BOEM OCEAN SCIENCE

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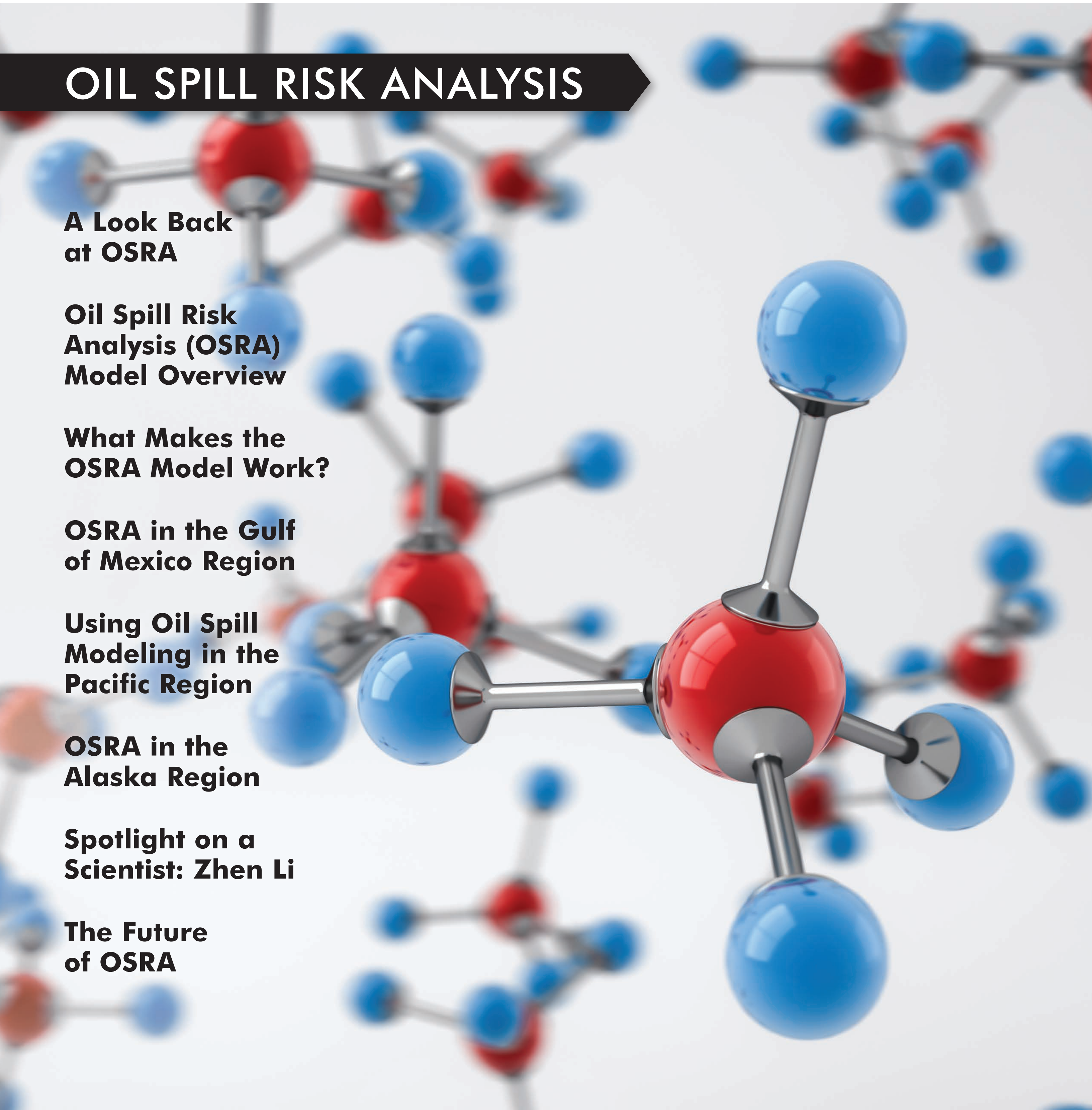

OIL SPILL RISK ANALYSIS

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ON THE COVER
3D rendering of methane molecules.
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Frequently Used Abbreviations

BOEM	Bureau of Ocean Energy Management
EIS	Environmental Impact Statement
ERA	Environmental Resource Area
ESP	Environmental Studies Program
GOM	Gulf of Mexico
LC	Loop Current
NEPA	National Environmental Policy Act
OCS	Outer Continental Shelf
OSRA	Oil Spill Risk Analysis
USGS	U.S. Geological Survey

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For More Information

Check out the Bureau of Ocean Energy Management website at **www.boem.gov**.

The Director's Message

As the new Director of this great bureau, I am honored to greet you for the first time from the pages of *BOEM Ocean Science*. For some time now, I have admired the important work that BOEM conducts every day as a leading ocean science agency focused on domestic Outer Continental Shelf (OCS) energy. To have this opportunity to be at the nexus of the safe and responsible development of conventional and renewable OCS energy is exciting – and humbling at the same time.

Part of our commitment to the American people is to make science-informed decisions when we evaluate OCS oil resources for exploration and development. This issue of *BOEM Ocean Science* highlights the Oil Spill Risk Analysis (OSRA) model used to estimate probabilities for oil spill occurrence and oil spill contact with various environmental and economic resources. We describe how the model developed, what information is used for inputs, and how our scientists use OSRA modeling outputs for environmental analyses.

Each of the Outer Continental Shelf regions faces unique challenges when conducting OSRA modeling. Region-specific environmental conditions, as well as a number of threatened and endangered species and sensitive habitats, must be considered when conducting an analysis of oil spill risk associated with conventional OCS energy development. For example, ice is an important factor for OSRA modeling in the Alaska OCS Region while the dynamics of the Loop Current are critical for modeling in the Gulf of Mexico OCS Region.

With oil spill modeling and many other disciplines of science represented within BOEM, we will continue to engage with federal partners and other stakeholders to deliver decisions based on world-class research.

I look forward to working with you and my colleagues in BOEM to meet the challenges of a pivotal time in our Nation's energy history. Please enjoy this issue of *Ocean Science*.

Abigail Ross Hopper, Director

A Look Back at OSRA

By Robert LaBelle, Special Advisor to the BOEM Director

The present day Oil Spill Risk Analysis (OSRA) modeling effort is a state-of-the-art approach that provides BOEM's environmental analysts with reliable, long-term estimates of spill risks associated with potential exploration and development activities in all federal offshore waters. The model was developed in the mid 1970s by U.S. Geological Survey (USGS) scientists and represented one of the first Geographic Information System (GIS) efforts put to broad use by the federal government. I joined the USGS Land Information and Analysis unit in 1980 and remember digitizing coastlines and seabird, fish, and marine mammal areas off maps from all over the Nation. Within a few months I was on my way up to Alaska(!) to work with the Regional Office on a model run for Cook Inlet. Indeed, the best part of being an OSRA modeler has always been to work closely with our environmental analysts in all of BOEM's regions to provide good underpinnings for our impact assessments. We had a small group of oceanographers, mathematicians, and biologists working to run the model (in those days, if you dropped the foot-tall deck of computer cards on the way to the card reader, you'd end up working overnight!). What an education we got as we worked with the best physical oceanographers from our Nation's top oceanographic institutes to provide the latest ocean observations and circulation modeling products to realistically drive our simulated spills. We were and are a linchpin between our Environmental Studies Program, which provides the research needed to sustain the OSRA effort, and our Environmental Assessment offices, who are our best customers in using the modeling results. All in all, a richly rewarding career for many fondly remembered folks, some of whom are still carrying on the OSRA effort in a modern, efficient, and effective manner, as described in this issue of *Ocean Science*.

Oil Spill Risk Analysis (OSRA) Model Overview

In 1975, the Department of the Interior (DOI) developed the Oil Spill Risk Analysis (OSRA) model as a tool to assist in evaluating oil spill risks to environmental resources from OCS oil and gas lease sales and related activities. The first OSRA report was written in 1976 for the North Atlantic Outer Continental Shelf (OCS) Lease Area. Today, as part of its responsibility to manage the oil and gas resources on the OCS, BOEM continues to use OSRA modeling to identify areas that may be contacted in the event of an oil spill.

How It Works

In simple terms, the OSRA model considers oil spill occurrence, oil spill trajectories (contact), and combined oil spill occurrence and contact. With its ability to factor in large areas (thousands of kilometers) and long periods of time (years to decades) of ocean current and wind input data, the model provides answers to two important questions:

1. *What is the probability of a large oil spill (greater than or equal to 1,000 barrels) occurring?*
2. *What is the probability that oil spilled at Point A (platforms, pipelines, tankers, etc.) reaches Point B (coastlines and environmental resources)?*

The results, which provide probabilistic estimates of oil spill occurrence and contact with biological, social, and economic resources located on the U.S. OCS and adjoining coasts, are used in preparation of National Environmental Policy Act (NEPA) documents such as Environmental Impact Statements (EISs) or Environmental Assessments (EAs). Information from the OSRA model can also be used in oil spill response plans as well as for consultations related to endangered species and essential fish habitats. The OSRA model considers spills greater than or equal to 1,000 barrels because those spills would persist on the water long enough for the model to follow its path in a trajectory analysis. For small spills that are less than 1,000 barrels, BOEM would estimate the type of oil and the number and size of a spill(s) in the EIS.

What OSRA Provides

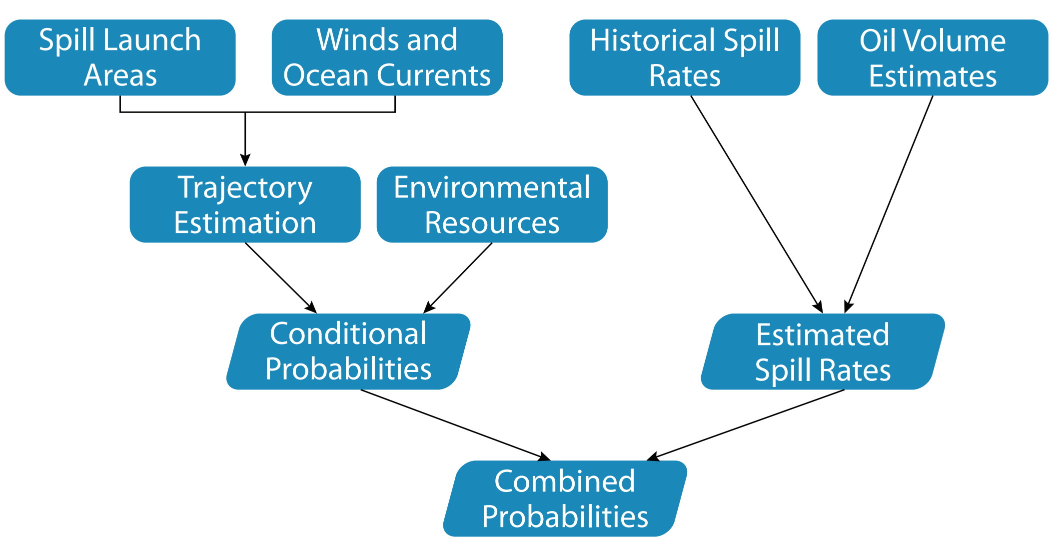
The OSRA model's basic products are conditional probabilities, estimated chance of large spill occurrence, and combined probabilities.

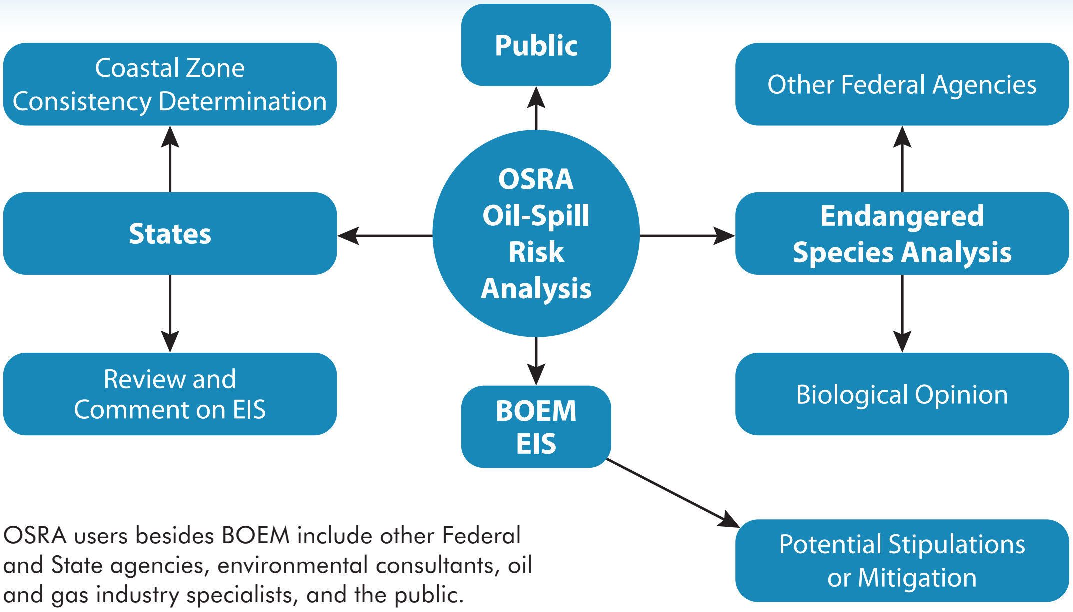
- **Conditional Probabilities** Conditional probabilities are based on the assumption (condition) that an oil spill has occurred at a given location. They reflect the hypothetical paths (trajectories) that oil would take based on modeled ocean surface currents, ice (if appropriate), and local wind conditions in the study area. Many trajectories are simulated from each hypothetical spill location, and the number of contacts to environmentally sensitive areas and land segments within 3, 10, and 30 days of travel at sea are tabulated. The percentage of the trajectories contacting a given environmental resource is

The OSRA Model

- Calculates the **trajectory** (simulated movement of a single hypothetical oil spill, based on historical wind and current ice data, generally for up to 30 days or until it contacts land);
- Factors in a **hypothetical spill location** (platforms, pipelines, tankers, etc.) from which trajectories are simulated;
- Considers **environmental resources**, which are digitized and input to the OSRA model;
- Sees **land** as a special environmental resource comprised of an entire coastline, including major islands. **Land segments**, which are generally of equal length or based on county/borough boundaries, allow the OSRA model to specify where the contacts to land occur; and
- Considers **spill rates**, expressed in estimated mean number of spills per billion barrels of oil handled, based on historic production, transportation, and accident experiences (separate rates have been calculated for U.S. OCS platform spills, U.S. OCS pipeline spills, and worldwide tanker spills). A fault tree method is used to estimate spill rates in the Alaska region because there have been no recorded oil spills on the Federal OCS.

OSRA Process





OSRA users besides BOEM include other Federal and State agencies, environmental consultants, oil and gas industry specialists, and the public.

a measure of the "conditional probability" of an oil spill contacting that resource, with the assumption (condition) that the spill occurs at the hypothetical spill location. Conditional probabilities do not incorporate the likelihood of a spill occurring.

Manatee photo (top left) courtesy of USGS. Piping Plover (top right) photo courtesy of USFWS. Flower Garden Banks photo (bottom) courtesy of NOAA.

- **Estimated Probability of Oil Spill Occurrence**
  The OSRA model estimates the probability of oil spills occurring during the production and transportation of a specific volume of oil over the lifetime of the scenario being analyzed. This process uses a spill-rate constant, based on historic accidental spills greater than or equal to 1,000 barrels (42,000 gallons), expressed as a mean number of spills per billion barrels of produced or transported oil. The mean spill occurrence estimate is obtained by multiplying the rate constant by the volume of oil projected to be handled, which results in the mean number of spills estimated to occur relative to the hypothetical volume of oil produced. The mean number of spills is then used to estimate the probability of one or more spills occurring over the lifetime of the scenario.
- **Combined Probabilities**
  The "combined probabilities" represent the estimated overall (combined) probability that one or more such spills (greater than or equal to 1,000 barrels) will both occur and contact environmental resources based on conditional probabilities, spill rates, volume of oil, and transportation scenarios. The result is an estimated probability of one or more spills of 1,000 barrels and greater occurring and contacting that environmental resource over the lifetime of the scenario.

– Rita Hess, Schatz Publishing

For More Information

OSRA Model

www.boem.gov/Oil-Spill-Modeling-Program

www.boem.gov/Environmental-Stewardship/Environmental-Assessment/Oil-Spill-Modeling/Oil-Spill-Occurrence-Rate-for-Oil-Spill-Risk-Analysis-(OSRA).aspx

www.boem.gov/Environmental-Stewardship/Environmental-Assessment/Oil-Spill-Modeling/Oil-Spill-Risk-Analysis-Model-(OSRAM).aspx

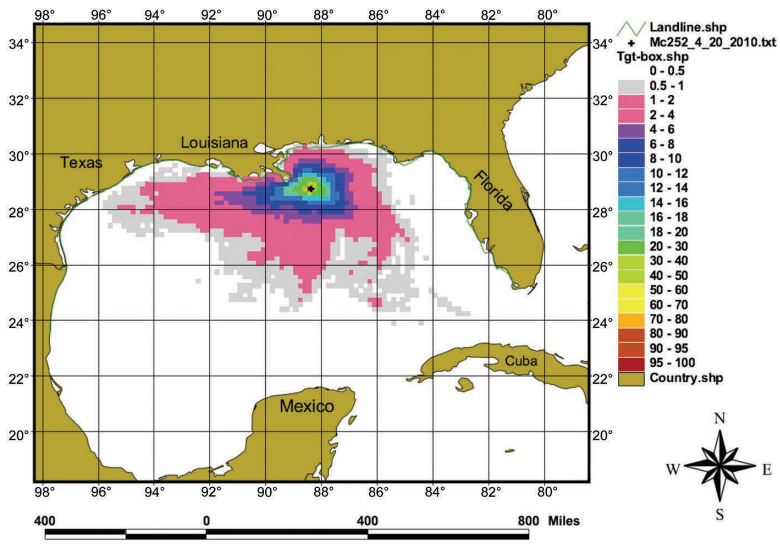
Smith, R.A., J.R. Slack, and R.K. Davis, 1976. An Oil Spill Risk Analysis for the North Atlantic Outer Continental Shelf Lease Area. U.S. Geological Survey Open-File Report 76-620.

What Makes the OSRA Model Work?

Field study results of actual oil spills often have limitations, as researchers may need to contend with ongoing response operations and legal issues in the midst of an unplanned event. These issues interfere with variable control and experimental design where incorporation advances the quality and utility of scientific research. Conversely, laboratory studies provide for experimental control and design but fall short of providing realistic environmental conditions (e.g., basin-wide scale meteorological and oceanographic data) important to determining effects in a real spill situation.

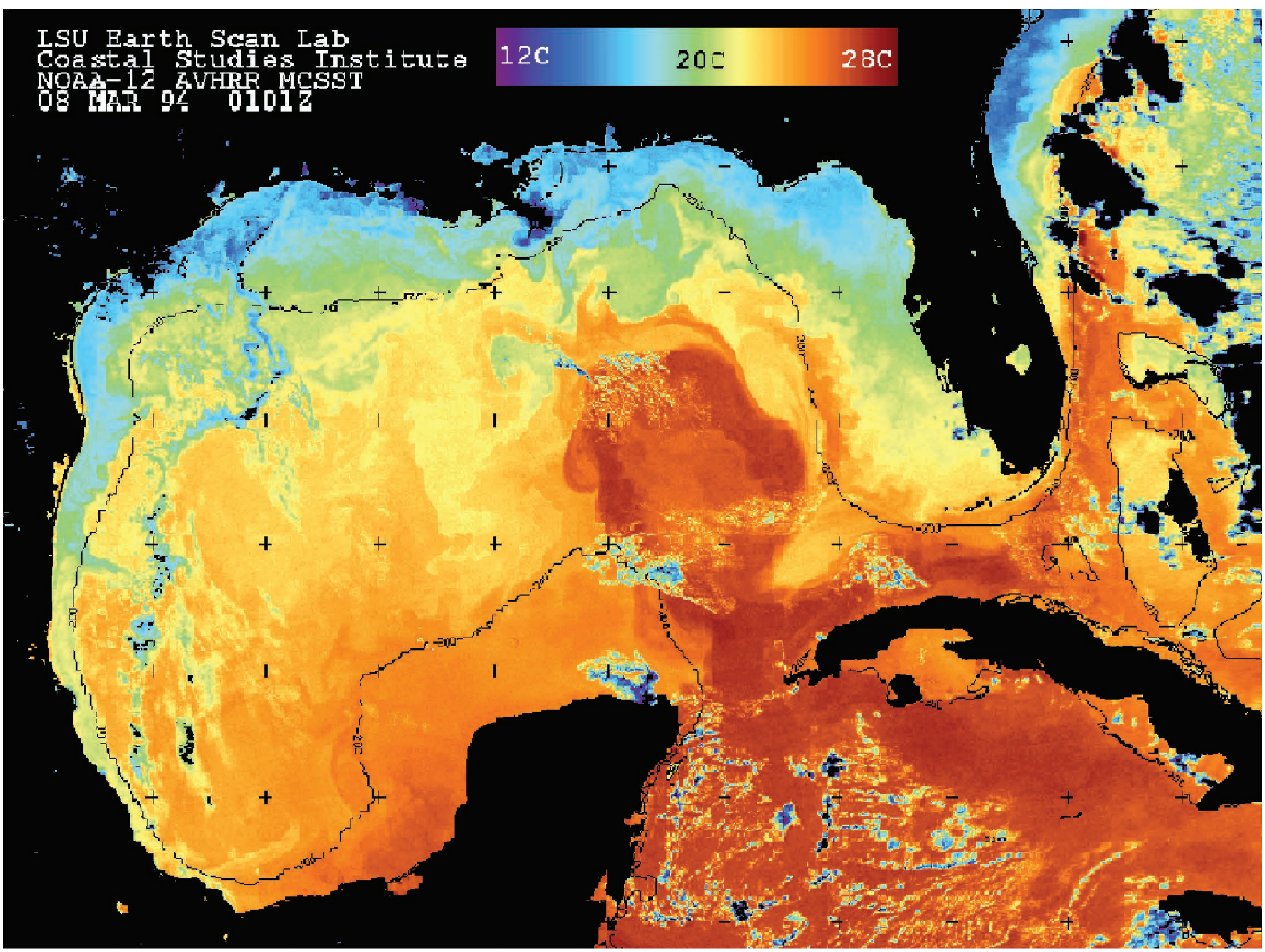
The OSRA Advantage

Results depend on the meteorological and oceanographic conditions of the study area, the environmental resources



The trajectories in the chart above were initiated every day for 360 days for the months of January through December, for the years 1993 through 1998.

Below: An image from NOAA's Advanced Very High Resolution Radiometer (AVHRR), a space-borne sensor, depicts the Loop Current (in dark orange) entering the Gulf of Mexico. Image courtesy of the Earth Scan Laboratory, Coastal Studies Institute, Louisiana State University.



within the study area, and the estimated volume of oil or gas resources that are assumed to be discovered, produced, and transported. For the model to work effectively, BOEM works closely with states and other federal agencies to obtain the best available geographic information regarding environmental resources and the shoreline (the land segments) to estimate the contact probabilities of trajectories to environmental resources.

One important test of the OSRA model was whether the historical wind and current data in the Gulf of Mexico from 1993 to 1998 would produce a pattern of probabilities similar to what was observed from the actual *Deepwater Horizon* spill. The OSRA model was run and the statistical patterns generated were similar to actual observations through surface oiling surveys.

The Importance of Inputs

One focus of BOEM's Environmental Studies Program is to develop supporting environmental datasets for the OSRA model. These datasets are the best available ocean current, sea ice, and wind fields from national and international sources. In addition to the driving wind and ocean current and ice (where applicable) fields, the OSRA model uses information on the geographical and temporal extents of resources such as seagrass beds, Native subsistence areas, coastal habitats, and recreational beaches. Studies and datasets characterizing sea-ice formation and distribution are used as well in areas where they are needed.

Wind speed and direction, as well as ocean current speed and direction estimates, are essential to OSRA results. In Arctic OCS areas, for example, ice conditions can influence the movement and final disposition of spilled oil. In the deep waters of the GOM, strong currents where water depths are between 1,000 and 2,000 meters (3,280 and 6,560 ft.) affect oil and gas operations, as can eddies and the continental slope—information that is critical when developing deepwater oil spill response plans.

Physical Oceanography and Meteorology

Physical oceanographic studies focus on understanding and verifying physical processes and features of the ocean and atmosphere on the OCS. These processes and features control the transport of materials and cause the mixing and redistribution of pollutants. The information obtained through studies in physical oceanography and meteorology help assess:

1. the transport of spilled oil,
2. the dispersion of discharge fluids and produced water, and
3. the effects of spills on the migration of marine mammals, the distribution of fish, and other biological resources.

– Merlin Hayes, Schatz Publishing

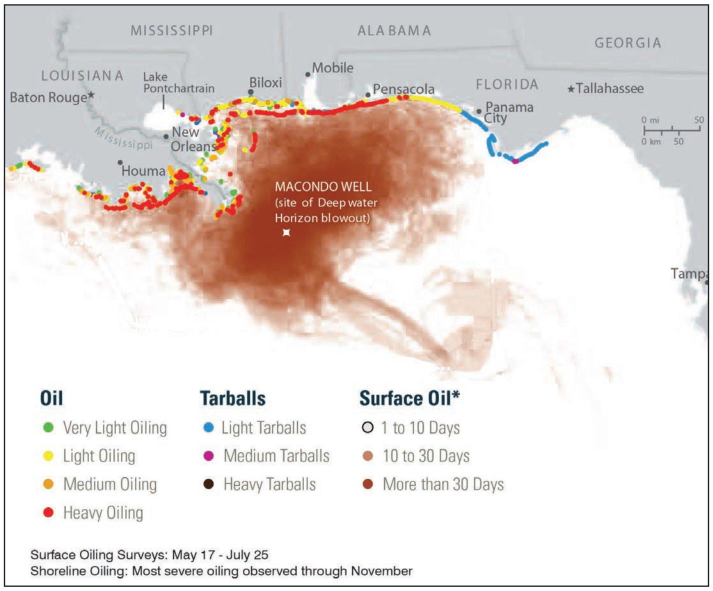
What are Oil Spill Trajectory Simulations?

Oil spill trajectory simulations are generated by the OSRA model. OSRA simulates the likely path (trajectory) of a surface slick, represented as a point started from locations where an accidental spill could occur. The point's trajectory is computed based on ocean currents or ice and winds. The OSRA model initiates thousands of oil spill simulations at hundreds to thousands of hypothetical spill locations to generate an ensemble of oil spill trajectories, which can statistically characterize oil spill risk over a large area, particularly in areas of prospective drilling and production and along existing or potential pipeline and tanker routes.

The OSRA model then tabulates the number of times that each trajectory moves across or touches a location (contact) occupied by polygons mapped on the gridded surface. These polygons represent locations of various environmental resources. The model compiles the number of contacts to each feature that result from the modeled trajectory simulations from all of the launch points for a specific launch area.

What are Conditional Probabilities of Contact?

The probability of contact to an environmental resource is calculated as the number of contacts by hypothetical spills at specific locations within a given time divided by the number of of trajectories started within each launch area. These probabilities are termed "conditional," because they will only happen if a spill has occurred.



Maximum Extent of Oil from the Presidential Oil Spill Commission Report, page 198, their Figure 7.1. The map was based on surface oil surveys from 17 May to 25 July 2010, as well as shoreline oiling, indicated by the colored circles.

OSRA in the Gulf of Mexico Region

OVERVIEW

The Gulf of Mexico (GOM) is estimated to contain the largest undiscovered technically recoverable oil and gas resources on the Nation's Outer Continental Shelf (OCS). It is also the most active offshore area for oil and gas exploration and development. The OSRA model was developed to provide analysts with probabilistic estimates of oil spill occurrence and contact with environmental resources. The OSRA model estimates the chance of oil spills occurring as a function of the oil production and transportation scenarios for the GOM, relying on the occurrence rates of historical accidental spills (see Anderson et al., 2012). Given the long history of oil and gas activities in the Gulf, historical oil spill rates are considered to provide an appropriate means of estimating future spill occurrence. The first Gulf OSRA run was performed in 1978 for Eastern Gulf proposed Sale 68; since then over 30 Gulf OSRA reports have been published describing new model runs and their results.

PHYSICAL OCEANOGRAPHIC STUDIES

BOEM is continuously improving its understanding of physical oceanographic processes in the GOM, incorporating understanding from ongoing field experiments into improved model capabilities. The Environmental Studies Program plays an important role in providing the funding to perform these new oil spill-related studies. One study, *Dynamics of the Loop Current*, made observations inside the highly energetic Loop Current (LC). The LC is an influential driving force in the GOM; it is the main source of water for the Gulf, transporting relatively warm and salty waters from the Caribbean Sea. During its north-south incursion cycle, the LC sheds large warm anticyclonic eddies (diameters of 200–400 km). This strong current is also the beginning of the Gulf Stream Current, which is part of the meridional circulation of the Atlantic Ocean.

Most of what is known about the LC comes from hydrographic surveys, satellite studies, numerical modeling, and moorings. These data provide additional insight into the shedding mechanisms and energy transfers from surface to bottom, and also help improve numerical model predictions.

A second study, *Lagrangian Study of the Deep Circulation in the Gulf of Mexico*, follows up on a previous study near the Mississippi Delta in which deep drifters (current sensors) were released and tracked acoustically for nearly six months, producing tantalizing observations. For example, deep circulation of the northern Gulf consists of a western and eastern cell divided at about 90°W; some tracks showed little net movement, while others locked onto isobaths and moved along them. However, the short observing period and geographically limited releases did not allow for broader, more robust conclusions.

The Lagrangian study, an approach to study and visualize the movement of individual fluid particles through space and time, employed submerged drifters that were deployed for 12 months and tracked using sound; afterward, they surfaced and transmitted their data via satellite. The Gulf was then re-seeded with more drifters immediately and the entire cycle repeated for three consecutive years. The results are providing information on the strength and direction of deep currents that will help with the assessment of accidental pollutant releases and will shed light on the transport and dispersal of larvae. These improved current observations will be used by BOEM and industry to prepare for and avoid high current areas, make better biological assessments for our regulatory documents, and increase our understanding of the deep circulation and its variability.

ADVANCES IN OIL SPILL MODELING

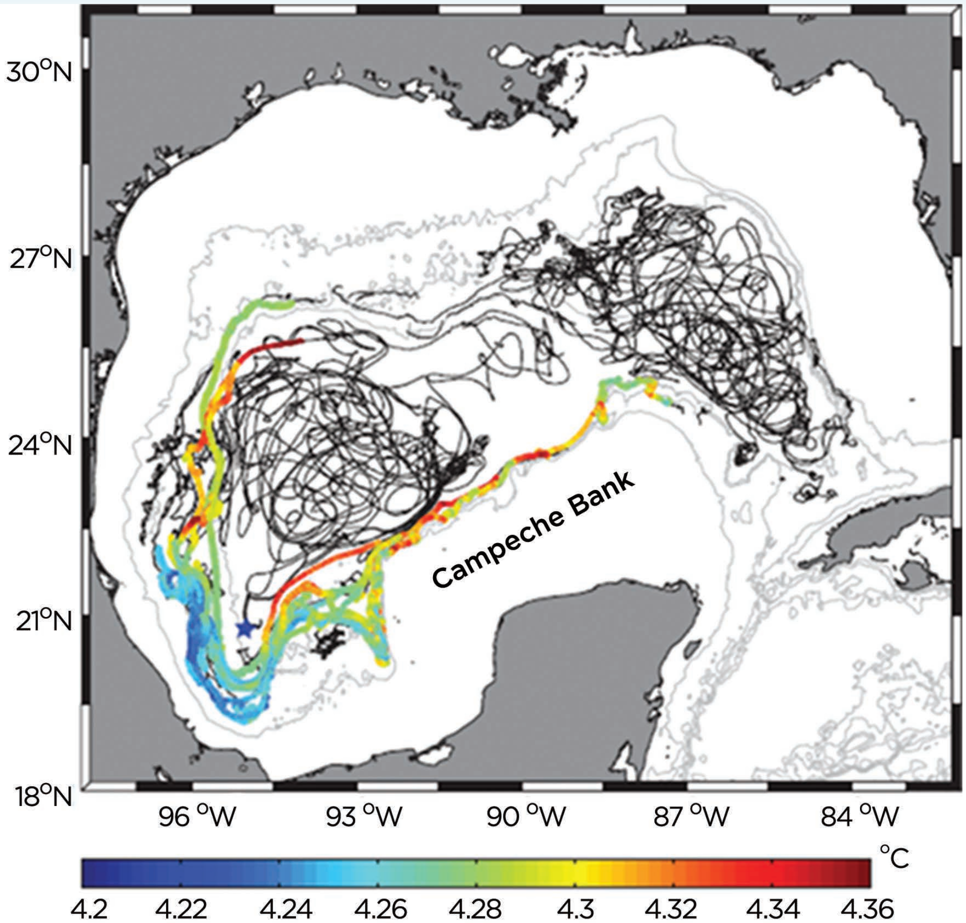
BOEM is continuously updating its approach to oil spill risk to incorporate the most accurate methodologies and representation of Gulf energy activities. The trend of drilling into ever deeper waters has also brought with it unique risks which, unfortunately, were evidenced during the 2010 *Deepwater Horizon* oil spill. Several environmental studies were designed to improve understanding of deepwater oil and gas releases, as well as the use of subsea dispersants.

One such study, *Simulation Modeling of Ocean Circulation and Oil Spills in the Gulf of Mexico*, simulated plume behavior in

Gulf Sturgeon

The National Marine Fisheries Service and U.S. Fish and Wildlife Service listed the Gulf sturgeon as a threatened species on September 30, 1991. Subsequently, a recovery plan was developed to ensure the preservation and protection of Gulf sturgeon spawning habitat. Critical habitat was proposed on June 6, 2002, in the Federal Register (67 FR 39105 39199) and was designated on April 18, 2003. Critical habitat is defined as specific geographic areas that are essential for the conservation and recovery of a threatened or endangered species and that may require special management consideration or protection.

BOEM used OSRA to estimate the probability of an oil spill that could potentially impact the Gulf sturgeon critical habitat. BOEM found that the probability of spill contact in the Western Planning Area with Gulf sturgeon critical habitat is <0.5 percent. The probability for spill contact with Gulf Sturgeon critical habitat was also estimated for a Central Planning Area proposed action. The probabilities range from 1-2 percent within 10 days to 2-4 percent within 30 days.



A sample of 1500 and 2500-m RAFOS float trajectories collected as part of the Lagrangian study. Float trajectories are drawn in black, and portions of the trajectories that illustrate the deep boundary current are colored based on temperature.

both surface and deep subsurface waters and performed a variety of scenario runs.

The objective of this project is to develop and apply an integrated oil spill model that incorporates many processes that are unique to deep oil spills, with the ultimate goal of accurately simulating oil plume behavior at different depths in the water column. Model results will explore outcomes from deep oil spills. The study includes development of a new predictive blowout model.

Another study, *Remote Sensing Assessment of Surface Oil Transport and Fate during Spills in the Gulf of Mexico*, is developing a better understanding of the movement, properties, and fate of surface oil from past spills in the GOM. The physical and chemical processes affecting oil movement are unique to each spill, and this study is investigating several historical spills to understand differences. The study will examine mechanisms responsible for oil movement in surface waters using remote sensing products to describe the location and characteristics of surface oil during spill events. A wealth of remote sensing, overflight, and in situ measurements have been collected in recent years during spill events in the GOM. These observations will help BOEM more precisely quantify wind and ocean current forces on oil spill movement, and the study results will be used by BOEM in environmental analyses.

FUTURE DIRECTIONS

BOEM will continue to advance its methodology for oil spill risk assessment in the GOM using state-of-the-art approaches. Ensemble modeling techniques are currently being explored in a BOEM study with the goal of using multiple hydrodynamic model inputs to better quantify uncertainties. Additionally, incorporation of 3D modeling capabilities will remain a high priority.

– Rita Hess, Schatz Publishing

FOR MORE INFORMATION

Anderson, Cheryl M., Melinda Mayes, and Robert LaBelle. 2012. Update of Occurrence Rates for Offshore Oil Spills. OCS Report BOEM 2012-069.

http://www.boem.gov/uploadedFiles/BOEM/Environmental_Stewardship/Environmental_Assessment/Oil_Spill_Modeling/AndersonMayesLabelle2012.pdf

Dynamics of the Loop Current **(GM-08-01)**

http://www.boem.gov/uploadedFiles/BOEM/Environmental_Stewardship/Environmental_Studies/Gulf_of_Mexico_Region/Ongoing_Studies/GM-08-01.pdf

Lagrangian Study of the Deep Circulation in the Gulf of Mexico **(GM-10-03)**

http://www.boem.gov/uploadedFiles/BOEM/Environmental_Stewardship/Environmental_Studies/Gulf_of_Mexico_Region/Ongoing_Studies/GM-10-03.pdf

Simulation Modeling of Ocean Circulation and Oil Spills in the Gulf of Mexico **(GM-11-02)**

http://www.boem.gov/uploadedFiles/BOEM/Environmental_Stewardship/Environmental_Studies/Gulf_of_Mexico_Region/Ongoing_Studies/GM-11-02.pdf

Remote Sensing Assessment of Surface Oil Transport and Fate during Spills i n the Gulf of Mexico **(GM-12-02)**

http://www.boem.gov/uploadedFiles/BOEM/Environmental_Stewardship/Environmental_Studies/Gulf_of_Mexico_Region/Ongoing_Studies/GM-12-02.pdf

Using Oil Spill Modeling in the Pacific Region

Over its 40-year history, the Pacific OCS Region has changed from a frontier to a mature oil and gas producing area with 43 existing leases offshore southern California producing nearly 19 million barrels of oil and nearly 28 billion cubic feet of natural gas annually. The produced oil is transported from the platforms to shore via pipelines and the majority of wells require some type of artificial lift. Although no new leasing or platforms are expected, operators have long-term plans to continue these operations, so oil spill modeling is needed in the event of spills from platforms and pipelines to help determine the potential environmental effects.

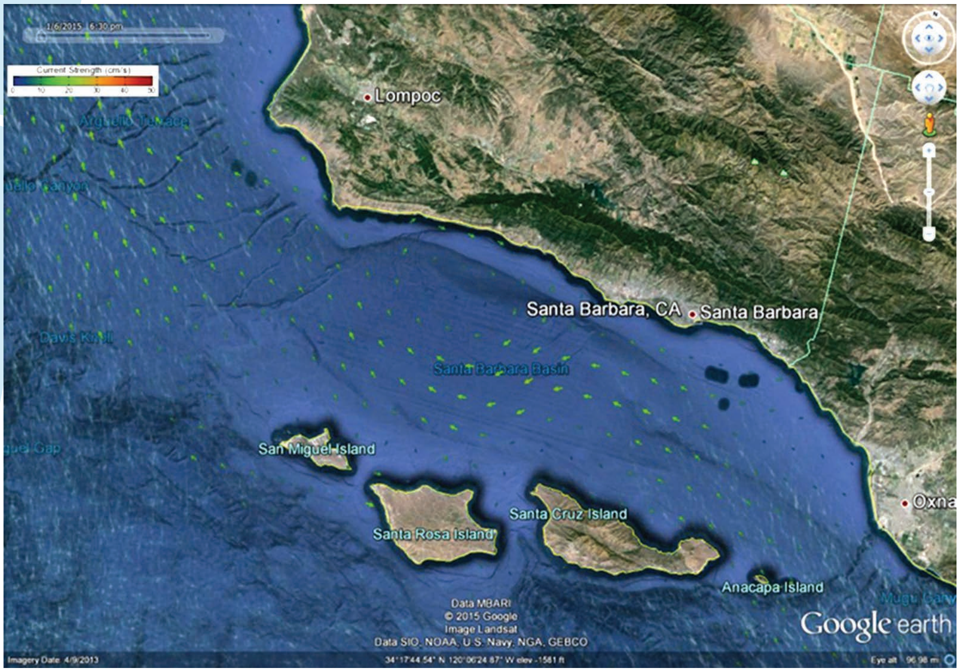


Figure 1. An example of the Santa Barbara Channel eddy. Current strength (cm/s) is indicated by the color of the arrows. See color bar.

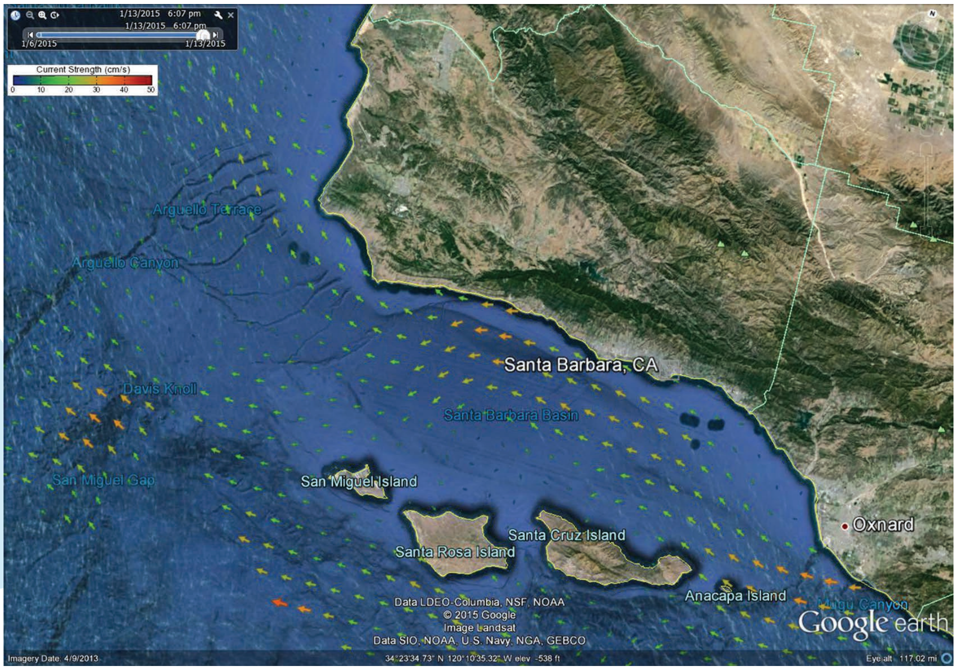


Figure 2. An example of water entering the Santa Barbara Channel from the south. Current strength (cm/s) is indicated by the color of the arrows. See color bar.

The Role of Winds and Currents

Since 1980, meteorological data-gathering buoys positioned along the southern, central, and northern California coasts have provided long-term, at-sea records of near-surface meteorological conditions over the California OCS. In 1992, the National Research Council (NRC) recommended that the former Minerals Management Service (MMS, now BOEM) conduct studies to determine the oceanography of the Southern California Planning Area and incorporate the information into environmental analysis documents for offshore oil and gas development. Several studies were conducted over a 10-year period and the results integrated into the OSRA model for the Pacific Region (e.g., Harms and Winant, 1998; Hickey et al., 2003). The studies demonstrated that the seasonal patterns in the California Current system drive the oceanography within the Southern California Bight. Winds and atmospheric pressure gradients are the primary physical factors that influence current speed and direction. Pressure gradients provide most of the driving force, while local winds force current velocity only in the winter and spring during infrequent wind events. An eddy (a rotating pool of water) often forms in the Santa Barbara Channel (Figure 1) or the warmer water from the south moves through the Channel and exits the western end (Figure 2) and may move to the north or come in contact with the California Current and turn to the south. The ability to model these complex currents is critical to oil spill risk analyses in the Southern California Bight, where cold upwelled waters meet with warm subtropical waters.

To help estimate how oil may move in this oceanographically complex area, BOEM uses two oil spill models: OSRA

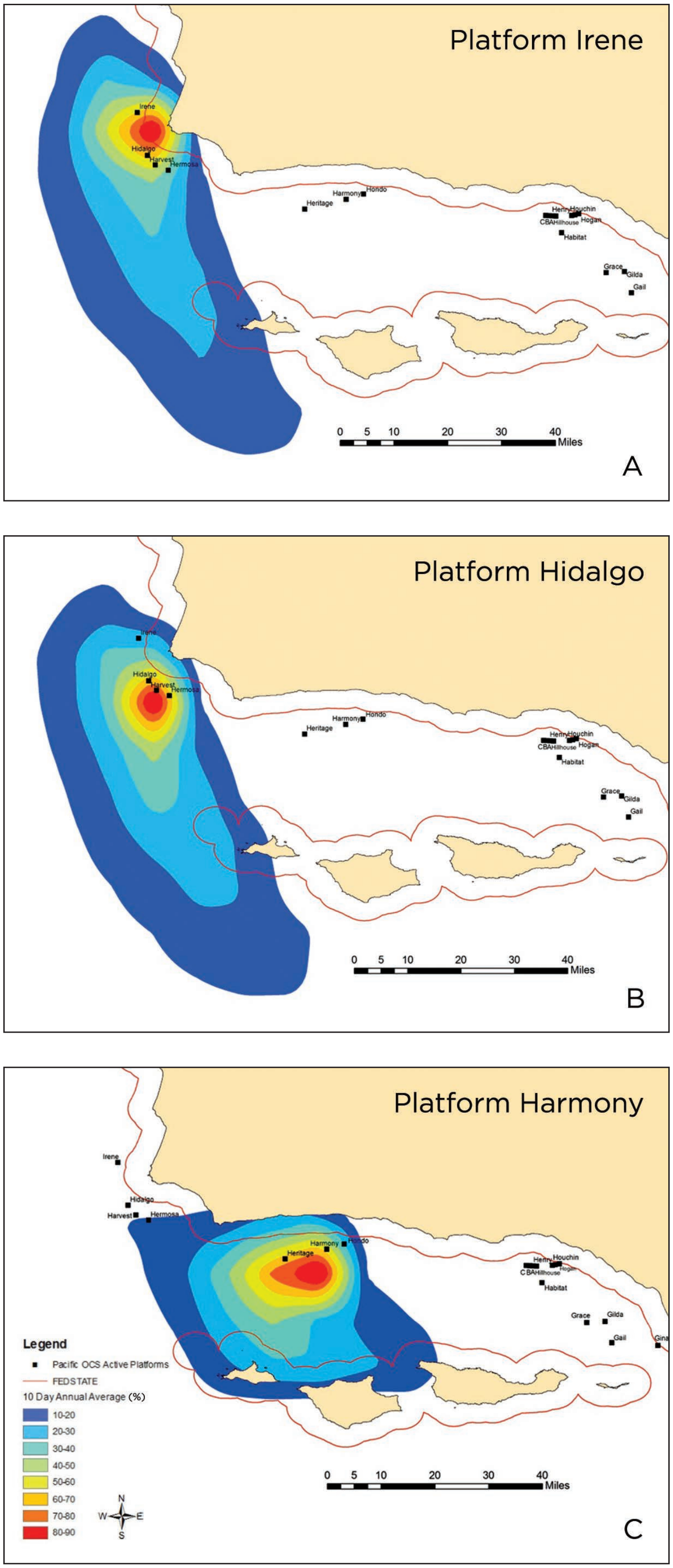


Figure 3. OSRA outputs for three platforms (Platforms Irene, Hidalgo, and Harmony) in the Southern California Planning Area. Simulated oil was released over 10 days from a platform launch point. The model utilized annual average current fields. The modeled probability that oil will contact certain land and ocean locations ranges between 10 and 90 percent.

and the GNOME (General NOAA Operational Modeling Environment) model, a tool developed by NOAA. Generally, OSRA is used for planning purposes and other regional or region-wide projects, whereas GNOME is used for site-specific oil spill simulations, drills, and spills. Both OSRA and GNOME simulate oil movement due to winds and currents while GNOME also accounts for some characteristics of the spilled oil, such as the gravity (heaviness) and viscosity (thickness).

The Role of Oil Spill Modeling in Protecting the Pacific Region

In the Pacific Region, BOEM uses oil spill modeling for region-wide and project-specific planning to obtain a better understanding of where oil may travel and what resources may be contacted. Oil spill risk analysis allows BOEM to estimate potential impacts from OCS operations and informs planning for oil spill response. Each operator maintains an oil spill response plan that indicates, in the event of a spill, where oil may travel from their facilities (Figure 3). Oil spill modeling informs environmental analyses, project decisions, and planning for accidental oil spills.

What's Ahead in the Pacific Region

The wide variety of species off the West Coast and the need to minimize impacts to those species will continue to make oil spill risk analyses an important part of BOEM's responsibilities in the Pacific Region.

BOEM continues to invest in oceanographic research to enhance its modeling capabilities in the Pacific Region and is expanding the geographic area for oil spill risk analysis to include central California to the U.S.-Mexico border. An ongoing BOEM study, *Expansion of West Coast Oceanographic Modeling Capability*, is conducting a 10-year hindcast of wind, waves, and currents at a 1-km resolution. Data generated from this study will be integrated into GNOME and OSRA models to provide more precise oil spill risk analyses.

– David Panzer and Susan Zaleski, BOEM

For More Information

Expansion of West Coast Oceanographic Modeling Capability study

http://www.boem.gov/pc-14-01/

Harms, S. and C.D. Winant. 1998. Characteristic patterns of the circulation in the Santa Barbara Channel. *Journal of Geophysical Research*, 103(C2): 3041-3065.

Hickey, B.M., E.L. Dobbins, and S.E. Allen. 2003. Local and remote forcing of currents and temperature in the central southern California bight. *Journal of Geophysical Research* 108 (C3): 3081.

General NOAA Operational Modeling Environment (GNOME)

http://response.restoration.noaa.gov/gnome

OSRA in the Alaska Region

Northstar is a joint Federal/State of Alaska oil and gas producing unit located in the Beaufort Sea about 12 miles northwest of Prudhoe Bay. The six producing Federal wells fall under BSEE regulatory authority while the State wells fall under the State of Alaska regulatory oversight. All the wells have been drilled and the rig has been demobilized.

In the Alaska OCS Region, as in other areas, OSRA model results are used in Environmental Impact Statements (EISs) and Environmental Assessments (EAs) for BOEM lease sales, as well as industry Exploration Plans and Development and Production Plans. OSRA results are also included in industry oil spill response plans and Endangered Species Act or Essential Fish Habitat consultations. A multidisciplinary staff—with expertise in physical and biological oceanography, social science, biology, ecology, economics, and anthropology—conducts each oil spill risk analysis.

As in other regions, BOEM uses the OSRA model to estimate the chance of contact *(conditional probability)* and the chance of occurrence **and** contact *(combined probability)* to four types of environmental resources that include environmental resource areas (ERAs, which represent concentrations of wildlife, habitat, subsistence-hunting areas, or subsurface habitats), Land Segments, Grouped Land Segments, and Boundary Segments.

Unlike other regions, sea ice is a factor in the Alaska OCS areas. The transport of real and hypothetical oil spills depends not only on the winds and ocean currents but on ice as well. For cases where the ice concentration is below 80 percent, each trajectory is constructed by adding the vectors of the ocean current field and 3.5 percent of the instantaneous wind field. For cases where the ice concentration is 80 percent or greater, the model ice velocity is used to transport the oil.

In the Arctic OCS, conditional probabilities are calculated for three seasons (annual, summer, and winter) and six time periods (3, 10, 30, 60, 180, and 360 days) to account for the possibility of oil spills freezing into and melting out of sea ice over the seasonal cycles in the Arctic. In the Chukchi Sea Planning Area, the summer period is from June 1 through October 31 and generally represents open water or Arctic summer. The winter period is from November 1 through May 31 and generally represents ice cover or Arctic winter.

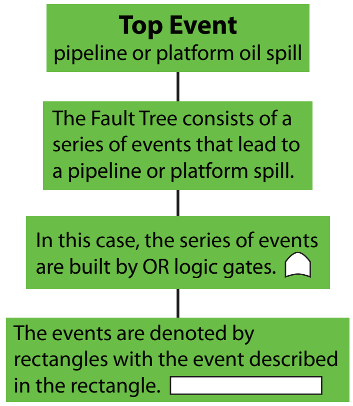
BOEM relies on the current, ice, and wind data from a new coupled ocean-ice general circulation model to simulate hypothetical oil spill trajectories. Depending on the path of the hypothetical oil spill and its surrounding environment, the trajectory is allowed to travel for a minimum of 30 days (if the spill is in open water the entire time) to a maximum of 360 days (if the spill is in the ice the entire time where ice concentration is 80 percent or greater). For those trajectories that come out of the ice and melt into open water, the trajectory is allowed to travel for a maximum of 30 days. The total combined time that the trajectory can travel in the open water and ice does not exceed 360 days.

OSRA results help BOEM, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service estimate potential oil spill impacts to a variety of resources in and adjacent to the Alaska OCS, including:

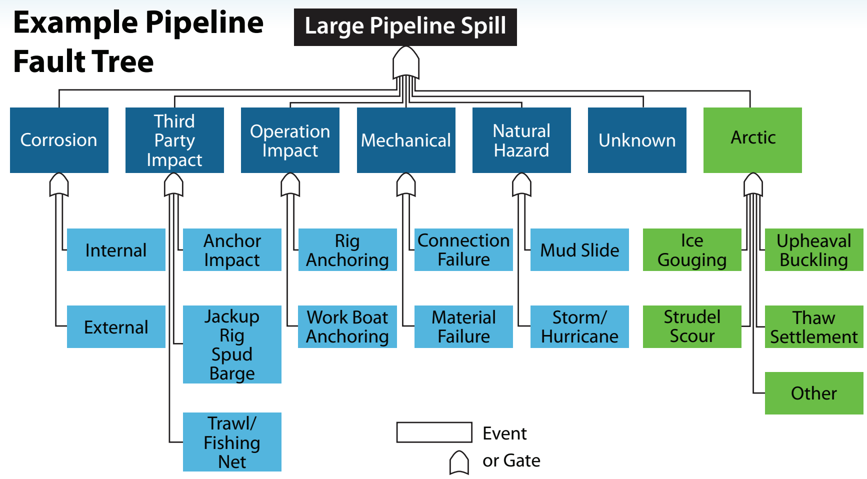
- Water Quality
- Lower-Trophic Level Organisms
- Fish, Commercial and Recreational Fisheries, and Essential Fish Habitat
- Marine Mammals
    - Cetaceans (Bowhead, Fin, Humpback, Gray, Beluga, North Pacific Right, Sperm, Blue, North Pacific Sei, Beaked Whales)
    - Pinnipeds (Stellar Sea Lions, Walrus, Ringed Seals, Bearded Seals, Spotted Seals, Harbor Seals, Fur Seals)
    - Mustelidae (Sea Otters)
    - Ursids (Polar Bears)
- Marine and Coastal Birds
- Terrestrial Mammals (River Otters, Caribou, Bears, Musk Ox, Fox, Deer)
- Vegetation and Wetlands
- Subsistence Harvest Patterns
- Archaeological and Cultural Resources
- Recreation, Tourism, and Visual Resources
- National and State Parks, Refuges, and Protected Areas

Fault Tree Analysis

A method of estimating probability of occurrence of events resulting from interactions of other events.



Example Pipeline Fault Tree



Arctic OCS Spill Rates

Because there are no recorded large oil spill data in the offshore Arctic, the Alaska OCS Region derives large oil spill rates using a *fault tree analysis*. A fault tree analysis is a method for estimating the spill rate resulting from interactions of other events. Fault trees are logical structures that describe the causal relationship between the basic system components and events resulting in system failure.

Two general fault trees were constructed, one for large pipeline spills and one for large platform/well spills. Arctic effects were considered by modifying existing spill causes that occur in other OCS regions, such as trawling accidents, as well as other unique spill causes that occur only in the Arctic. Unique causes of pipeline spills in the Arctic included ice gouging (floating ice gouges into the seafloor), strudel scour (water flows down through a vertical hole in sea ice and creates a scour depression in the seabed), upheaval buckling (pressure causes pipe to bend upward), thaw settlement (pipe settles as surrounding sediments thaw), and other causes. For platforms, these included ice force, low temperature, and other causes. The estimates of uncertainty in each fault tree event also include the non-Arctic variability such as spill size, spill frequency, and facility parameters, including wells drilled, number of platforms, number of subsea wells, and subsea pipeline length. The consideration of various Arctic effects, non-Arctic variability, and facility parameters in the fault tree analysis is intended to provide a realistic estimate of spill-occurrence rates on the Arctic OCS and their uncertainties.

Using the fault tree method, oil spill data from the GOM and Pacific OCS were modified to include both Arctic and non-Arctic variability (Bercha Group, Inc., 2014b). It also includes loss-of-well-control frequencies from a recently completed Loss of Well Control study (LOWC; Bercha Group Inc., 2014a). Using information from both the SINTEF worldwide database and the U.S. GOM and Pacific OCS, the LOWC study updated offshore LOWC frequency data through 2011 for the GOM, the Pacific OCS, and the North Sea.

The study concluded that platforms are likely to have the most, but smaller spills, while wells will have the least number but larger spills. Pipelines fall in between these two structures, with more spills than wells. The fault tree analysis method provides a means for using the OSRA model in Arctic OCS areas where there is no history of large OCS spills.

Future Directions

BOEM will continue to further advance the OSRA in the Alaska Region. Stakeholders have expressed interest in developing Geographic Information System tools for visually displaying the OSRA tabular results. Maintaining state of the art general circulation models remains a top priority for BOEM's Environmental Studies Program as well as collecting observational results for sensitivity testing and validation of the model results.

– Merlin Hayes, Schatz Publishing

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Arctic OCS Spill Rates

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Alaska North Slope Spill Rates

Nuka Research and Planning Group, LLC. 2013. *Oil Spill Occurrence Rates for Alaska North Slope Crude and Refined Oil Spills.* OCS Study BOEM 2013-205.

http://www.boem.gov/uploadedFiles/BOEM/BOEM_Newsroom/Library/Publications/131104_BOEMOilSpillOccurrenceFinalReport.pdf

Spotlight on a Scientist: Zhen Li

What is your job at BOEM?

I am a physical oceanographer in the Branch of Physical and Chemical Sciences, Division of Environmental Sciences (DES) at BOEM's Herndon headquarters. My job is to conduct Oil Spill Risk Analysis (OSRA) to support our regional analysts who need to complete Environmental Impact Statements (EIS) for potential oil and gas lease sales. I evaluate and analyze the results of ocean circulation models in the Gulf of Mexico and ocean-ice models in the Arctic. The work is very technical and requires more computing power than the average workstation, but that's my passion. Additionally, I have managed several projects for BOEM's Environmental Studies Program that could potentially improve OSRA in the future.

Zhen Li

Why did you decide to work for BOEM?

I joined BOEM in May 2010. I was attracted to DES because its Environmental Studies Program conducts cutting-edge applied science research to inform decisions on offshore oil and gas development. As a scientist working on OSRA modeling, a critical element for the EIS preparation, I feel I'm making a real contribution to the decision-making process.

What role do you play in BOEM's OSRA modeling?

I recently completed OSRA modeling and wrote an OSRA report for the Chukchi Sea Oil and Gas Lease Sale 193. This effort supported our Alaska regional analysts for writing the Second Supplemental Environmental Impact Statement (Second SEIS) for Lease Sale 193 in response to a federal court order. The OSRA model used newly available ocean current and ice data sets from a coupled ice-ocean model, and a new exploration and development scenario to estimate the probability of oil spill occurrence, probability of contact, and combined probability of oil spill occurrence and contact to sensitive environmental resources from accidental large oil spills related to Lease Sale 193. For this analysis, 3,240 trajectories were simulated from each of 375 launch points over the 18 years of wind, current, and ice data for a total of 1.215 million trajectories. My next project is to conduct OSRA modeling for the Liberty Prospect in Alaska's Beaufort Sea.

How has your educational background and experience prepared you for the work you do?

I earned a Ph.D. in physical oceanography from the University of Maryland. My thesis focused on numerical modeling of estuarine circulation. I worked at NASA Goddard's Global Modeling and Data Assimilation Office for five years on large-scale ocean climate modeling. My work on the Pacific Ocean modeling led to a paper published in the *International Journal of Remote Sensing* (Li and Adamec, 2009), and I was honored to receive the 2010 Len Curtis Award from the Remote Sensing and Photogrammetry Society for "the best scientific paper published in the open literature of remote sensing during the year 2009." This work led to another publication in *Ocean Modelling* in 2012 (Li, 2012), in which I computed the 3D trajectories of water particles in the South Pacific. So, my many years of numerical modeling experience prepared me for working on OSRA at BOEM.

What do you find most exciting or rewarding about your work?

The most exciting part of my work is that it can make an impact on our agency's decision making process. It is very rewarding to see the OSRA modeling for the Lease Sale 193 Second SEIS published. My work requires extensive collaboration with the regional offices and I have learned a lot from such a diverse group of experts. Striking the right balance between preserving the natural resources and conducting the safe exploration and production of oil and gas in the U.S. OCS, especially in Alaska, is not easy. It will keep my work exciting and rewarding for years to come.

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Li, Z., W.R. Johnson, and C.E. Murphy. 2015. Supplement to the Oil-Spill Risk Analysis: Chukchi Sea Planning Area, OCS Lease Sale 193. BOEM 2015-010. 138 pp.

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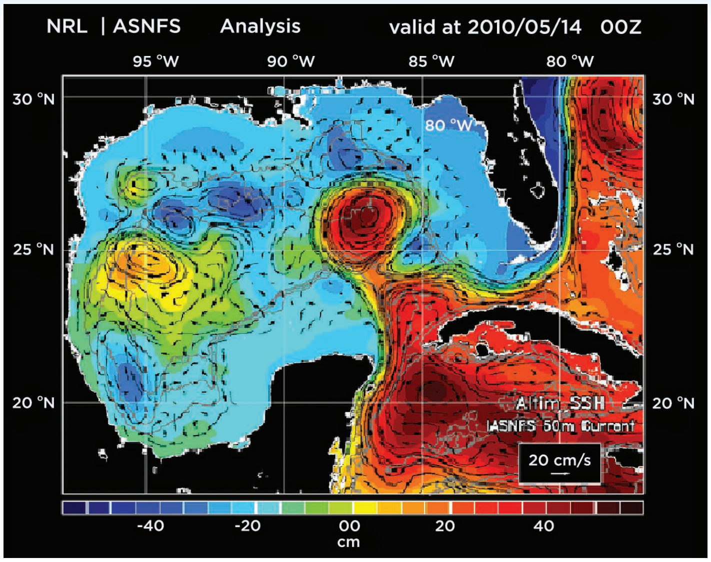
The Future of OSRA

For decades, the OSRA model has provided important information to BOEM scientists for NEPA analyses, and has provided valuable information for oil spill response plans. Today, scientists at BOEM conduct OSRA model runs and deliver the final products to the OSRA coordinators in regional offices.

BOEM continually aims to improve OSRA, and the potential for extreme events such as the 2010 *Deepwater Horizon* spill in the GOM, as well as possible climate change events make this imperative. Opportunities for improvements are being addressed in several current studies.

As mentioned earlier, BOEM initiated a study to simulate deepwater oil spills and to improve 3D modeling capabilities using the observations obtained from the *Deepwater Horizon* spill.

BOEM also embarked on a study to improve oil spill risk analysis in the GOM OCS region using a multiple hydrodynamic model approach by incorporating several sets of input from different proven ocean models.



Intra-Americas Sea Nowcast/Forecast System (IASNFS) re-analysis of GOM current data below the surface boundary at 50 m (black vectors) superimposed over color-coded satellite altimeter sea surface height for May 14, 2010. OCS Study BOEM 2014-1003.

OSRA in the Future?

What follows is a partial list of considerations—a strategic plan—although other opportunities for enhancements and improvements may exist as well.

Improving Hydrodynamic Model on a Recurring Schedule for All Regions. BOEM will continue its efforts to improve the ocean general circulation model and coupled ocean-sea ice model as they provide critical inputs to the OSRA model. BOEM intends to fund a study to develop a high-resolution model of Beaufort Sea nearshore areas. The goal is to provide high-resolution (~1 km) simulated fields of winds and surface currents around the Stefansson Sound barrier islands in the Beaufort Sea for use in OSRA modeling for the Liberty Prospect. In the Mid- and South Atlantic areas, BOEM proposes to obtain an updated ocean model hindcast that is properly validated and parameterized to inform potential conventional energy activities in the future. With much of the Atlantic oil and gas resource potential in deep waters (>200 m/656 ft), it is important for the model to be tested for and applicable to the deep and even ultra-deep ocean. Additionally, BOEM has supported many field programs across all OCS regions that provide in situ measurements for validation of model results and testing parameters of the ocean model or coupled ocean-sea ice model, and will continue supporting these efforts.

Modeling Deepwater Oil Spills. Offshore exploration and production continues to increase, which, in turn, increases the potential for accidental oil and gas spills. As these activities develop in deeper waters and new geographic areas, OSRA modeling will be critical because oil and natural gas releases in deepwater behave much differently than in shallow water, primarily due to density stratification, high pressures, and low temperatures. It is important to know whether oil released at depth will surface and, if so, where and when the oil slick will occur and how thick it will be. Using OSRA modeling in deepwater will also help industry and government officials prepare effective spill response plans.

Developing Supporting Tools for OSRA. BOEM's Alaska OCS region is developing ArcGIS methods for displaying the conditional and combined probabilities of potential oil spills to environmental resources from launch areas and pipelines by loading the statistics from OSRA model outputs to a geospatial database. This tool would help scientists write NEPA analyses and would be useful to other OCS regions.

Enhancement of OSRA Model Code and Documentation of the OSRA Process. The OSRA model code was written in the 1980s and has been significantly improved since then. The code has served its purpose well, yet it lacks portability and is not very user friendly. There is also a need to document the OSRA process, which includes the OSRA model code, preprocessing of input files into the model, and post-processing of the model's output for regional subject matter experts to use for their NEPA analysis.

Data Management and Storage. OSRA typically uses 10–20 years of ocean model output as the forcing files to drive the trajectory model. Archiving these datasets requires a huge amount of storage space for BOEM's computer system. Additionally, plans to conduct multiple oil spill risk analyses using several model outputs as input forcing files will create a growing demand for disk space in the near future.

– Rita Hess, Schatz Publishing

For More Information

Ko, Dong S. and Dong-Ping Wang. 2014. Intra-Americas Sea Nowcast/Forecast System Ocean Reanalysis to Support Improvement of Oil Spill Risk Analysis in the Gulf of Mexico by Multi-Model Approach. OCS Study BOEM 2014-1003.

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New Waves

Late-Breaking News & Information

Proposed Regulations for Future OCS Drilling

BOEM and the Bureau of Safety and Environmental Enforcement (BSEE) recently released proposed regulations to ensure that future exploratory drilling activities on the U.S. Arctic Outer Continental Shelf (OCS) are done safely and responsibly, subject to strong and proven operational standards.

Boundary segments in the Beaufort and Chukchi seas used for the oil-spill trajectory analysis.

"As we move forward with making the Arctic's oil and gas resources available for oil and gas leasing, we have an obligation to provide the American people with confidence that these shared resources can be developed responsibly," said BOEM Director Abigail Ross Hopper.

The proposed regulations codify requirements that all Arctic offshore operators and their contractors are appropriately prepared for Arctic conditions and that operators have developed an integrated operations plan that details all phases of the exploration program for purposes of advance planning and risk assessment. With an emphasis on safe and responsible exploration, the proposed rule would also require operators to submit region-specific oil spill response plans, have prompt access to source control and containment equipment, and have available a separate rig to drill a relief well in the event of a loss of well control. The proposed rule continues to allow for technological innovation, as long as the operator can demonstrate that the level of its safety and environmental performance satisfies the standards.

The proposed regulations were developed with significant up-front public input from the State of Alaska, North Slope communities, industry, and non-governmental organizations. The proposed regulations will be open for additional public comment to solicit feedback from all stakeholders. Both bureaus and the Department of the Interior will continue rigorous stakeholder engagement as well as formal tribal consultation in the region. A draft Environmental Assessment, required by the National Environmental Policy Act, is also available for public comment.