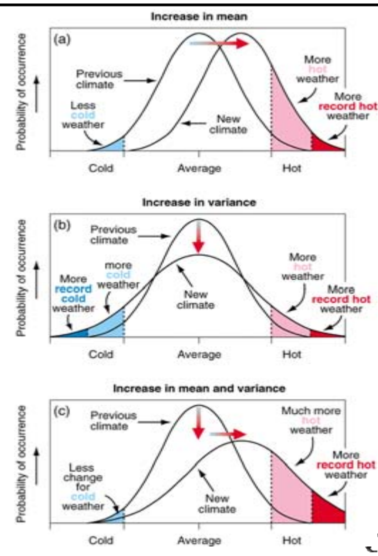


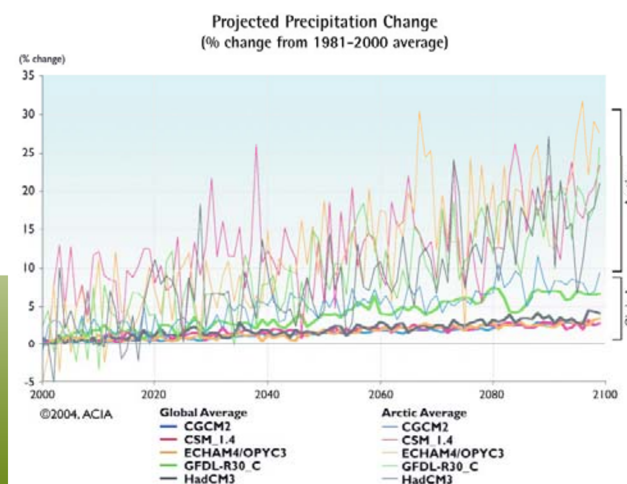


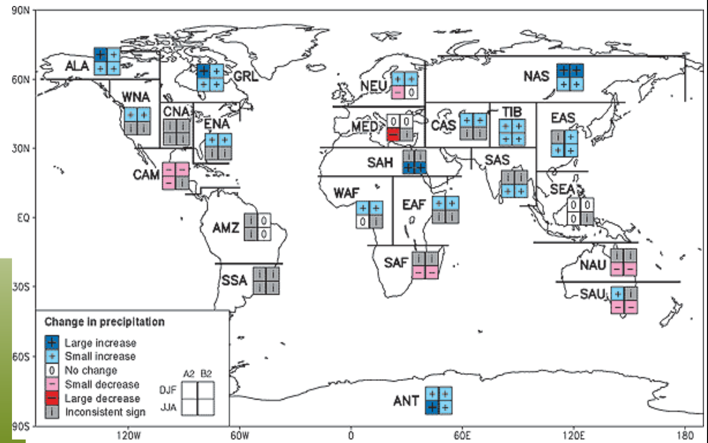
Temperature Changes (2010-2039)



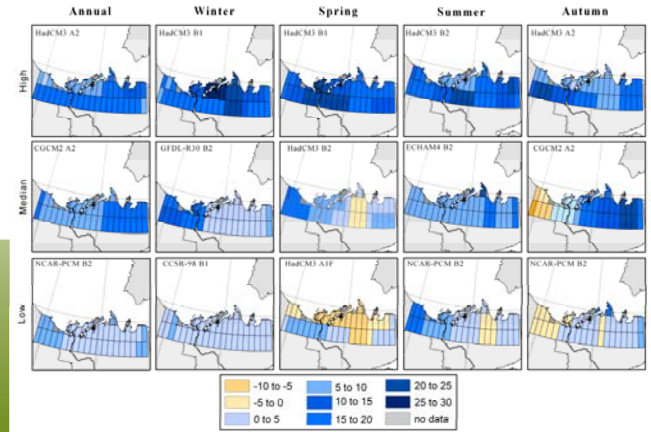
Temperature Extremes







Precipitation Changes (2010-2039)

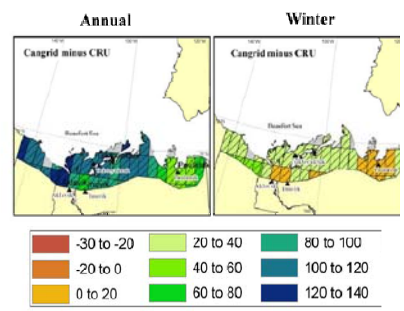


Summary

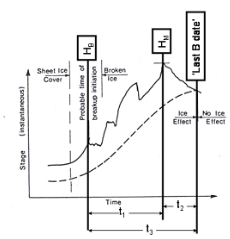
- Significant trends in climate and associated impacts over the Beaufort Sea, North Slope, and Mackenzie Delta during last 50 years
- All future climate scenarios indicate continued warming (particularly, during winter), increased precipitation, more high temperature extremes, and a likely increase in precipitation extremes as compared to current climate
- However, there is considerable variability within these future projections
- How will this future climate and related uncertainties impact Future Northern Oil & Gas Development?

Key Research Issues

Consistent climatic and hydro-metric data within the Mackenzie Basin/Beaufort Sea region required to characterize and understand past and future hydro-climate.



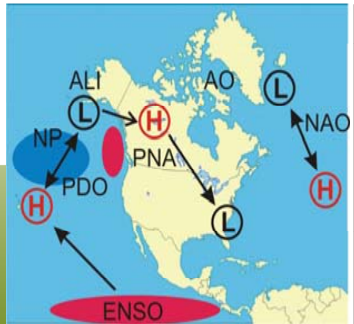
Observed Data Comparisons

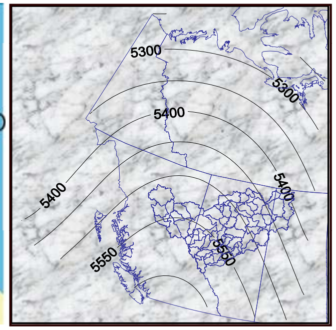


Extraction from Original Chart Records

Key Research Issues

Better understanding of atmospheric linkages to infer regional changes to future hydro-climate

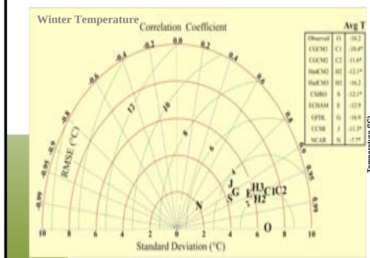


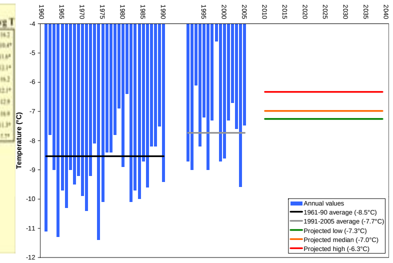


Large-Scale Teleconnections **Synoptic-Scale Circulation**

Key Research Issues

Reliable future climate projections at the appropriate spatial and temporal scales: GCMs/RCMs.

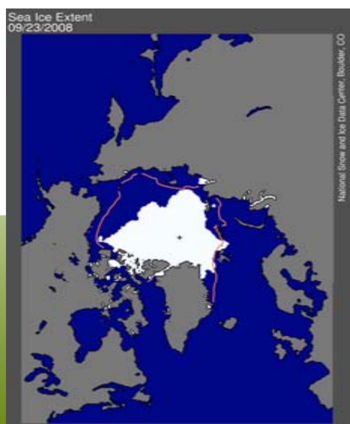


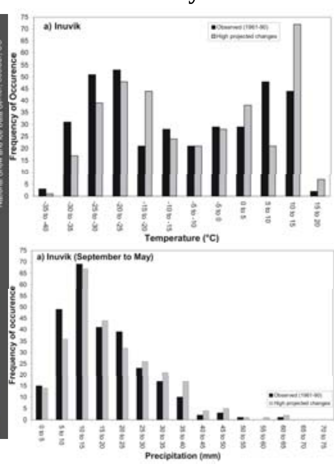


GCM/RCM Comparisons **Rate of Projected Changes**

Key Research Issues

Better understanding of extremes and variability





Thank You

5.6.10 Spatial and Temporal Dynamics of Lake Ice on the Arctic Coastal Plain of Alaska,

Chris Arp, Benjamin Jones & Joel Schmutz

U.S. Geological Survey, Alaska Science Center, 4210 University Drive, Anchorage, AK..

Email: carp@usgs.gov

Ice is a dominant attribute of Arctic lakes because most are only as deep as maximum ice thickness, such that many freeze solid. Lakes that do not freeze solid can provide winter aquatic refugia and water supply. To better understand temporal lake ice variability in a spatially-relevant context, we coupled point, ground penetrating radar, and synthetic aperture radar measurements of ice thickness with modeled ice thickness from 1971 to 2007. In May 2007, floating ice averaged 169 cm with often thicker bed-fast ice. Remotely-sensed ice measurements indicated that 52%, of 185 lakes surveyed, froze solid. Estimates of maximum annual ice growth over 39 years ranged from 153 to 198 cm and significantly thinned by 0.5 cm/yr ($r2=0.44$, $p<0.0001$), while timing of freeze onset and maximum growth showed no decadal trends. Mean monthly temperatures in October and April explained 68% of the interannual variation ($p<0.0001$) in ice-thickness. This spatial variability coupled with temporal trends will likely have profound implications for water supply, fish and waterfowl habitat, lake energy (heat and carbon) storage, and surface albedo, in a changing Arctic climate.

5.6.11 BP-DOE Cooperative Alaska Gas Hydrate Research, Mount Elbert #1 Stratigraphic Test,

Ray Boswell, Robert Hunter, & Timothy Collett

[1] Email: ray.boswell@netl.doe.gov

[2] Arctic Slope Regional Corporation. Email: Robert.Hunter@asrcenergy.com

[3] US Geological Survey. Email: tcollett@usgs.gov

In February 2007, the U.S. Department of Energy, BP Exploration (Alaska), Inc., and the U.S. Geological Survey conducted an extensive data collection effort at the "Mount Elbert #1" gas hydrates stratigraphic test well on the Alaska North Slope (ANS). The 22-day field program acquired significant gas hydrate-bearing reservoir data, including a full suite of open-hole well logs, over 500 feet of continuous core, and open-hole formation pressure response tests. Hole conditions, and therefore log data quality, were excellent due largely to the use of chilled oil-based drilling fluids. The logging program confirmed the existence of approximately 100 feet of gas hydrate-saturated, fine-grained sand reservoirs. Gas hydrate saturations were observed to range from 60% to 75% largely as a function of reservoir quality. Continuous wire-line coring operations (the first conducted on the ANS) achieved 85% recovery through 500 feet of section, providing more than 250 subsamples for analysis. The "Mount Elbert" data collection program culminated with open-hole tests of reservoir flow and pressure responses, as well as gas and water sample collection, using Schlumberger's Modular Formation Dynamics Tester (MDT) wireline tool. Four such tests, ranging from six to twelve hours duration, were conducted. This field program demonstrated the ability to safely and efficiently conduct a research-level openhole data acquisition program in shallow, sub-permafrost sediments. The program also demonstrated the soundness of the program's pre-drill gas hydrate characterization methods and increased confidence in gas hydrate resource assessment methodologies for the ANS.

5.6.12 Evaluation of Sub-Sea Physical Environmental Data for the Beaufort Sea OCS and Incorporation into a Geographic Information System (GIS) Database, *Warren Horowitz*

The MMS has developed a comprehensive database that synthesizes spatial and attribute information collected during shallow geological and geophysical surveys of the Federal Outer Continental Shelf in the Beaufort and Chukchi Sea planning areas from 1985 through 2001. The original shallow hazards database for the Beaufort Sea was published by the MMS under MMS OCS Study 2002-017. The final report and geospatial database from this completed study can be downloaded from the following link. <http://www.mms.gov/alaska/reports/2002rpts/>. ESRI's ArcView 3.2a, and Microsoft Access 97 were used to build the visual displays for the shallow hazards data. A Graphical User Interface was developed for ArcView that allows the user to query and display information from the database in map form. Since 2005, shallow hazards data collected from site-surveys within the Chukchi Sea have been added to existing shallow hazard survey database. The database and user interface were migrated from ArcView 3.2 to ArcGIS 9.1. The present MMS database includes raw and interpreted data from the collection of high-resolution seismic data in the Beaufort and Chukchi seas. The included survey data are from twenty eight site-clearance surveys for the Beaufort Sea and nine similar site clearance surveys from the Chukchi Sea. The database also includes four years of repetitive pipeline-route surveys for the Northstar Development area, two years of repetitive pipeline-route surveys for the proposed Liberty Development, and three years of survey data for the Boulder Patch. In addition, the database includes boring and grab-sample data, bathymetry, and historical earthquake data. The database provides spatial and attribute information for surface features such as the “Boulder Patch”, strudel scour, ice gouges, and bottom relief (bathymetry); spatial data on subsurface features such as shallow faults, shallow gas, and channels; and spatial data on other features such as shotpoint surveys, shallow borings, and earthquakes.

5.6.13 Empirical Sea Ice Thickness Estimation in the Arctic Ocean,

N. G. Platonov, D. C. Douglas, V. A. Eremeev & I. N. Mordvintsev

[1] Institute of Ecology and Evolution, Russian Academy of Sciences, Moscow, Russia.

E-mail: belchans@eimb.ru

[2] U.S. Geological Survey, Alaska Science Center, Juneau, AK, USA. E-mail: david_douglas@usgs.gov

A better understanding of sea ice characteristics such as ice thickness helps inform both oil and gas infrastructure and ecological discussions in the Arctic. This study evaluates methods to improve a recently developed neural network (NN) algorithm that estimates sea ice thickness with spatial resolution of approximately 100 km at monthly intervals during 1982 – 2003 (Belchansky et al., 2008, J. Climate, 21:716-729). For any grid cell, at each position along its drift trajectory, sea ice thickness changes are controlled by geophysical inputs that include dynamic and thermodynamic forcing parameters such as short- and long-wave radiation, cumulative freeze-degree days, ice drift velocity, and an ice-drift derived divergence/convergence index. Improvements to the original method included: 1) expanding the learning data with updated submarine draft data from NSIDC; 2) partitioning all learning data into non-overlapping categories of ice thickness; 3) learning the NN independently for each ice thickness category, and then combining fractions of ice categories to derive a sea ice thickness distribution for each grid cell; 4) replacing and expanding the original NCEP-NCAR Reanalysis radiation inputs with their analogs from the NCEP-DOE Reanalysis-2 data sets; 5) reconstructing the ice divergence-convergence index; and 6) separating the learning data into level ice and ridged ice categories. The contributions of dynamical and thermodynamical components to sea ice volume change in the central Arctic were examined. The influence of ice thickness to the sea ice volume balance is predominant for high latitudes, while for low latitudes, ice volume is related to ice extent.

5.6.14 Ice and Snow Helicopter-borne Observation Sensors used over Canadian Ice-Infested Waters Showing Results of April 2004 and 2008 from the Canadian Beaufort Sea Shelf,

Simon Prinsenberg, Ingrid Peterson & Scott Holladay

[1] Ph.D., Bedford Institute of Oceanography, Fisheries and Oceans Canada.

Email: prinsenbergs@mar.dfo-mpo.gc.ca

[2] Ph.D., Geosensors Inc. Email: scott.holladay@geosensors.com

Helicopter-borne sensors have been used in Canada since 1991 to collect ice properties to validate ice signatures seen in satellite imagery. The Electromagnetic-Laser system has evolved from a two frequency towed science sensor into a fixed-mount operational four frequency sensor that provides real-time ice thickness data. The video-laser system provides independently video frames and high frequency surface roughness data. Since 2006, a Ground-Penetrating-Radar-laser system has been tested to collect snow depth as well as freshwater ice thicknesses.

Ice property data was collected along helicopter flight paths over the land-fast ice and mobile pack ice in the eastern Canadian Beaufort Sea in April 2004 and 2008 using a Canadian Ice breaker over-wintering in the Arctic pack ice as a logistic base. September Arctic sea ice extent shows that 2003 and 2007 were respectively the start and the continuation of the rapid decline of ice extent within the Arctic Ocean. The observations of sea ice properties in April 2004 and 2008 reflect this change in the eastern Canadian Beaufort Sea. The land-fast ice extent and thickness were less, mobile ice were thinner and the thin ice extent (0-20cm thick ice) rarely present in 2004 were extensively found in 2008 with areas of up to 50km in width. In addition, the 2008 pack ice (lower ice extent) was more mobile under the wind forcing.

5.6.15 Under-ice Interaction and Mixing of Spring Floodwaters with Continental Shelf Water in the Alaskan Beaufort Sea,

M.A. Savoie, J.H. Trefry & R.P.Trocine

[1] Kinnetic Laboratories, Inc., Anchorage, AK. Email:msavoie@kinneticlabs.com

[2] Florida Institute of Technology, Melbourne, FL. Email: jtrefry@fit.edu

[3] Florida Institute of Technology, Melbourne, FL. Email: rtrocine@fit.edu

Spring floods transport more than half of the annual amounts of river water, suspended sediment and dissolved solids from northern Alaska to a frozen Beaufort Sea. In this study, offshore hydrography, water samples, and time series measurements were obtained through the ice during the period of spring breakup to determine the interaction and extent of mixing of under-ice river plumes from the Sagavanirktok and Kuparuk Rivers with offshore shelf waters. A 1-2 m thick under-ice river plume was traced >15 km offshore, and the fate of river-borne physical parameters in coastal seawater was found to be variably controlled by mixing and the volume and timing of the river discharge. Offshore transport and dispersion of spring floodwater under 2-m thick ice was linked to the seasonal river hydrographs with noticeable inter-annual variations that were due to river flow and the cooling and refreezing of flood waters during a given year. Observed variations in river flow and mixing with coastal seawater during this multi-year study provide insights to possible future responses to environmental change and increased river runoff in the Arctic.

5.6.16 Transport and Fate of Spring Floodwater from Rivers in the Alaskan Beaufort Sea,

John H. Trefry, Robert P. Trocine, Carrie M. Semmler, Matthew B. Alkire, Mark A. Savoie & Robert D. Rember

[1]Florida Institute of Technology, Melbourne, FL.Email: jtrefry@fit.edu

[2]Louisiana Universities Marine Consortium, Chauvin, LA

[3]Oregon State University, Corvallis, OR

[4]Kinnetic Laboratories, Inc., Anchorage, AK

[5]IARC, University of Alaska, Fairbanks. AK

Most rivers that drain into the Arctic Ocean carry 40-80% of their annual volume of water, suspended solids and dissolved chemicals during the 2-3 week period of the spring floods. In many cases, these large seasonal discharges are carried to an ocean covered with ~2-m thick ice. The magnitude, timing and fate of riverine inputs in the coastal ocean have important consequences on the hydrology of the Arctic and on estuarine food webs.

River water and suspended sediments were collected from the Sagavanirktok, Kuparuk and Colville rivers during the spring floods of 2001, 2002, 2004 and 2006 with an emphasis on the Sagavanirktok and Kuparuk rivers based on ease of accessibility. Water and suspended sediments also were collected beneath landfast ice in the coastal Alaskan Beaufort Sea.

Concentrations of total suspended solids (TSS) in the Sagavanirktok and Kuparuk rivers typically peaked during the first week of the spring floods. Peak values for TSS in the Sagavanirktok River ranged from 249 mg/L in 2002 to 609 mg/L in 2001 and were much higher than the range of peak values of 66-120 mg/L for the Kuparuk River that has no mountain source of suspended particles. Despite the large range in values for TSS, concentrations of particulate metals and organic carbon in the river-borne suspended sediments (per gram dry wt.) were quite uniform during the spring. In contrast, values for dissolved Fe, Pb, Cu, Mn and some other trace metals, along with DOC, increased by 3- to 25-fold in river water within 7 days of the onset of runoff due to thawing of ponds and upper soil layers. These peak values during peak flow decreased to near baseline values in a few days.

The flow of river water under ice into the Beaufort Sea was traced as far as 15 km offshore by collecting vertical profiles for salinity, temperature and turbidity as well as by collecting water and suspended particles for analysis. The data sets for suspended sediments and water across the salinity gradient under ice show that TSS does not follow a simple mixing trend as particles are settling out of the surface plume of river water. Data for dissolved As for all offshore samples show a more conservative trend. In contrast, the plot for DOC (as well as many other substances) versus salinity is complicated by the sharply shifting concentrations of DOC in the rivers during the brief study period.

The main conclusions of the study are as follows: (1) spring floods deliver >80% of the suspended sediment and >50% of the dissolved chemical to the Beaufort Sea in 2-3 weeks and riverine concentrations of selected dissolved metals and organic carbon often peak during peak flow and (2) river water is transported >15 km offshore, under ice during the spring melt showing transport pathways for freshwater, suspended sediment and dissolved chemicals.

Financial support for this research was derived from the U.S. Department of the Interior, Minerals Management Service, contract 1435-01-04-CT-32080.

APPENDIX I

FORUM PARTICIPANTS

INAC FORUM PARTICIPANTS

Last Name	First Name	Organization	City/State/Zip	E-mail
Aldrich	Lori	Alaska Department of Environmental Conservation	Anchorage, AK 99501	lori.aldrich@alaska.gov
Angliss, Ph.D.	Robyn	NOAA/NMFS	Seattle, WA 98103	robyn.angliss@noaa.gov
Arthur	Steve	Alaska Department of Fish & Game	Fairbanks, AK 99701	steve.arthur@alaska.gov
Ashjian	Carin	Woods Hole Oceanographic Institution	Woods Hole, MA 02543	cashjian@whoi.edu
Aughe	Stacey	ASRC Energy Services	Anchorage, AK 99503	stacey.aughe@asrcenergy.com
Bacchus	Paul	Environment Canada	Gatineau, Quebec K1A 0H3	paul.bacchus@ec.gc.ca
Baffrey	Michael	U.S. Department of the Interior, Office of the Secretary - Alaska	Anchorage, AK 99501	
Bailey, Ph.D.	Alan	Petroleum News	Anchorage, AK 99516	abailey@petroelumnews.com
Bain	Lawrence "Hugh"	Fisheries and Oceans Canada	Ottawa, ON K1A 0E6	hugh.bain@dfo-mpo.gc.ca
Baker	Terry	Indian and Northern Affairs Canada	Ottawa, ON K2J 5N5	terry.baker@rogers.com
Barnes	Paul	Canadian Association of Petroleum Producers	St. Johns, NF A1C 1B6	barnes@capp.ca
Baryluk	Steve	Joint Secretariat, Inuvialuit Game Council	Inuvik, NT X0E 0T0	travel@jointsec.nt.ca

Last Name	First Name	Organization	City/State/Zip	E-mail
Beardsley	Betsy	Alaska Wilderness League	Anchorage, AK 99501	betsy@alaskawild.org
Beaulieu	Jean-Marie	Canadian Polar Commission	Ottawa, ON K1R 7X7	beaulieuj@polarcom.gc.ca
Becker	Charles	Becker & Associates	Anchorage, AK 99503	cbecker39@yahoo.com
Bercha, Ph.D.	Frank	Bercha International Inc	Calgary, AB T2N 3S9	
Berg	Catherine	U.S. Fish & Wildlife Service	Anchorage, AK 99501	catherine_berg@fws.gov
Berman, Ph.D.	Matthew	UAA ISER	Anchorage, AK 99508	matthew.berman@uaa.alaska.edu
Beswick	Bette	Golder Associates	Calgary, AB T2P 3T1	bette_beswick@golder.com
Bettis	Patricia	Alaska Department of Natural Resources	Anchorage, AK 99501	patricia.bettis@alaska.gov
Blanchard	Whitney	National Oceanic & Atmospheric Administration, Coastal Response Research Center	Durham, NH 03824	
Blasco	Steve	Natural Resources Canada	Dartmouth, NS B2Y 4A2	sblasco@nrcan.gc.ga
Bleaney	Bob	ConocoPhillips Canada	Calgary, Alberta T2P 2H7	bob.bleaney@conocophillips.com
Bonsal, Ph.D.	Barrie	Environment Canada	Saskatoon, SK 57S 1L2	barrie.bonsal@ec.gc.ca
Borbey	Patrick	Northern Affairs Organization, Indian and Northern Affairs Canada	Gatineau, QC K1A0H4	BorbeyP@ainc-inac.gc.ca

Last Name	First Name	Organization	City/State/Zip	E-mail
Boswell	Ray	National Energy Technology Laboratory	Morgantown, WV 26507	ray.boswell@net1.doe.gov
Boveng	Peter	National Marine Mammal Laboratory	Seattle, WA 98115	
Bowers	Peter	Northern Land Use Research Inc.	Fairbanks, AK 99709	pmb@nothernlanduse.com
Boyd	Ken	StatoilHydro	Eagle River, AK 99577	kenbo@gci.net
Boyle	Michael	Federal Energy Regulatory Commission	Washington, DC 20246	michael.boyle@ferc.gov
Bradford	John	Boise State University, Center for Geophysical Investigation of Shallow Subsurface	Boise, ID 83725	johnb@cgiss.boisestate.edu
Bradley	Erin	Jacques Whitford-AXYS	Calgary, AB T2P 1H7	erin.bradley@jacqueswhitford.com
Brainerd	Scott	Alaska Department of Fish & Game	Fairbanks, AK 99701-1599	scott.brainerd@alaska.gov
Braund	Stephen		Anchorage, AK 99510	srba@alaska.net
Braunstein	Bob	BGES	Anchorage, AK 99501	bob@bgesinc.com
Braunstein	Carol	BGES	Anchorage, AK 99501	
Broje	Victoria	Shell	Houston, TX 77082	victoria.broje@shell.com
Brower	Harry	Alaska Eskimo Whaling Commission	Barrow, AK 99723	harry.brower@north-slope.org

Last Name	First Name	Organization	City/State/Zip	E-mail
Brown	Anne	Department of Natural Resources, State Pipeline Coordinators Office	Anchorage, AK	abrown@jpo.doi.gov
Brown	John	Exponent	Natick, MA 01760	
Brown	Tammas	State of Alaska	Anchorage, AK 99501	tbrown@jpo.doi.gov
Brudie	Nina	AK Dept of Natural Resources, Coastal Management	Anchorage, AK 99502	nina.brudie@alaska.gov
Brueggemann	Rudy	Consulate of Canada, Anchorage	Anchorage, AK 99501	rudy.brueggemann@international.gc.ca
Buerkert	Thomas	Repsol YPF	The Woodlands, TX 77380	tbuerkertb@repsolypf.com
Buist	Ian	SL Ross Environmental Research Ltd.	Ottawa, ON K1G 0Z4	ian@slross.com
Bunio	Gary	MGM Energy Corp	Calgary, AB T2P 3N9	gary.bunio@mgmenergy.com
Burgess	Margo	Natural Resources Canada, Geological Survey of Canada	Ottawa, ON K1A 0E8	mburgess@nrcan.gc.ca
Burwell	Michael	Minerals Management Service	Anchorage, AK 99503	michael.burwell@mms.gov
Cacy	Robin	Minerals Management Service	Anchorage, AK 99503	-
Campbell	Chris	Minerals Management Service	Anchorage, AK 99503	
Campbell-Johnson	Brenda	PAS, Inc	Anchorage, AK 99504	-

Last Name	First Name	Organization	City/State/Zip	E-mail
Case, Ph.D.	Ray	Government of the NWT	Yellowknife, NT X1A 3L3	ray_case@gov.nt.ca
Chiperzak	Doug	KAVIK-AXYS Inc.	Calgary, AB T2P 1H7	dchiperzak@kavik-axys.com
Clapham	Phillip	National Marine Mammal Laboratory	Seattle, WA 98115	
Clark, Ph.D.	James	ExxonMobil Research & Engineering	Fairfax, VA 22037	jim.r.clark@exxonmobil.com
Clarke	Anne	Canadian Environmental Assessment Agency	Ottawa, ON K1A 0H3	ann.clearke2@ceaa-acee.gc.ca
Clarke	Janet	SAIC	Buckley, WA 98321	janet.clarke@saic.com
Cliff	Amanda	Inuvialuit Regional Corporation; Inuvik, Northwest Territories	Waterloo, ON N2J 2P9	amandacliff@sympatico.ca
Cobb	Don	Northern Research Energy Development Fisheries & Ocean Canada Arctic Research Division	Winnipeg, MB R3T 2N6	don.cobb@dfo-mpo.gc.ca
Collett	Timothy	U.S. Geological Survey, Office of Communication	Reston, VA 20192	tcollett@usgs.gov
Cologgi	John	ConocoPhillips	Anchorage, AK 99510	john.r.cologgi@conocophillips.com
Combes	Marcia	U.S. Environmental Protection Agency	Anchorage, AK 99513	combes.marcia@epa.gov
Conlan	Kathy	Canadian Museum of Nature	Ottawa, ON K1P 6P4	kconlan@mus-nature.ca
Convillion	Annalie	The Nature Conservancy	Anchorage, AK	aconvillion@tnc.org

Last Name	First Name	Organization	City/State/Zip	E-mail
Coon	Catherine	Minerals Management Service	Anchorage, AK 99503	
Coon, Ph.D.	Max	NorthWest Research Associates, Inc.	Redmond, WA 98052	max@nwra.com
Cowles, Ph.D.	Cleve	Minerals Management Service	Anchorage, AK 99503	cleveland.cowles@mms.gov
Creasey	Roger	Shell Global Solutions (Canada)	Calgary, AB T2L 1Y8	roger.creasey@shell.com
Crockett	Marilyn	Alaska Oil and Gas Association	Anchorage, AK 99501	info@aoga.org
Crowley	Heather	Minerals Management Service	Anchorage, AK 99503	
Curney	Gregory	SOA Department of Natural Resources	Anchorage, AK 99501-3560	greg.curney@alaska.gov
Cutler	Thor	Environmental Protection Agency	Seattle, WA 98101	cutler.thor@epa.gov
Darigo	Nancy	URS Corporation	Anchorage, AK 99503	nancy_darigo@urscorp.com
Davis	Rolph	LGL AK Research Associates, Inc.	Anchorage, AK 99518	alaska@lgl.com
DeBruyn	Terry	Minerals Management Service	Anchorage, AK 99503	
Derksen	Dirk	U.S. Geological Survey, Alaska Science Center	Anchorage, AK 99503	dirk_derksen@usgs.gov
Derocher	Andrew	University of Alberta	Edmonton, AB T6G 2H1	derocher@ualberta.ca

Last Name	First Name	Organization	City/State/Zip	E-mail
Deutsch	Kathleen	U.S. Dept of Energy, Office of Policy & International Affairs	Washington, DC 20585	kathleen.deutsch@hq.doe.gov
Devaris	Aimee	NOAA National Weather Service, Alaska Region	Anchorage, AK 99513-7575	aimee.devaris@noaa.gov
DeVries	Mark R	BP Exploration Alaska	Anchorage, AK 99508	mark.devries@bp.com
Dickson	David	Alaska Wilderness League	Washington, DC 20001	david@alaskawild.org
Dilabio	Ron	Geological Survey of Canada, Natural Resources Canada	Ottawa, ON K1A OE8	rdilabio@nrcan.gc.ca
Doyle	William	Office of the Federal Coordinator	Washington, DC 20004	gdavis@arcticgas.gov
Ducker	James	Bureau of Land Management	Anchorage, AK	jducker@blm.gov
Duggan	Douglas	Natural Resources Canada-FLMD	Ottawa, ON	dduggan@nrcan.gc.ca
Dunton, Ph.D.	Ken	University of Texas, Marine Science	Port Aransas, TX 78373	
Durell	Greg	Battelle	Duxbury, MA 02332	
Durner	George	U.S. Geological Survey	Anchorage, AK	gdurner@usgs.gov
Dygas	Joe	Joint Pipeline Office/BLM	Anchorage, AK	jdygas@jpo.doi.gov
Eicken	Hajo	University of Alaska Fairbanks	Fairbanks, AK 99775-7320	hajo.eicken@gi.alaska.edu

Last Name	First Name	Organization	City/State/Zip	E-mail
Eschenbach	Ted	TGE Consulting	Anchorage, AK 99504	tede1@ak.net
Etherington	Karen	TransCanada	Calgary, AB T2F 5H1	karen_etherington@transcanada.com
Falk	Martha	I.C.A.S.	Barrow, AK 99723	icas.natural@barrow.com
Farrell, Ph.D.	John	U.S. Arctic Research Commission	Arlington, VA 22203	jfarrell@arctic.gov
Ferrero	Rick	DOI/USGS	Seattle, WA 98104	rferrero@usgs.gov
Feschuk	Ron	MGM Energy Corp	Calgary, AB T2P 3N9	ron.feschuk@mgmenergy.com
Fischbach	Anthony	U.S. Geological Survey	Anchorage, AK	afischbach@usgs.gov
Fisk	Bob	Bureau of Land Management	Anchorage, AK 99512	bfisk@blm.gov
Forbes	Don	Natural Resources Canada	Dartmouth, NS B2Y 4A2	dforbes@nrcan.gc.ca
Fordham	Tami	Environmental Protection Agency	Anchorage, AK 99513	fordham.tami@epa.gov
Fortier	Martin	ArcticNet Inc	Quebec, QC G1K 7P4	martin.fortier@arcticnet.ulaval.ca
Fox	James	U.S. Fish & Wildlife Service	Fairbanks, AK 99701	jimmy_fox@fws.gov
Funk	Dale	LGL AK Research Associates, Inc.	Anchorage, AK 99518	dfunk@lgl.com

Last Name	First Name	Organization	City/State/Zip	E-mail
Galganitis	Michael	Applied Sociocultural Research	Anchorage, AK 99510-1352	msgalginaitis@alaska.net
Gardner	Dale	ADEC	Anchorage, AK 99501	dale.gardner@alaska.gov
Geddes	Steve	ConocoPhillips Alaska, Inc.	Anchorage, AK 99501	s.w.geddes@conocophillips.com
George	Morris	EISC	Inuvik, NT X0E 0T0	eisc@jointsec.nt.ca
Goll	John	Minerals Management Service	Anchorage, AK 99503	john.goll@mms.gov
Gore	Anne		Anchorage, AK 99501	anne_gore@tws.org
Greene, Ph.D.	Ben	North Slope Borough, Planning Department	Barrow, AK 99723	ben.greene@north-slope.org
Gustafson	Gary	Denali Pipeline	Anchorage, AK 99508-4650	gary.gustafson1@bp.com
Guyer	Scott	Bureau of Land Management	Anchorage, AK 99513	sguyer@ak.blm.gov
Haddad	Geoffrey	ConocoPhillips Alaska, Inc.	Anchorage, AK 99510	geoffrey.a.haddad@conocophillips.com
Hall, Ph.D.	James	ExxonMobil Upstream Research Company	Houston, TX 77098	james.hall@exxonmobil.com
Hanrahan	Michael	Centre for Marine CNG Inc.	St. John's, NF A1C 5H5	michael.hanrahan@cmcng.com
Harwood	Lois	Department of Fisheries and Oceans Canada	Yellowknife, NT X1A 1E2	lois.hardwood@dfo-mpo.gc.ca

Last Name	First Name	Organization	City/State/Zip	E-mail
Haskett	Geoff	U.S. Fish & Wildlife Service	Anchorage, AK	tauline_davis@fws.gov
Haut, Ph.D.	Richard	Houston Advanced Research Center	The Woodlands, TX 77381	rhaut@harc.edu
Hawkins, Ph.D.	James	Imperial Oil Ltd	Calgary, AB T2P-3M9	jim.r.hawkins@exxonmobil.com
Hearon	Greg	Coastal Frontiers Corporation	Chatsworth, CA 91311-05759	ghearon@coastalfrontiers.com
Hedstrom	Kate	University of Alaska Fairbanks	Fairbanks, AK 99775-7320	
Heinrichs	Thomas	University of Alaska Fairbanks-GINA	Fairbanks, AK 99775	tom.heinrichs@alaska.edu
Herczeg	Bryan	U.S. Environmental Protection Agency	Anchorage, AK 99513-7599	herczeg.bryan@epa.gov
Holland-Bartels, Ph.D.	Leslie	U.S. Geological Survey	Anchorage, AK 99508	lholland-bartels@usgs.gov
Horowitz	Warren	Minerals Management Service	Anchorage, AK 99503	warren.horowitz@mms.gov
Howell	David	Bureau of Land Management	Anchorage, AK 99513-7575	d1howell@blm.gov
Hudson	Tim	National Park Service	Anchorage, AK 99501	tim_hudson@nps.gov
Huffines	Eleanor	The Wilderness Society	Anchorage, AK 99501	eleanor_huffines@tws.org
Hughes	Layla	World Wildlife Fund	Juneau, AK 99801	layla.hughes.wwfus.org

Last Name	First Name	Organization	City/State/Zip	E-mail
Hunter	Robert	ASRC Energy Services E&P Technology	Anchorage, AK	robert.hunter@asrcenergy.com
Iversen	Allison	Petroleum Systems Integrity Office	Anchorage, AK 99501	allison.iversen@alaska.gov
Jen	Mark	U.S. Environmental Protection Agency	Anchorage, AK 99513-7599	jen.mark@epa.gov
Johnson	Kim	Shell Canada Energy	Calgary, AB T2P 2H5	kim.johnson@shell.com
Kasper	Jeremy	University of Alaska Fairbanks	Fairbanks, AK 99775-7320	
Kerr	Dave	Golder Associates	Calgary, AB	dave_kerr@golder.com
Kimball, Ph.D.	Suzette	U.S. Geological Survey	Reston, VA 20192	suzette_kimball@usgs.gov
Kinsinger	Anne	DOI/U.S. Geological Survey	Seattle, WA 98104	akinsinger@usgs.gov
Kleeschulte	Charles	Senator Lisa Murkowski's Office	Washington, DC 20510	chuck_kleeschulte@murkowski.senate.gov
Kleinleder	Rich	URS Corporation	Homer, AK 99603	richard_kleinleder@urscorp.com
Klieforth	Robert	SLR	Anchorage, AK	-
Kofinas	Gary	Institute of Arctic Biology, University of Alaska Fairbanks	Fairbanks, AK 99775-7000	gary.kofinas@uaf.edu
Koss	Lee	BLM	Anchorage, AK 99513	lkoss@blm.gov

Last Name	First Name	Organization	City/State/Zip	E-mail
Kotokak, Sr.	Max	Joint Secretariat, Fisheries Joint Management Committee	Inuvik, NT X03 OTO	travel@jointsec.nt.ca
Lafata	Renee	BGES	Anchorage, AK 99501	
Lage	Janet	ASRC Energy Services	Anchorage, AK 99503	jana.lage@asrcenergy.com
Lampe	Doreen	I.C.A.S.	Barrow, AK 99723	doreen.lampe@north-slope.org
Larsen, Ph.D.	Amy	NPS	Fairbanks, AK 99709	amy_larsen@nps.gov
Leavitt, Sr.	Price	ICAS	Barrow, AK 99723	icas.executive@barrow.com
Lee	Ken	Fisheries and Oceans Canada	Dartmouth, NS B2Y 4A2	WorkmanK@mar.dfo-mpo.gc.ca
Lennie	Johnny	Industry, Tourism & Investment	Inuvik, NT X03 OTO	johnny_lennie@gov.nt.ca
Lilly	Michael	GW Scientific	Fairbanks, AK 99708	mlilly@gwscientific.com
Lina	Julie	Pioneer	Anchorage, AK 99516	julie.lina@pxd.com
Lincoln	Elvina	UIC Oilfield Services, LLC	Anchorage, AK 99518	elincoln@ukpik.com
Link	Michael	LGL AK Research Associates, Inc.	Anchorage, AK 99518	mlink@lgl.com
Livingstone, Ph.D.	David	Indian and Northern Affairs Canada	Yellowknife, NT X1A 1E2	livingstoned@ainc-inac.gc.ca

Last Name	First Name	Organization	City/State/Zip	E-mail
Lohman	Tom	North Slope Borough	Anchorage, AK 99507	tomlohman2@aol.com
Lomax	Terri	State of Alaska DEC	Anchorage, AK 99501	terri.lomax@alaska.gov
Machtans	Craig	Environment Canada	Yellowknife, NT X1A 1E2	craig.machtans@ec.gc.ca
Macrander	Michael	Shell	Anchorage, AK	a.macrander@shell.com
Mairs	Heide	ExxonMobil Exploration Co	Houston, TX 77060	heide.l.mairs@exxonmobil.com
Mann	Stephanie	State of Alaska DEC	Anchorage, AK 99501	stephanie.mann@alaska.gov
Marsh, Ph.D.	Philip	Environment Canada	Saskatoon, SK S7N 3H5	philip.marsh@ec.gc.ca
Mason, Ph.D.	Owen	Geoarch	Anchorage, AK 99509-1554	geoarch@ptialaska.net
Matteucci	Mike	UIC Oilfield Services, LLC	Anchorage, AK 99518	mmatteucci@ukpik.com
Matthias	Karen	Consulate of Canada, Anchorage	Anchorage, AK 99501	karen.matthias@international.gc.ca
McCammon	Molly	Alaska Ocean Observing System	Anchorage, AK 99501	mccammon@aoos.org
McCoard	Ruth	Office of Communications, Bureau of Land Management		ruth_mccoard@blm.gov
McCrimmon	Glenn	Imperial Oil Ltd	Calgary, AB	glen.mccrimmon@esso.ca

Last Name	First Name	Organization	City/State/Zip	E-mail
McFarland	Fred	EISC	Inuvik, NT X0E 0T0	fjm@ripnet.com
McGhee	Robyn	ConocoPhillips Alaska, Inc.	Anchorage, AK 99501	robyn.e.mcghee@conocophillips.com
McGuire	J Rich	Federal Energy Regulatory Commission	Washington, DC 20246	rich.mcguirie@ferc.gov
McIntosh	Stacie	Bureau of Land Management	Fairbanks, Alaska 99709	stacie_mcintosh@ak.blm.gov
McKechnie	Ruth	Northern Oil & Gas Branch, Indian and Northern Affairs Canada	Gatineau, QC K1A 0H4	mckechnier@ainc-inac.gc.ca
McKim	Julie	U.S. Army Corps of Engineers	Anchorage, AK 99504	julie.w.mckim@usace.army.mil
McWhorter	Rob	Argonne National Lab	Anchorage, AK 99508	rnmassociates@gci.net
Means	Kathy	State of Alaska/DOG	Anchorage, AK 99501	kathy.means@alaska.gov
Melling, Ph.D.	Humfrey	Fisheries and Oceans Canada	Sidney, BC V8L 4B2	mellingh@dfo-mpo.gc.ca
Mendivil	Gary	Alaska Department of Environmental Conservation	Juneau, AK 99811	gary.mendivil@alaska.gov
Merten, Ph.D.	Amy	National Oceanic & Atmospheric Administration, Office of Response & Restoration	Silver Springs, MD 20910	amy.merten@noaa.gov
Miller	Pamela	Northern Alaska Environmental Center	Fairbanks, AK 99708	pam@northern.org
Miner	Lydia	SLR	Anchorage, AK	lminer@slrcorp.com

Last Name	First Name	Organization	City/State/Zip	E-mail
Monnett	Charles	Minerals Management Service	Anchorage, AK 99503	
Montague, Ph.D.	Jon	Alaskan Command	Elmendorf AFB, AK 99506	jerome.montague@elmendorf.af.mil
Moore	Susan	Shell Offshore	Anchorage, AK 99503	sue.moore@shell.com
Mullin	Joseph	Minerals Management Service	Herndon, VA 20170-4817	joseph.mullin@mms.gov
Murphy	Ted	Bureau of Land Management	Anchorage, AK 99510	ted_murphy@blm.gov
Natale	John	U.S. Coast Guard Research & Development Center	Groton, CT 06340-6048	john.a.natale@uscg.mil
Neff, Ph.D.	Jerry	Neff & Associates, LLC	Duxbury, MA 02332	neffjm@comcast.net
Neidig	Hans	U.S. Department of the Interior, Office of the Secretary - Alaska	Anchorage, AK 99501	hans_neidig@ios.doi.gov
Nelson	Edward	PGS Onshore, Inc.	Anchorage, AK 99503	ed.nelson@pgsonshore.com
Nelson	Kristen	Petroleum News	Anchorage, AK 99517	knelson@petroleumnews.com
Newbury	Thomas	Minerals Management Service	Anchorage, AK 99503	thomas.newbury@mms.gov
Newman	Richard	Minerals Management Service	Anchorage, AK 99503	
Nielsen, Ph.D.	Jennifer	U.S. Geological Survey	Anchorage, AK 99508	jlnielsen@usgs.gov

Last Name	First Name	Organization	City/State/Zip	E-mail
Noblin	Rebecca	Center for Biological Diversity	Anchorage, AK 99510	rnoblin@biologicaldiversity.org
Paget	Todd	Gov NWT	Yellowknife, NT X1A 1E2	todd_paget@gov.nt.ca
Parker	Walter	Parker Associates, Inc.	Anchorage, AK	wbparker@gci.net
Paule	Bridget	The Nature Conservancy	Anchorage, AK	bpaule@tnc.org
Paulic	Joclyn	Fisheries and Oceans Canada	Winnipeg, MB R3T 2N6	Joclyn.Paulic@dfo-mpo.gc.ca
Payne	John	Bureau of Land Management, North Slope Science Initiative	Anchorage, AK 99513-7599	john_f_payne@blm.gov
Pearce	Drue	Office of the Federal Coordinator, Alaska Natural Gas Transportation Projects	Washington, DC 20004	dpearce@arcticgas.gov
Pegau	Scott	Prince William Sound Oil Spill Recovery Institute	Cordova, AK 99574	wspegau@pwssc.gen.ak.us
Perham	Craig	U.S. Fish and Wildlife Service	Anchorage, AK	craig_perham@fws.gov
Perrin	Don	State of Alaska DNR	Anchorage, AK	donald.perrin@alaska.gov
Perry	Nelson	Parks Canada Agency	Inuvik, NWT X0E 0T0	nelson.perry@pc.gc.ca
Peterson	Sean	BGES	Anchorage, AK 99501	
Pexton	Scott	ADNR State of Alaska	Anchorage, AK 99501	spexton@jpo.doi.gov

Last Name	First Name	Organization	City/State/Zip	E-mail
Pierce	Brenda	U.S. Geological Survey	Reston, VA 20192	bpierce@usgs.gov
Pierce	Jon	Canadian Environmental Assessment Agency	Ottawa, ON K1A 0H3	jon.pierce@ceaa.gc.ca
Pokiak	Frank	Joint Secretariat, Inuvialuit Game Council	Inuvik, NT X03 OTO	travel@jointsec.nt.ca
Porta	Louie	Joint Secretariat, Fisheries Joint Management Committee	Inuvik, NT X03 OTO	travel@jointsec.nt.ca
Potter	Steve	SL Ross Environmental Research Ltd.	Ottawa, ON K1G 0Z4	steve@slross.com
Pourchot	Pat	Audubon Alaska	Anchorage, AK 99501	ppourchot@alaska.net
Powell	Abby	U.S.Geological Survey, Alaska Cooperative Fish & Wildlife Research Unit	Fairbanks, AK 99775	ffanp@uaf.edu
Prentki	Richard	Minerals Management Service	Anchorage, AK 99503	
Prinsenberg	Simon	Bedford Institute of Oceanography, Fisheries and Ocean Canada	Dartmouth, NS B2Y 4A2	prisenbergs@mar.dfo-mpo.gc.ca
Quakenbush	Lori	Alaska Department of Fish & Game	Fairbanks, AK 99701	lori.quakenbush@alaska.gov
Rader	Matthew	Alaska DNR Div of Oil and Gas	Anchorage, AK 99501	matt.rader@alaska.gov
Ramlal, Ph.D.	Patricia	Fisheries and Oceans Canada	Winnipeg, MB R3T 2N6	partricia.ramlal@dfo-mpo.gc.ca
Rea	Caryn	ConocoPhillips Alaska, Inc.	Anchorage, AK 99509	caryn.rae@conocophillips.com

Last Name	First Name	Organization	City/State/Zip	E-mail
Rearden	Spencer	ASRC Energy Services	Anchorage, AK 99503	spencer.rearden@asrceneergy.com
Reece, Ph.D.	Allan	Shell International E&P Inc	Houston, TX 77001-0481	allan.reece@shell.com
Reist, Ph.D.	James	Fisheries and Oceans Canada	Winnipeg, MB R3T 2N6	jim.resit@dfo-mpo.gc.ca
Revie, Ph.D.	Winston	Natural Resources Canada	Ottawa, ON K1A 0E4	wrevie@NRCan.gc.ca
Reynolds	James	Repsol E&P USA, Inc.	The Woodlands, TX 77380	jreynoldsr@repsolypf.com
Richard	Pierre	Fisheries and Oceans Canada	Winnipeg, MB R3T 2N6	richardp@dfo-mpo.gc.ca
Rizzolo	Dan		Fairbanks, AK 99709	
Robey	Stephen	URS Corporation	Anchorage, AK 99502	stephen_robey@urscorp.com
Rockwell	Ted	Environmental Protection Agency	Anchorage, AK 99513	fordham.tami@epa.gov
Rocque	Deborah	U.S. Fish & Wildlife Service	Fairbanks, AK 99701	deborah_rocque@fws.gov
Rotterman	Lisa	NMFS PRD	Anchorage, AK	lisa.rotterman@noaa.gov
Ruckhaus	Glenn	ARCADIS U.S., Inc.	Anchorage, AK 99501	glenn.ruckhaus@arcadis-us.com
Rugh	David	National Marine Mammal Laboratory	Seattle, WA 98115	

Last Name	First Name	Organization	City/State/Zip	E-mail
Saint Onge	Ellen	Federal Energy Regulatory Commission	Washington, DC 20246	ellen.st.onge@ferc.gov
Sanzone, Ph.D.	Diane	BP	Anchorage, AK 99519	diane.sanzone@bp.com
Satterlee	Kent	Shell Alaska		-
Saupe	Susan	CIRCAC	Kenai, AK 99611	saupe@circac.org
Schaeffer	Jack	I.C.A.S.	Barrow, AK 99723	jschaefer@tikigaq.com
Schroeder	Mark	Minerals Management Service	Anchorage, AK 99503	mark.schroeder@mms.gov
Schultz	Gary	Alaska Dept of Natural Resources	Fairbanks, AK 99709	gary.schultz@alaska.gov
Seaberg	Stewart	ASRC Energy Services	Anchorage, AK 99503	stewart.seaberg@asrcenergy.com
Shanks	Tim	Natural Resources Canada	Ottawa, ON K1A 0E4	tshanks@nrcan.gc.ca
Shasby	Mark	U.S. Geological Survey	Anchorage, AK 99508-4650	shasby@usgs.gov
Shea	Natalie	Natural Resources Canada	Ottawa, ON K1A 0E4	nshea@nrcan-rncan.gc.ca
Sheets	Brent	U.S. DOE-NETL Arctic Energy Office	Fairbanks, AK 99709	brent.sheets@netl.doe.gov
Shideler	Richard	Alaska Department of Fish & Game	Fairbanks, AK 99701	dick.shidelerr@alaska.gov

Last Name	First Name	Organization	City/State/Zip	E-mail
Shuchman, PhD	Robert`	Michigan Tech Research Institute	Ann Arbor, MI 48105	shuchman@mtu.edu
Slaiby	Pete	Shell Exploration & Production Company	Anchorage, AK 99503	Michelle.D.Romak@shell.com
Slemons	Jonne	State of Alaska, DNR/Div of Oil & Gas	Anchorage, AK 99501	jonne.slemons@alaska.gov
Smith	Bert	ConocoPhillips	Houston, TX 77079-1175	albert.smith@conocophillips.com
Smith	Brad	NOAA/National Marine Fisheries	Anchorage, AK 99513-7599	brad.smith@noaa.gov
Smith	Caryn	Minerals Management Service	Anchorage, AK 99503	caryn.smith@mms.gov
Smith	Melanie	Audubon Alaska	Anchorage, AK 99510	masmith@audubon.org
Smith	Peter	DFO Canada	Dartmouth, NS	smithpc@nar.dfo-mpo.gc.ca
Smith, Ph.D.	Sharon	Geological Survey of Canada	Ottawa, ON K1A OE8	ssmith@nrcan.gc.ca
Snijder	Marcella	Indian & Northern Affairs Canada	Yellowknife, NT X1A Zr3	snijderrsm@inac.gc.ca
Snow	Norm	Joint Secretariat, Fisheries Joint Management Committee	Inuvik, NT X03 OTO	travel@jointsec.nt.ca
Snyder	Meda	Alaska Nanuuq Commission	Anchorage, AK 99516	meda@acsalaska.net
Snyder	Rex	UIC Oilfield Services, LLC	Anchorage, AK 99518	rsynder@ukpik.com

Last Name	First Name	Organization	City/State/Zip	E-mail
Soderlund	Dianne	Environmental Protection Agency	Anchorage, AK 99513-7599	soderlund.dianne@epa.gov
Solomon	Steve	Natural Resources Canada	Dartmouth, NS B2Y 4A2	ssolomon@nrcan.gc.ca
Sonnichsen	Gary	Natural Resources Canada	Dartmouth, NS B3A 2Y7	gary.sonnichsen@nrcan.gc.ca
Sørstrøm	Stein Erik	SINTEF	Trondheim, Norway	stein.e.sorstrom@sintef.no
Spies	Bob	Alaska Sealife Center	Seward, AK	bobs@alaskasealife.org
Stang	Paul	Stang Consulting	Anchorage, AK 99501	PRStang@alaska.net
Steedman, Ph.D.	Robert	Natural Energy Board	Calgary, AB T2P 0X8	Robert.Steedman@neb-one.gc.ca
Stotts	Dale	UIC Oilfield Services, LLC	Anchorage, AK 99518	dstotts@ukpik.com
Strom	Oyvind	StatoilHydro Gulf of Mexico	Houston, TX 77042	oysv@statoilhydro.com
Stubbs	Tom	Integrated Environments	Calgary, AB T3E 7K1	thom.stubbs@int-env.ca
Sumanik	Ron	EMR Oil & Gas Resources	Whitehorse, YT Y1A 2B2	ron.sumanik@gov.yk.ca
Suydam	Robert	Marine Mammal Commission and North Slope Borough	Barrow, AK 99723	Robert.Suydam@north-slope.org
Swail	Val	Environment Canada, Climate Research Division	Toronto, ON M3H 5T4	val.swail@ec.gc.ca

Last Name	First Name	Organization	City/State/Zip	E-mail
Swenson	Robert	State of Alaska Div of Geological & Geophysical Surveys	Fairbanks, AK 99709	robert.swenson@alaska.gov
Terminel	Dawn	Edison Chouest Offshore	Eagle River, AK 99577	dawn.terminel@chouest.com
Terminel	Michael	Edison Chouest Offshore	Eagle River, AK 99577	michael.terminel@chouest.com
Tesch	Laura	ERM	Bellevue, WA 98005	laura.tesch@erm.com
Thiemann, Ph.D.	Gregory			thiemann@yorku.ca
Thompson	Mike	Alaska Department of Natural Resources, State Pipeline Coordinators Office	Anchorage, AK 99501	mthompso@jpo.doi.gov
Thurston	Dennis	Minerals Management Service	Anchorage, AK 99503	Dennis.thurston@mms.gov
Timco, Ph.D.	Garry	National Research Council Canada	Ottawa, ON K1A 0R6	garry.timco@nrc-cnrc.gc.ca
Timmons	Saree	Alaska Department of Natural Resources	Anchorage, AK	saree.timmons@alaska.gov
Treadwell	Mead	U.S. Arctic Research Commission	Anchorage, AK 99501	usarc@acsalaska.net
Trefry, Ph.D.	John	Florida Institute of Technology	Melbourne, FL 32901	jtrefry@fit.edu
Tschannen	Anneliese	PAS, Inc	Anchorage, AK 99504	
Voss	Richard	Arctic National Wildlife Refuge	Fairbanks, AK 99701	richard_voss@fws.gov

Last Name	First Name	Organization	City/State/Zip	E-mail
Wagner	Mark	U.S.C.G. District 17	Juneau, AK	mark.c.wagner@uscg.mil
Walter	Taldi	Audubon Alaska	Anchorage, AK 99501	twalter@audubon.org
Way	Ruthie	Minerals Management Service	Anchorage, AK 99503	ruthie.way@mms.gov
Weingartner, Ph.D.	Tom	Institute of Marine Science, University of Alaska Fairbanks	Fairbanks, AK 99775-7220	weingart@ims-uaf.edu
Westlien	Erling	Shell	Anchorage, AK	erling.westlien@shell.com
Westphal	Kellie	Alaska Department of Natural Resources	Anchorage, AK 99501	kellie.westphal@alaska.gov
White	Daniel	University of Alaska Fairbanks	Fairbanks, AK 99775-5910	ffdmw@uaf.edu
Whitney, Ph.D.	John	NOAA OR&R Hazmat	Anchorage, AK 99501	John.Whitney@noaa.gov
Williams	Bill	Fisheries and Oceans Canada	Winnipeg, MB M3T 2N6	bill.williams@dfo-mpo.gc.ca
Williams	Dee	Minerals Management Service	Anchorage, AK 99503	dee.williams@mms.gov
Williams	Thomas	TerraPlatforms, LLC	Houston, TX 77007	twilliams@afsolutionsinc.com
Williamson	Lori	Minerals Management Service	Anchorage, AK 99503	
Winfree, Ph.D.	Robert	National Park Service	Anchorage, AK 99501	robert_winfree@nps.gov

Last Name	First Name	Organization	City/State/Zip	E-mail
Wisdom	Sheyna	URS Corporation	Anchorage, AK 99502	sheyna_wisdom@urscorp.com
Wong	Sally	Fisheries and Oceans Canada	Winnipeg, MB M3T 2N6	sally.wong@dfo-mpo.gc.ca
Wrona, Ph.D.	Fred	Environment Canada	Victoria, BC V8W 3R4	fred.wrona@ec.gc.ca
Yetsko	Chris	ConocoPhillips	Houston, TX 77079-1175	chris.m.yetsko@conocophillips.com
Ytteborg	Gina	Shell Technology Norway	Norway	gina.ytteborg@shell.com
Zerbini	Alexandre	National Marine Mammal Laboratory	Seattle, WA 98115	
Zhang	Jing	Geophysical Institute, University of Alaska Fairbanks	Fairbanks, AK 99775-7320	
Zhou	Joe	TransCanada	Calgary, AB T2F 5H1	joe_zhou@transcanada.com

APPENDIX II

POSTERS

POSTER SESSION

The Posters will displayed be in the second floor hall outside of the meeting room throughout the Forum with authors in attendance from 5:20-6:20 pm 28 October.

Initial Ichthyoplankton Analysis of the Mackenzie Plume Front
Sally Wong, Michael Papst, Wojciech Walkusz, and Joclyn Paulic

Hotspot and Biogeographic Analysis of Marine Larval Fish in the Nearshore Canadian Beaufort Sea
Joclyn Paulic

Sites of Upwelling on the Canadian Beaufort Shelf
William Williams and Eddy C. Carmack

Bowhead Whale Feeding Aggregations in the Canadian Beaufort Sea (2007 – 2008), and Their Role in the Mitigation of Effects of Seismic Underwater Noise
Lois Harwood, Amanda Joynt, and Sue Moore

Evaluation of sub-sea physical environmental data for the Beaufort Sea OCS and incorporation into a Geographic Information (GIS) database
Warren Horowitz

BP-DOE cooperative Alaska gas hydrate research Mount Elbert #1 stratigraphic test
Robert Hunter, Ray Boswell, and Timothy Collett

Archaeological Potential of Buried Terrestrial Landforms in the Beaufort Sea: a Review of Existing Geological and Geophysical Data
Nancy J. Darigo, Owen Mason, Peter Bowers, and Luke Boggess

Oil-in-ice: transport, fate, and potential exposure
Whitney Blanchard, Odd Gunnar Brakstad, Hajo Eicken, Liv-Guri Faksness, Per Johan Brandvik, Øistein Johansen, Nancy E. Kinner, Amy Merten, Rainer Lohmann, Scott Pegau, Chris Petrich and Mark Reed

Application of high-frequency surface current radar mappers to the Alaskan Beaufort Sea
Thomas Weingartner

Temporal Distributions and Patterns of Habitat Use by Black Brant Molting in the Teshekpuk Lake Special Area, Alaska
Tyler L. Lewis, Paul L Flint, Joel A. Schmutz, and Dirk V. Derksen

Effectiveness of Chemical Dispersants on Alaskan Oils in Cold Water
Randy Belore

Concept study: Exploration and production in environmentally sensitive Arctic areas
Richard C. Haut, Tom Williams, Michael Lilly, Shirish Patil, Yuri Shur, Cathy Hanks and Mikhail Kanevskiy

Design and operation of Arctic oilfields to minimize conflicts with grizzly bears
Richard Shideler

ERMA--a new high resolution environmental data display and management system for oil spill planning and response
Amy Merten and John Whitney

Using Technology to meet the Arctic Offshore Challenge
Allan Reece

Ice and Snow helicopter-borne observation sensors used over Canadian Ice-invested Waters showing results of April 2004 and 2008 from the Canadian Beaufort Sea shelf Simon Prinsenberg, Ingrid Peterson, and Scott Holladay

Transport and fate of spring floodwater from rivers in the Alaskan Beaufort Sea
John H. Trefry, Robert P. Trocine, Carrie M. Semmler, Mathew B. Alkire, Mark A. Savoie and Robert D. Rember

Measuring bioavailable hydrocarbons in the nearshore Beaufort Sea: comparison of caged mussels (*mytilus trossulus*) and semipermeable membrane devices (SPMDS)
J. L. Hardin, J. M. Neff, G. S. Durell, and F. C. Newton III

Population of origin of Arctic cisco (Coregonus autumnalis) collected in the Colville River subsistence fishery
Jennifer L. Nielsen

Under-ice Interaction and Mixing of Spring Floodwaters with Continental Shelf Water in the Alaskan Beaufort Sea
Savoie, M.A, Trefry, J.H., and Trocine, R.P.

Ecological Change in the Teshekpuk Lake Special Area: Effects on the Distributions of Arctic-nesting Geese
Joel Schmutz

Spatial and Temporal Dynamics of Lake Ice on the Arctic Coastal Plain of Alaska
Chris Arp, Benjamin Jones, and Joel Schmutz

Landward and Eastward Shift of Alaskan Polar Bear Denning Associated with Recent Sea Ice Changes
Anthony S. Fischbach, Steven A. Amstrup and David C. Douglas

Empirical sea ice thickness estimation in the Arctic Ocean
N. G. Platonov, D. C. Douglas, V. A. Eremeev, and I. N. Mordvintsev

Satellite Tracking of the Western Arctic Stock of Bowhead Whales
Lori Quakenbush, John Citta, Robert J. Small, John "Craig" George, Harry Brower, Jr, Mads Peter Heide-Jorgensen, and Lois Harwood