Mass Wasting Processes and Products of the Mississippi Delta Front: Data Synthesis and Observation

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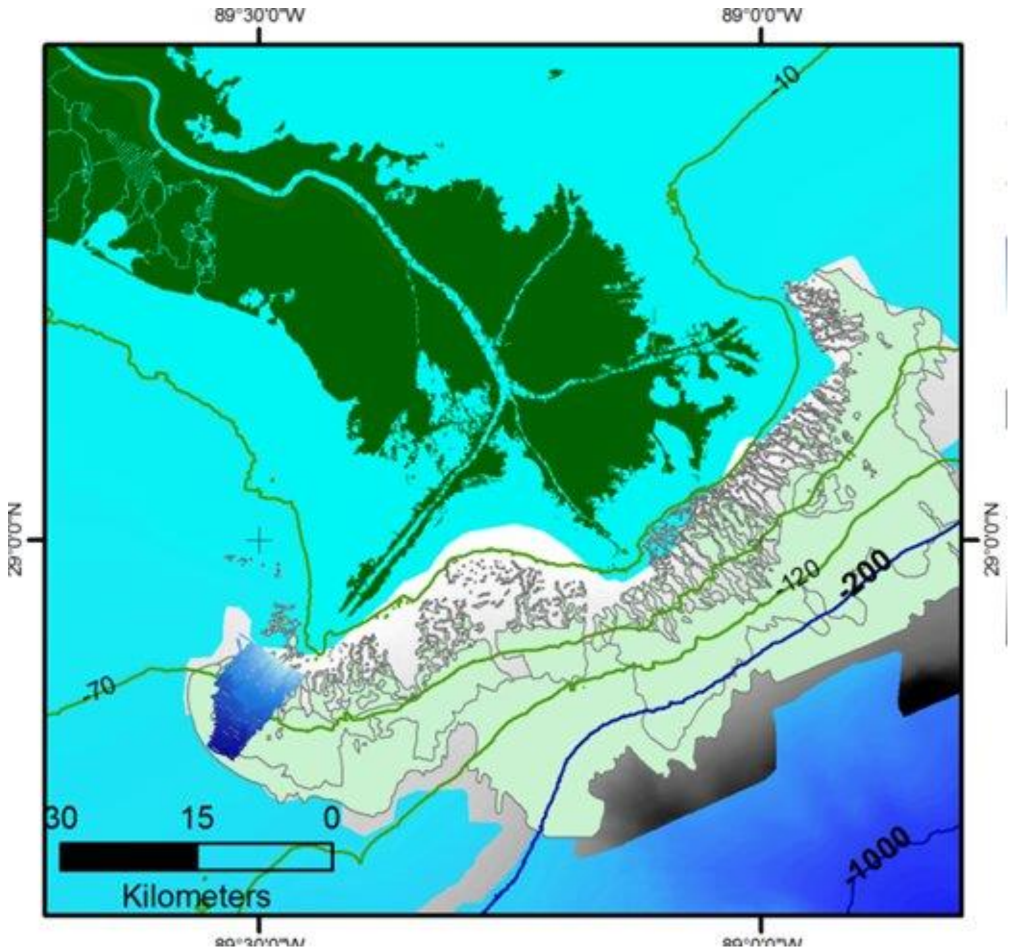

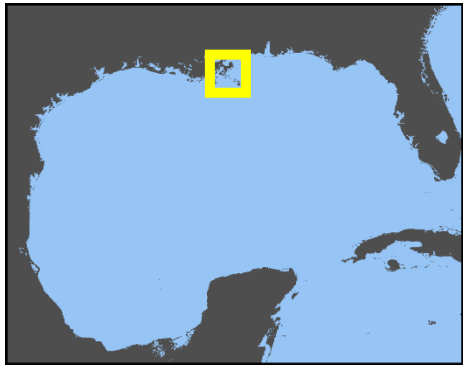

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BOEM
Bureau of Ocean Energy Management

River Deltas Worldwide

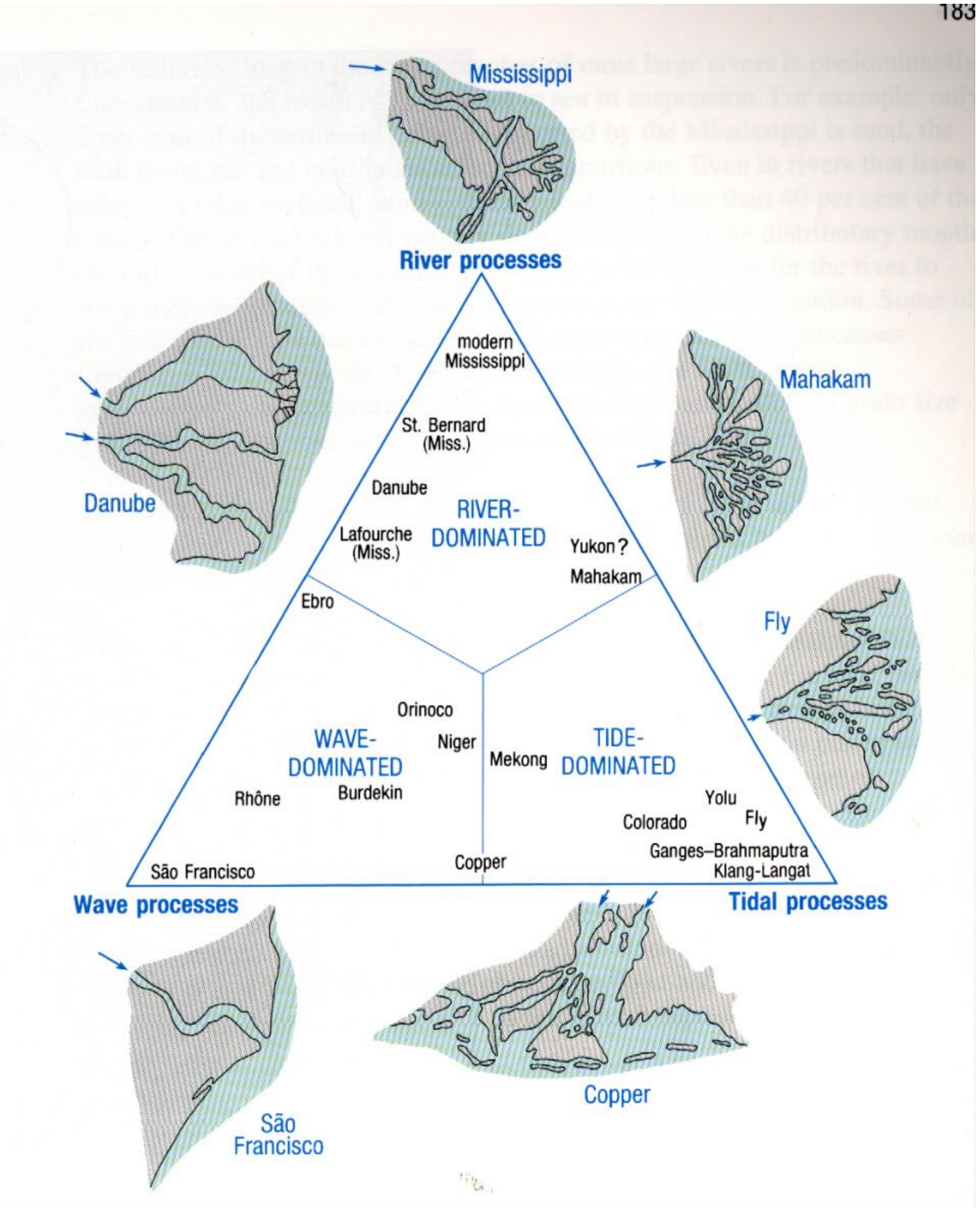
Influenced by:

- River water and sediment
- Wave reworking
- Tidal flows

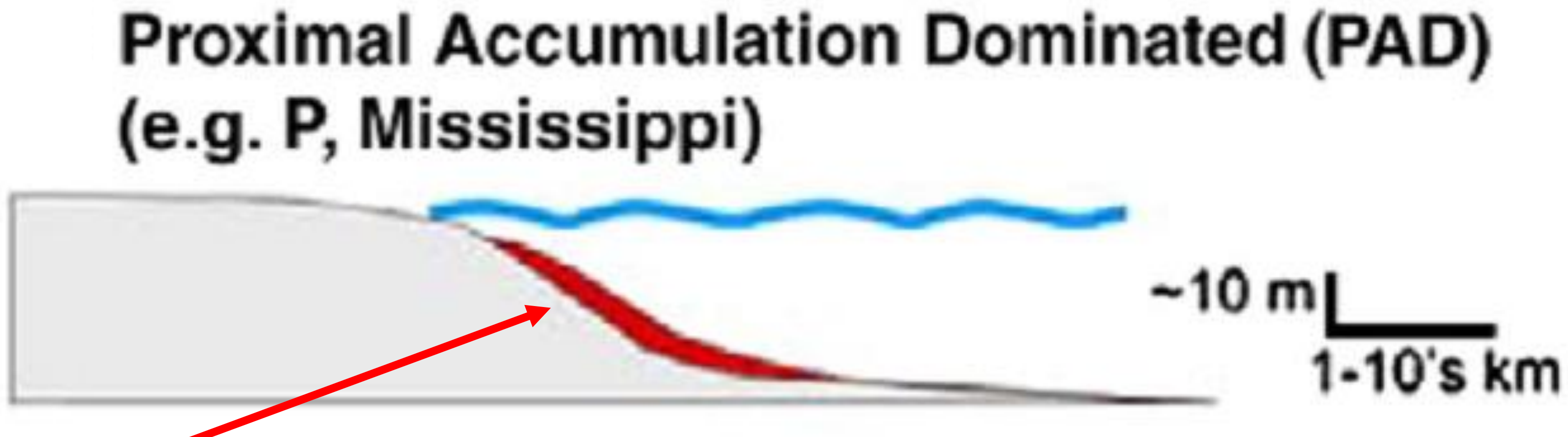
Examples of rivers with strongest Fluvial signature:

- Mississippi, Po, Fraser
- Yellow/Huang He
- Others

Figure: after Galloway, 1975



Delta Front: Active Marine Deposition from River Plumes



Delta Front

after Walsh and Nittrouer, 2009

Why is the delta-front region so important?

- Proximal location of abundant mud deposition from river plumes
- Sedimentary gateway between rivers and oceans
- Navigation, petroleum resources
- ***Geohazards – especially mass wasting, submarine landslides***

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Project Study Area and Objectives

The Mississippi River Delta Front:

- Petroleum: Active production and transfer region for O&G
- Impacted by submarine landslides at a range of temporal and spatial scales, producing substantial risk from these geohazards
- Last major regional survey and studies ca. 1977-1982

Objectives for the present project:

- Data gathering, synthesis, gap analysis
- Geophysical data: focus on high-quality digital data sets
- Pilot field studies using recent technologies for mapping, sampling, analysis
- Develop proposal for major new regional survey and field/modeling analyses and synthesis

Research Motivation and Questions:

We know that the Mississippi River Delta Front is a region of active sedimentation and submarine landslides

We know that major hurricanes cause landslides.

But: do submarine landslides occur under other conditions?

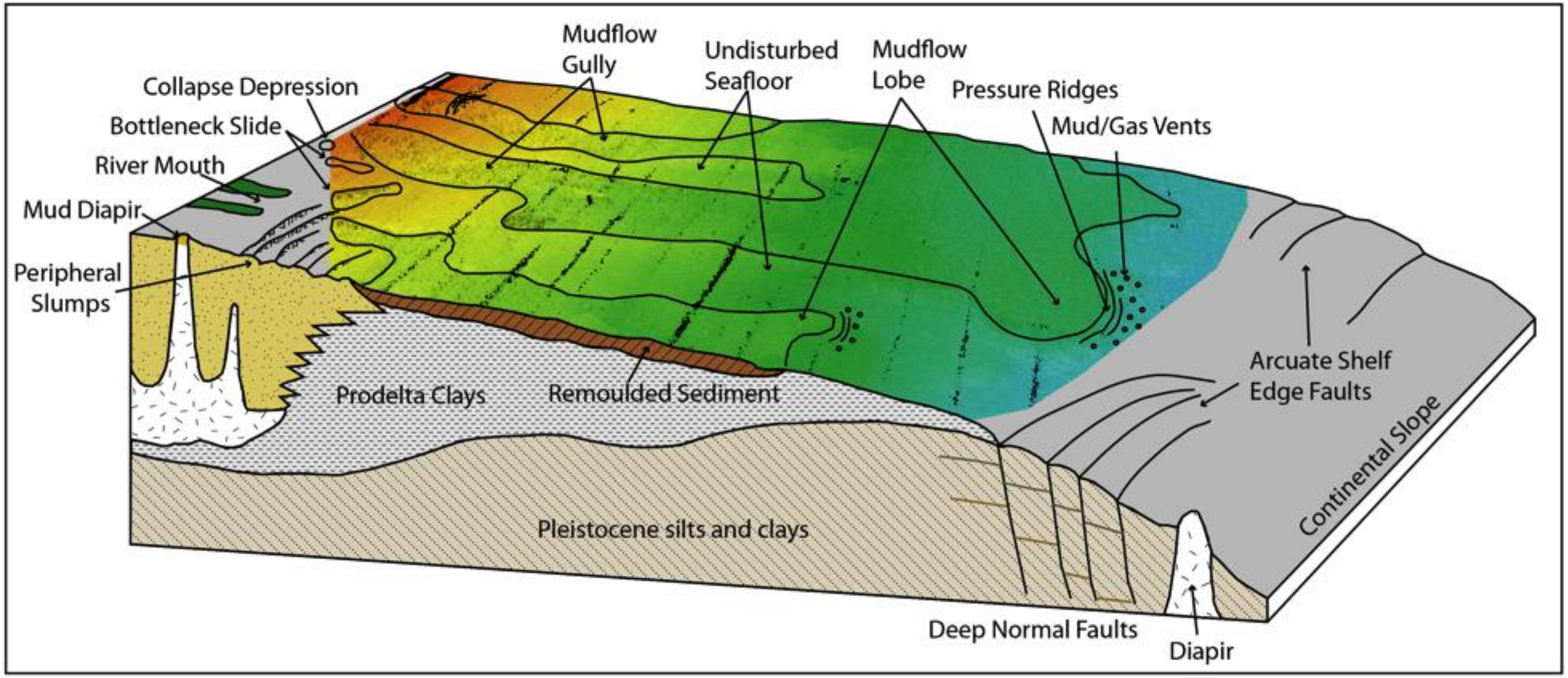
What other processes influence landslides and delta-front evolution? Winter storms? Smaller tropical cyclones? Floods?

The last major survey of this region was in 1977-1979

Our group was asked by the US Bureau of Energy Management to:

- Synthesize historical data on Mississippi delta-front morphology and processes
- Conduct pilot studies to determine rates and timing of sedimentation, mass-transport, landslides

Relevance



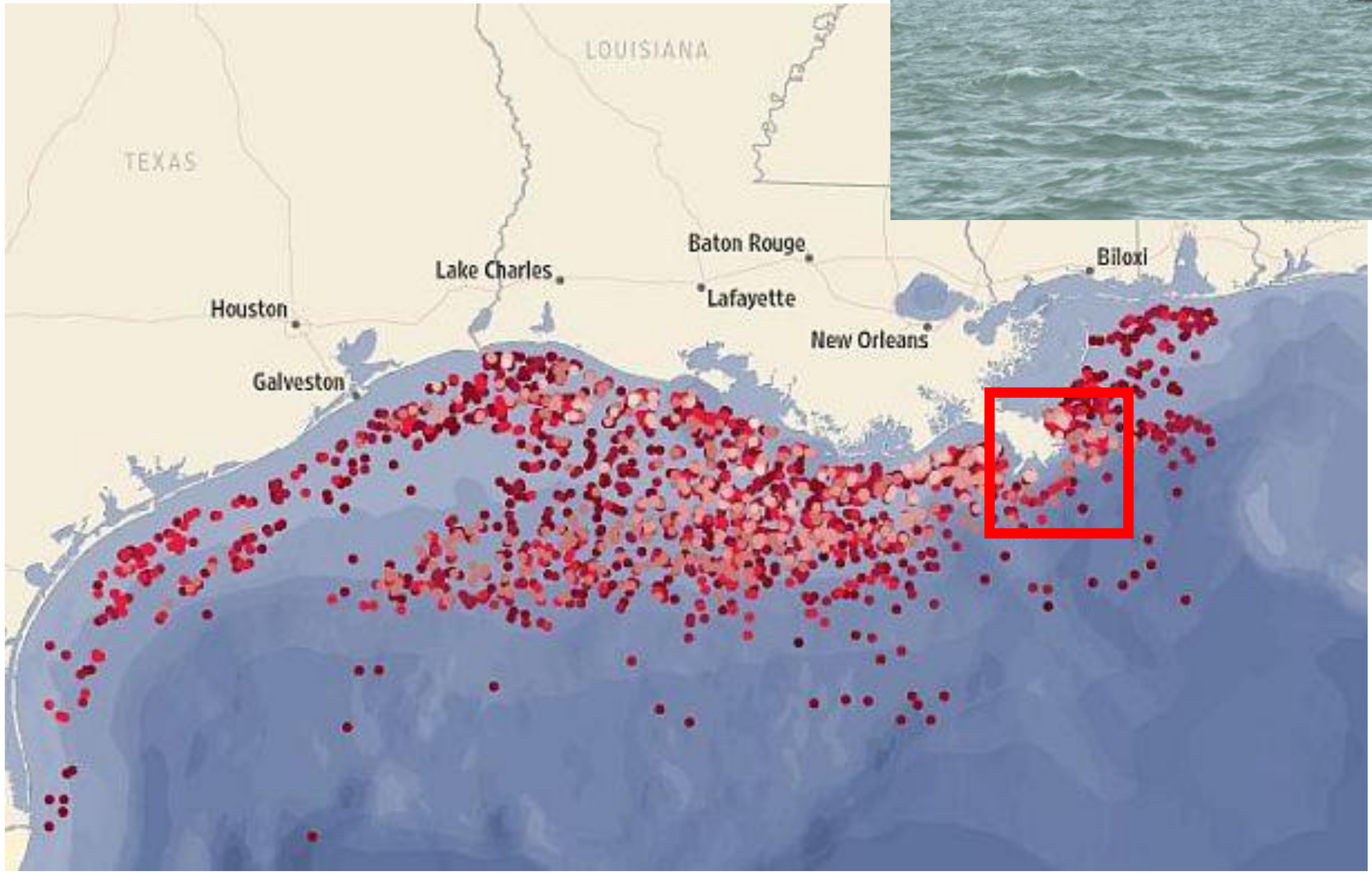
- ❖ Rapid accumulation rates enhance mudflow hazard
- ❖ Waves and other phenomena trigger mudflows
- ❖ Processes linked to subaerial delta

Figure: Maloney et al., in review Marine Geology (invited)

Gulf of Mexico Oil Platforms and Production

Over 4000 wells and platforms offshore of Louisiana alone

Submarine landslides in Mississippi River Delta Front (associated with river sedimentation) are major geohazards



Example: Hurricane Ivan, 2004

Waves from major hurricanes destabilize seabed and produce major submarine landslides

One large platform was destroyed by a landslide in 100 m water depth

Landslide thickness of ~30 m

16 oil wells flowed into ocean

A small amount of oil still leaks

Other platforms and pipelines damaged as well

NOLA.com | The Times-Picayune

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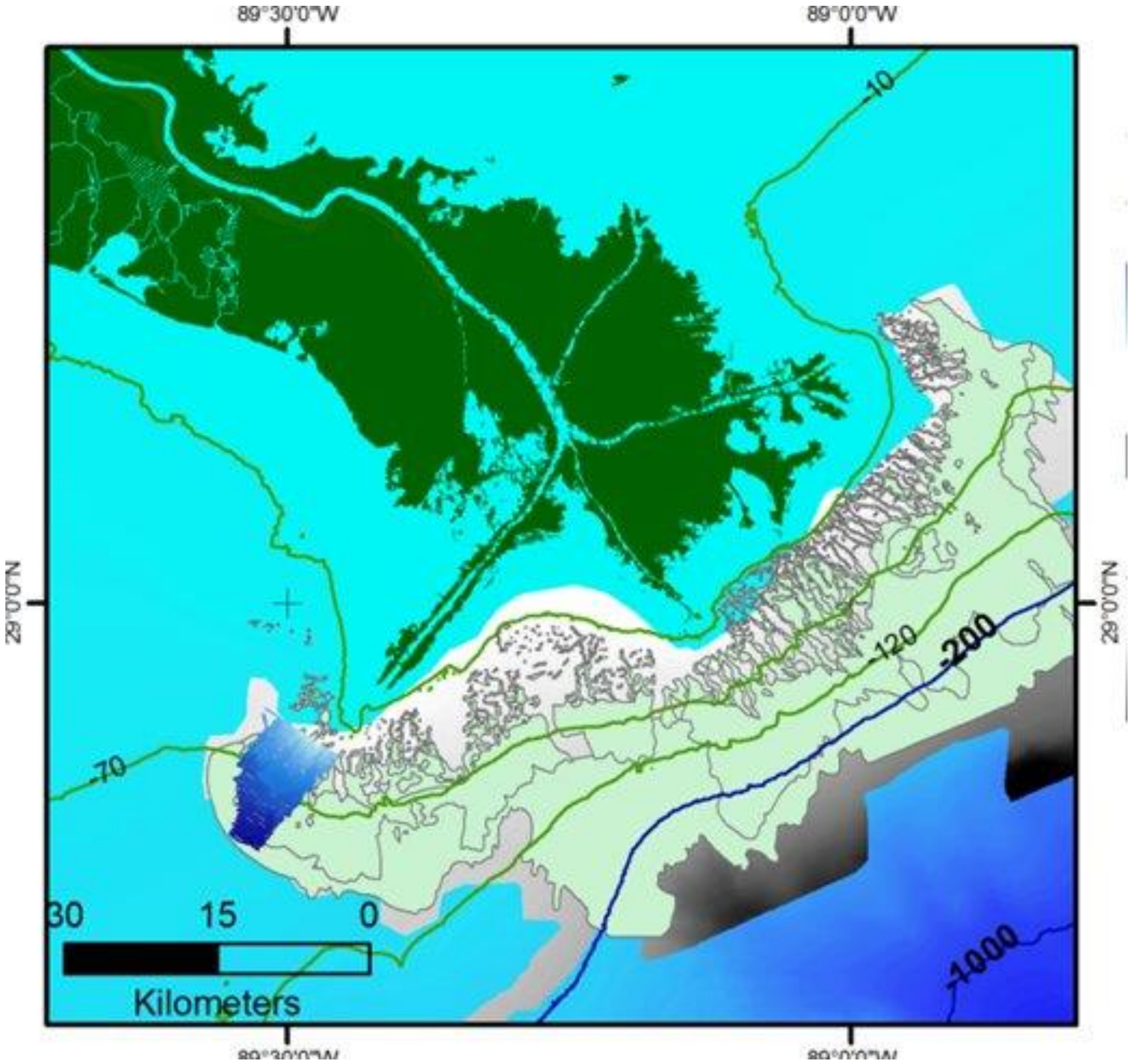
Outline

- Motivation and Aims
- Synthesis and analysis of historical data and studies
- Pilot studies 1 and 2
- Needs and concepts for future work

Figure data sources: Walsh et al., 2006; ETOPO Bathymetry; Coleman et al. 1980



Methods

Synthesis:

>100 geophysical, geological, and geotechnical data sets gathered since ca. 1969 for studies of oil platform and pipeline placement

>450 articles and reports on the study area

ArcGIS and Kingdom Suite projects using the available digital bathymetry and subbottom data

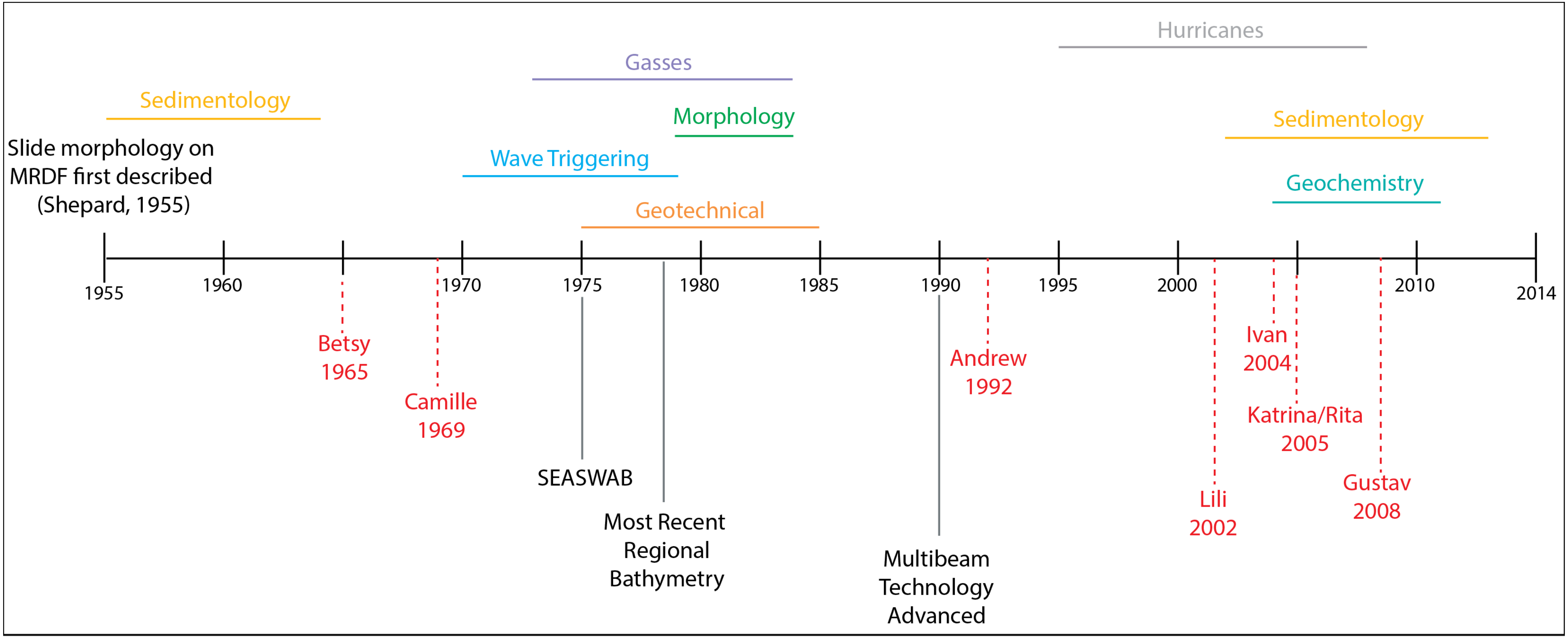
Pilot Studies 2014 and 2017: Survey of a small regions with multiple other small surveys since 2005

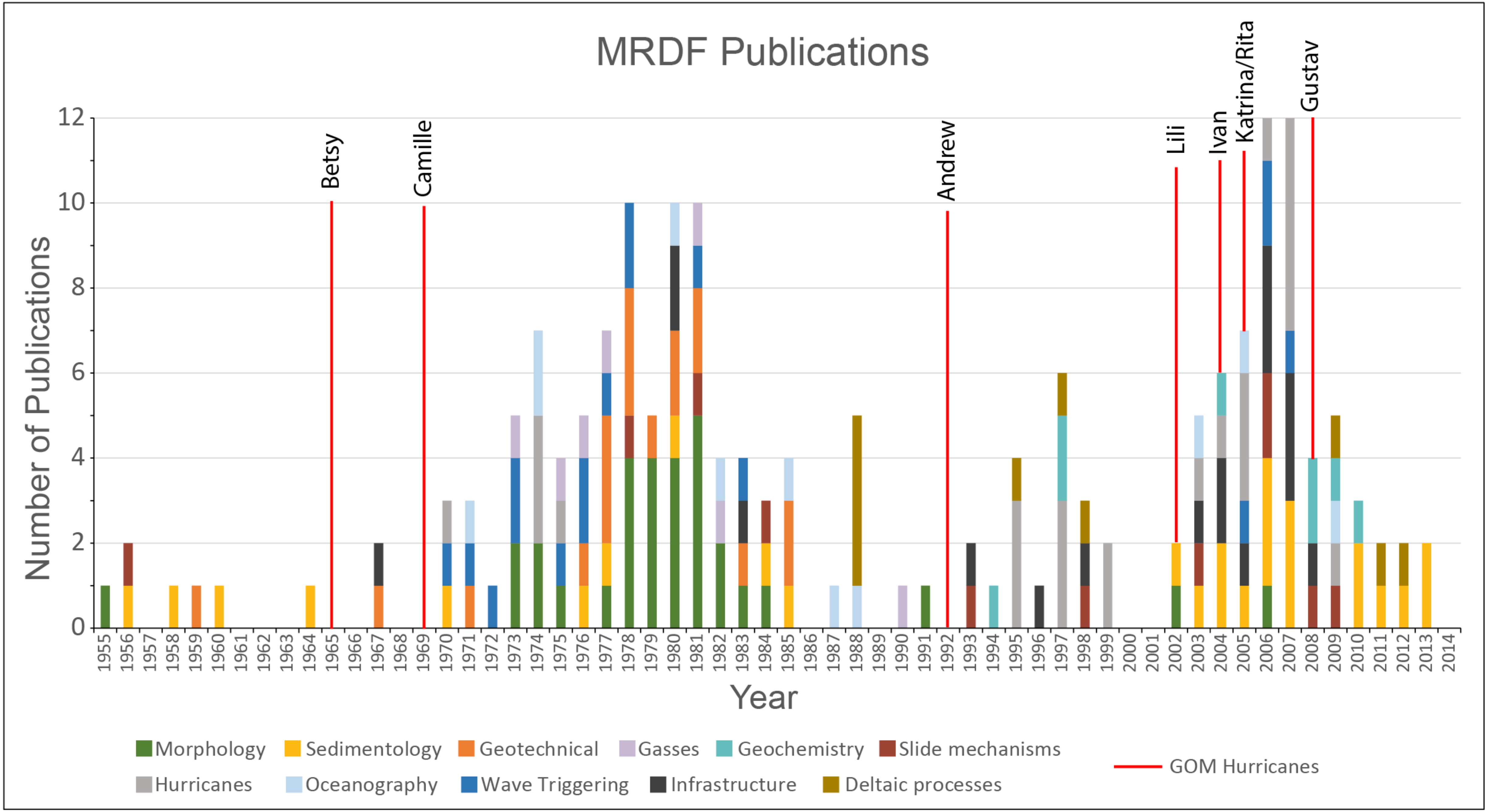
- Geophysics: Swath bathymetry, Subbottom survey using Edgetech DS2000 and 512i systems
- Geology and Geochronology: Coring to sample sediments
- Analysis of geological properties
- Dating deposits using Pb-210, Cs-137, Be-7 geochronology
- New geotechnical work ongoing

Data Synthesis and Gap Analysis

- Focus here:
- Timing and focus of historical studies
- Historic shift in delta progradation patterns
- In review: invited Marine Geology paper; in prep: invited review for Earth System Reviews

Major Events and Topical Focus of Earlier Projects





MRDF Publications
Number of Publications
Year
0
2
4
6
8
10
12
Betsy
Camille
Andrew
Lili
Ivan
Katrina/Rita
Gustav
1955
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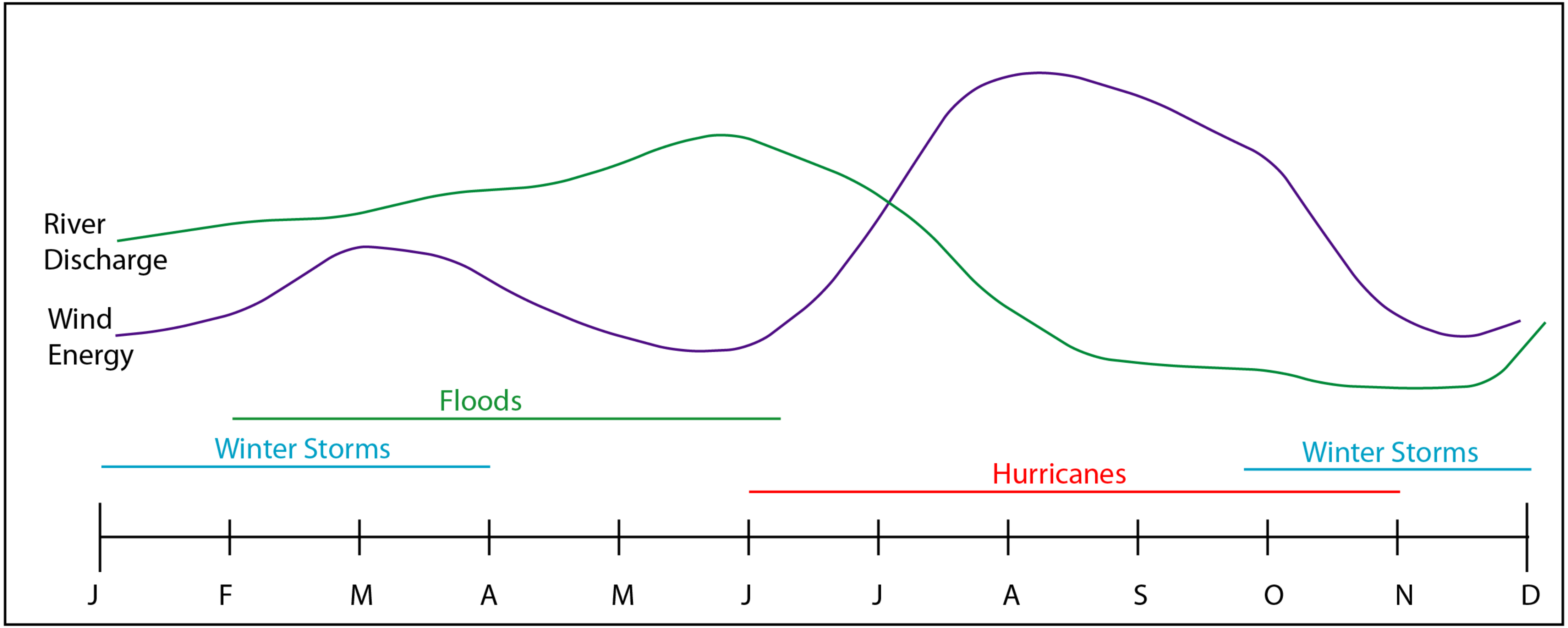
Morphology
Sedimentology
Geotechnical
Gasses
Geochemistry
Slide mechanisms
Hurricanes
Oceanography
Wave Triggering
Infrastructure
Deltaic processes
GOM Hurricanes

Forces Acting on the MRDF: Annual Patterns



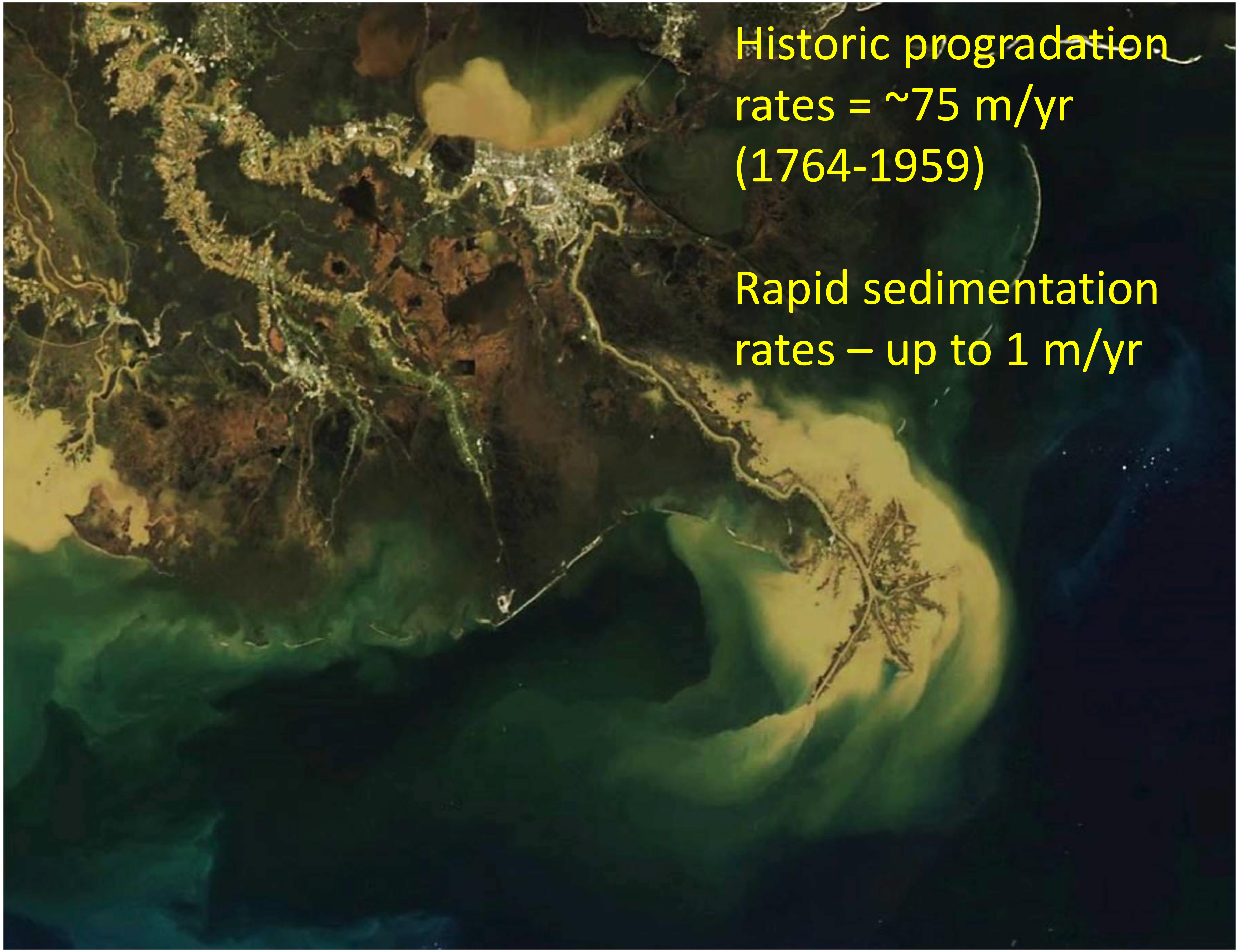
Historic Shift in patterns of delta front progradation

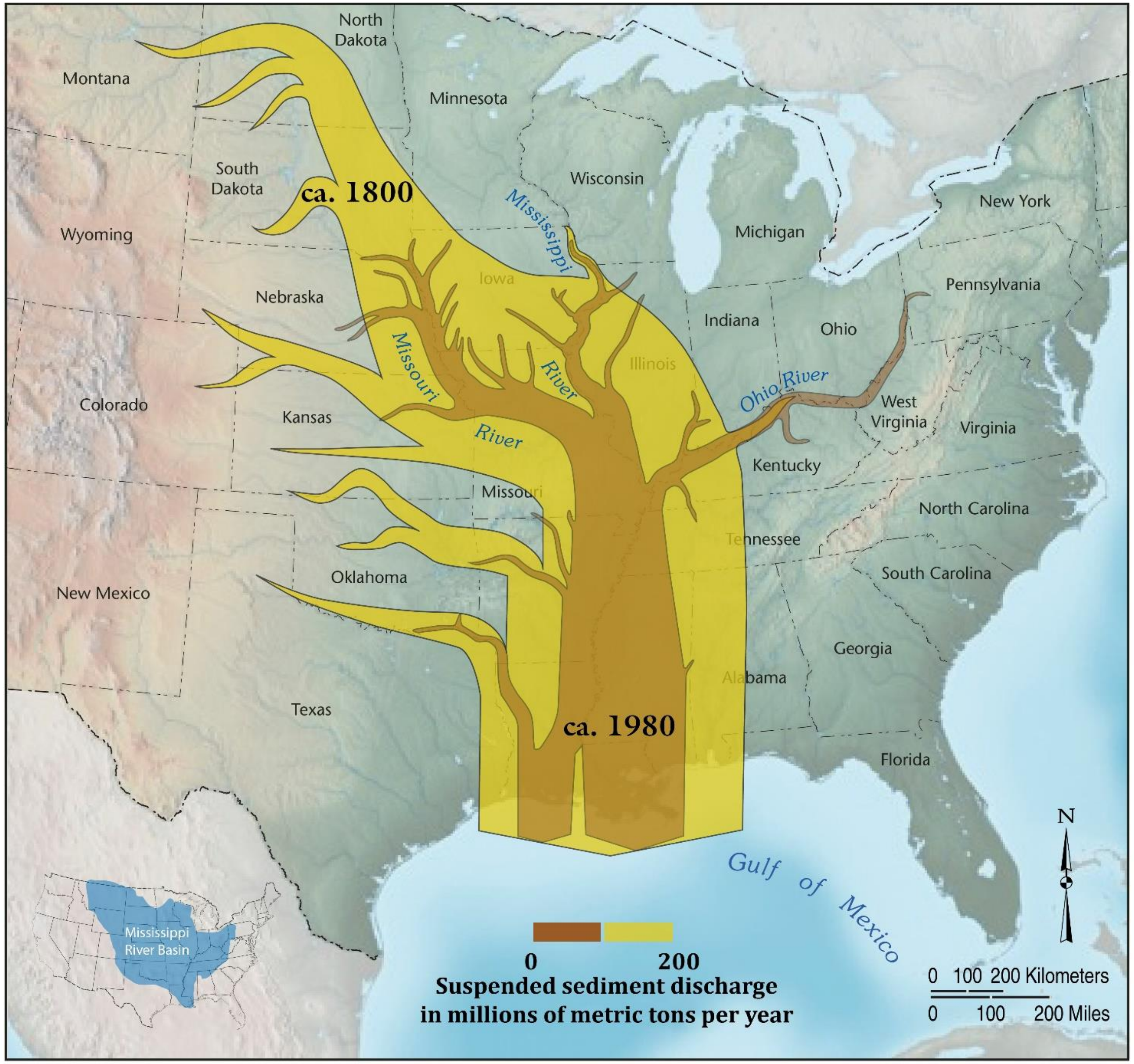
MODIS image:

LSU Earth Scan Laboratory

Maloney et al., submitted,

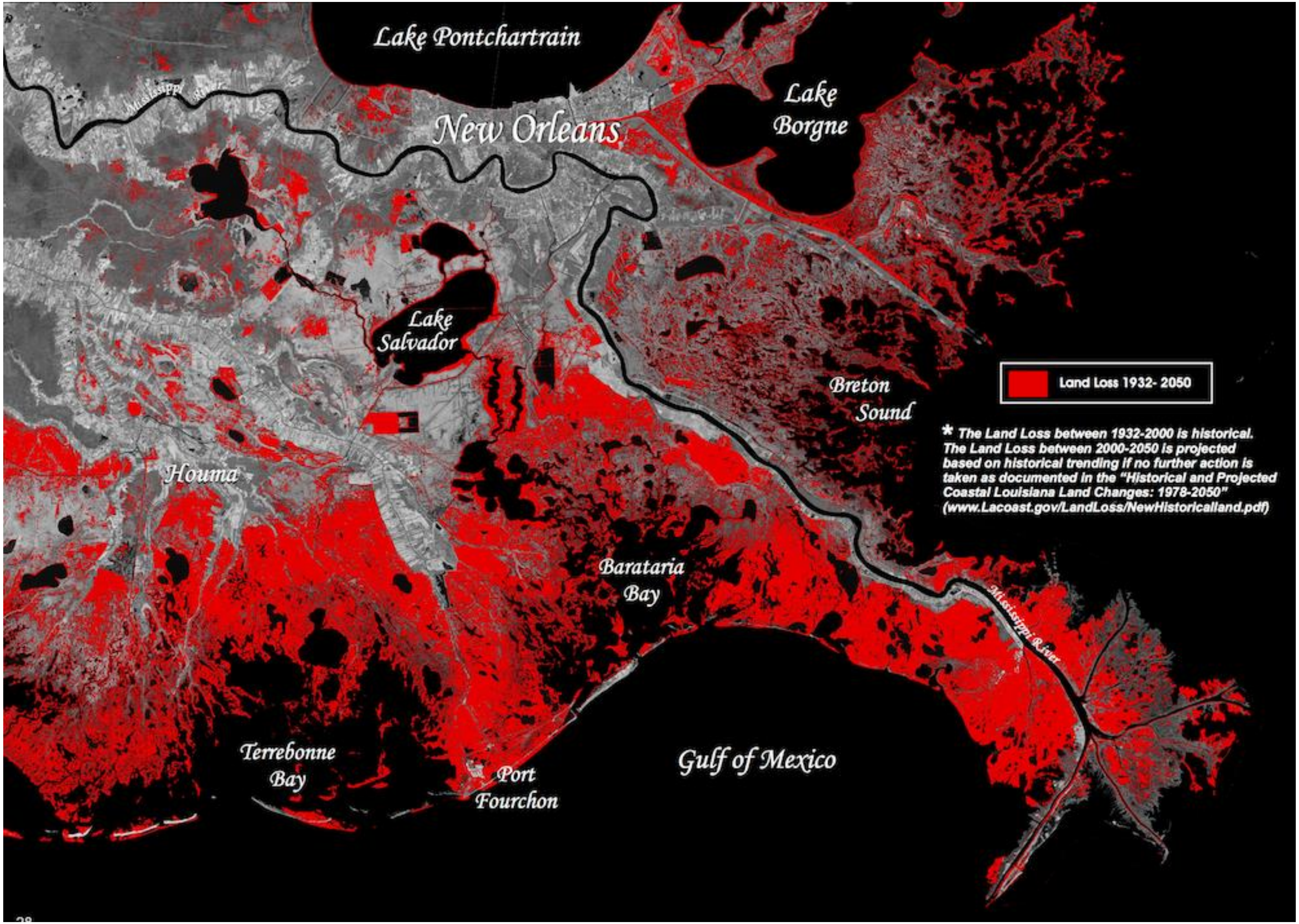
Invited paper for Marine Geology



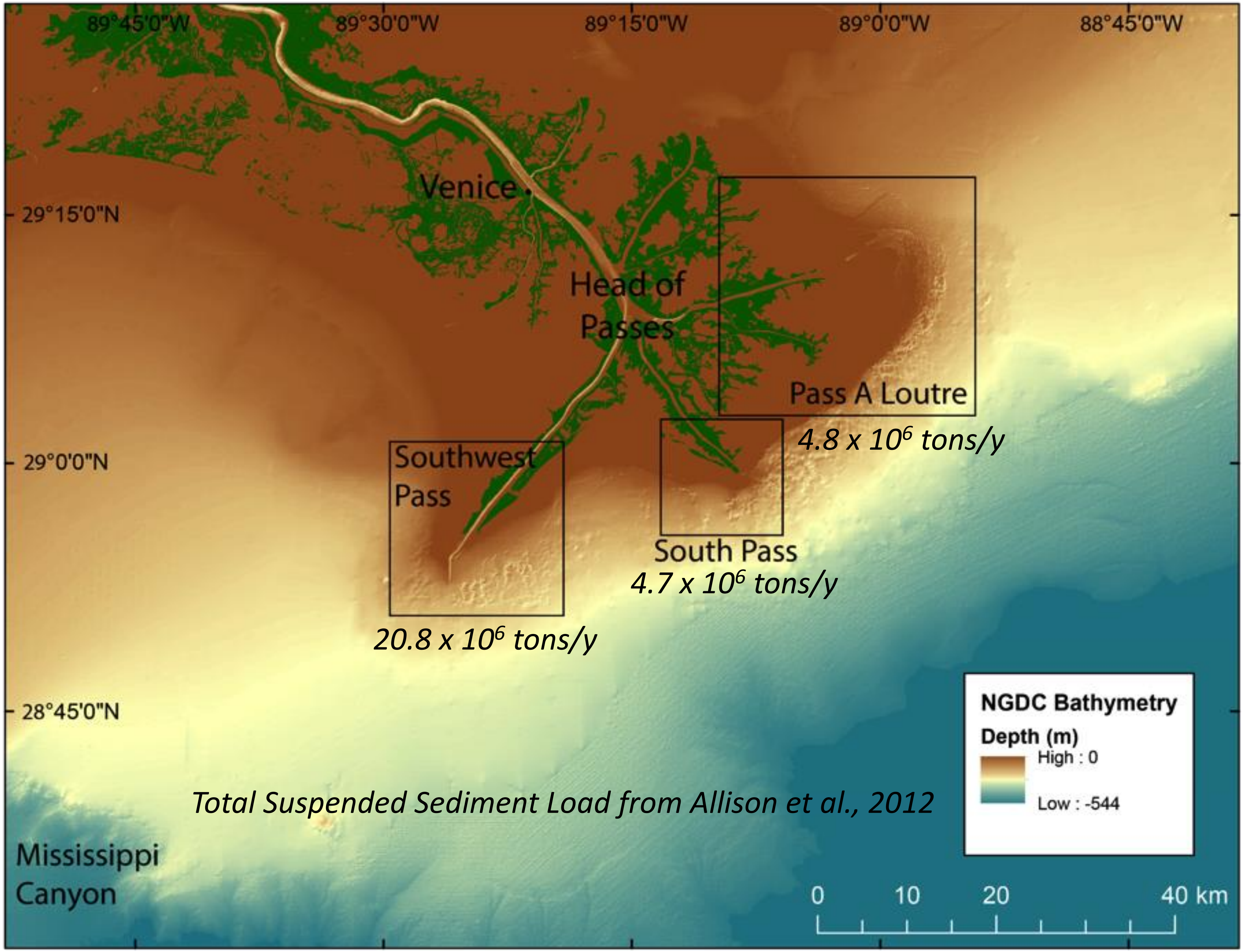


Meade and Moody, 2010; Bentley et al., 2016

Mississippi sediment load reduced 50% due to dam construction

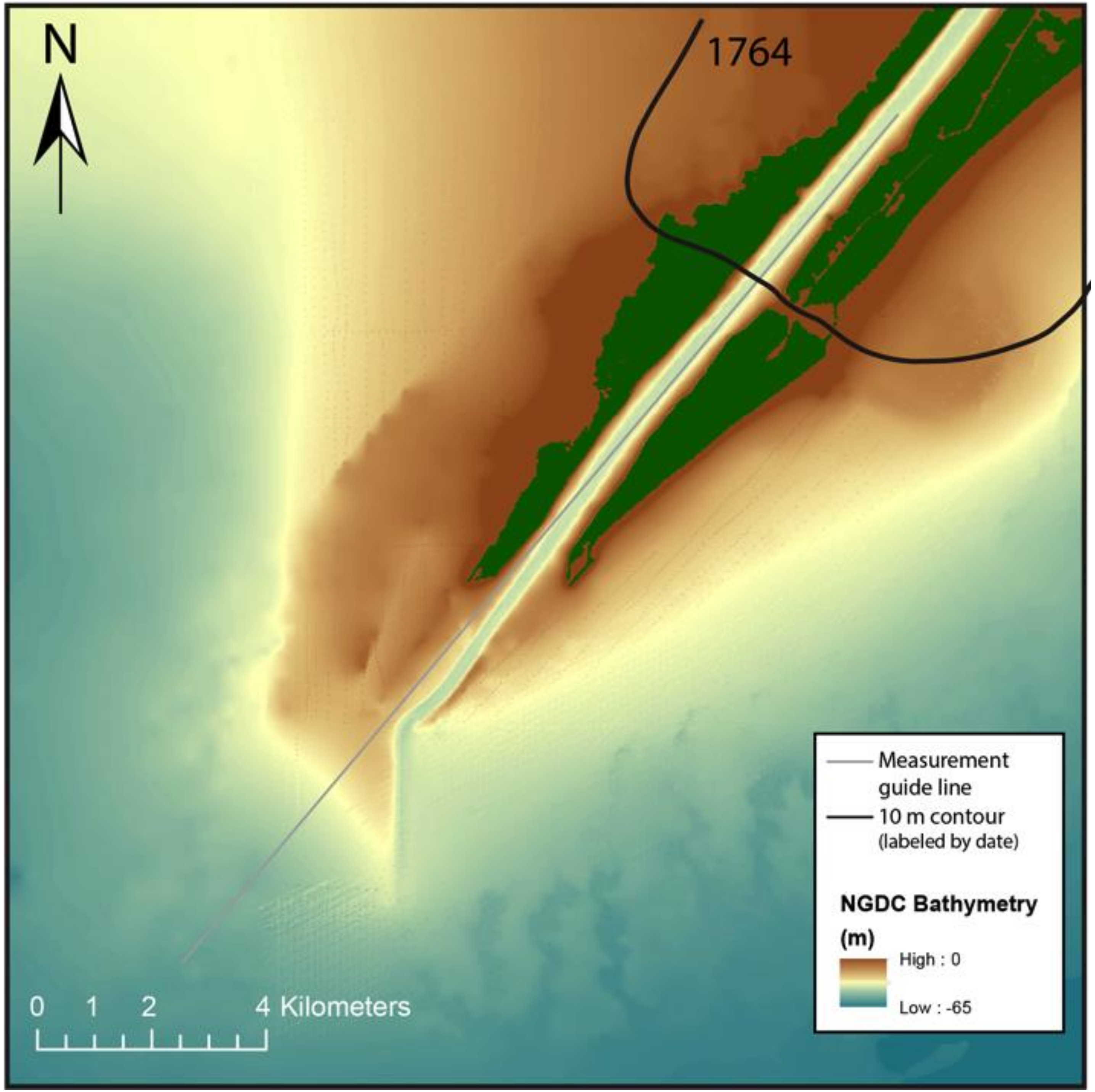


Lake Pontchartrain
Mississippi River
New Orleans
Lake Borgne
Lake Salvador
Land Loss 1932- 2050
Breton Sound
* The Land Loss between 1932-2000 is historical. The Land Loss between 2000-2050 is projected based on historical trending if no further action is taken as documented in the "Historical and Projected Coastal Louisiana Land Changes: 1978-2050" (www.Lacoast.gov/LandLoss/NewHistoricalland.pdf)
Houma
Barataria Bay
Mississippi River
Terrebonne Bay
Port Fourchon
Gulf of Mexico

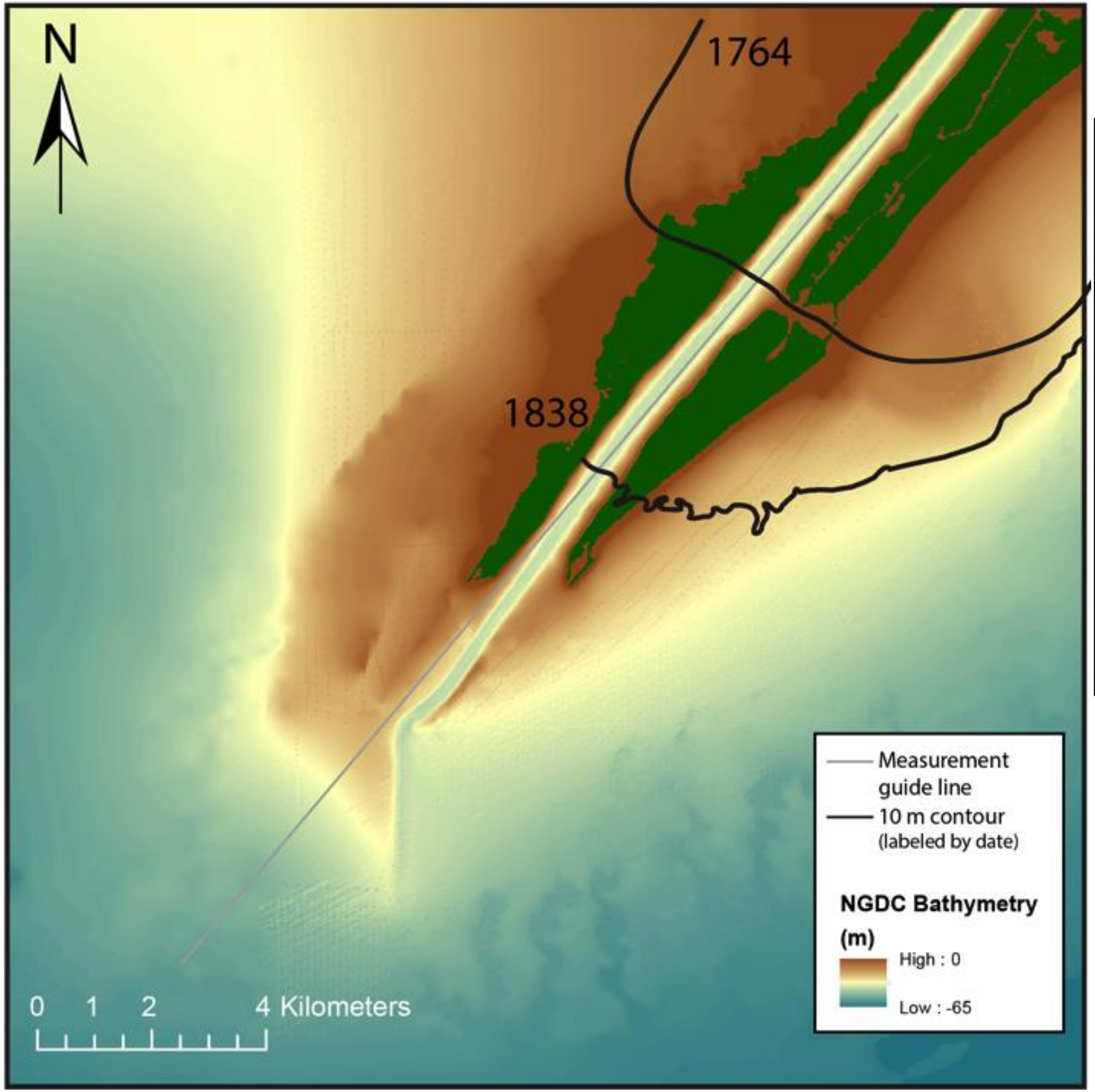

89°45'0"W
89°30'0"W
89°15'0"W
89°0'0"W
88°45'0"W
29°15'0"N
29°0'0"N
28°45'0"N
Venice
Head of Passes
Pass A Loutre
4.8 x 10^6 tons/y
Southwest Pass
South Pass
4.7 x 10^6 tons/y
20.8 x 10^6 tons/y
Total Suspended Sediment Load from Allison et al., 2012
NGDC Bathymetry
Depth (m)
High : 0
Low : -544
Mississippi Canyon
0 10 20 40 km

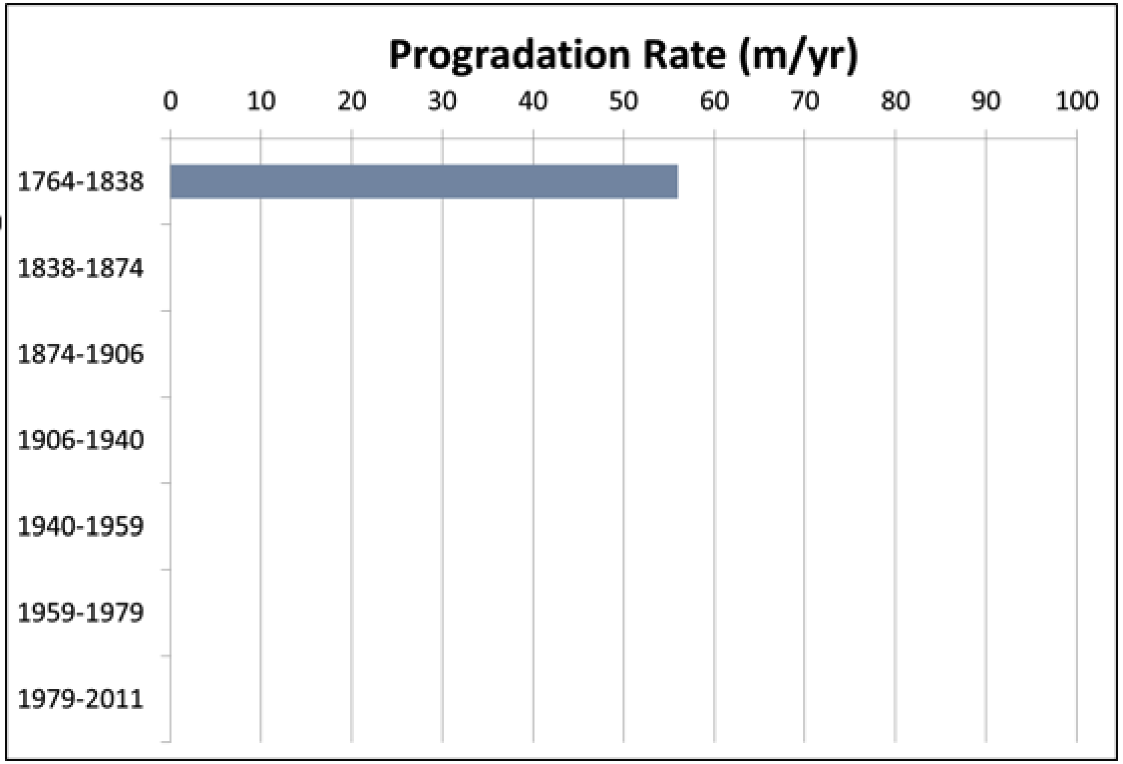
Southwest Pass Progradation

Seafloor data from historical nautical charts, Coleman et al., 1980, & NOAA.

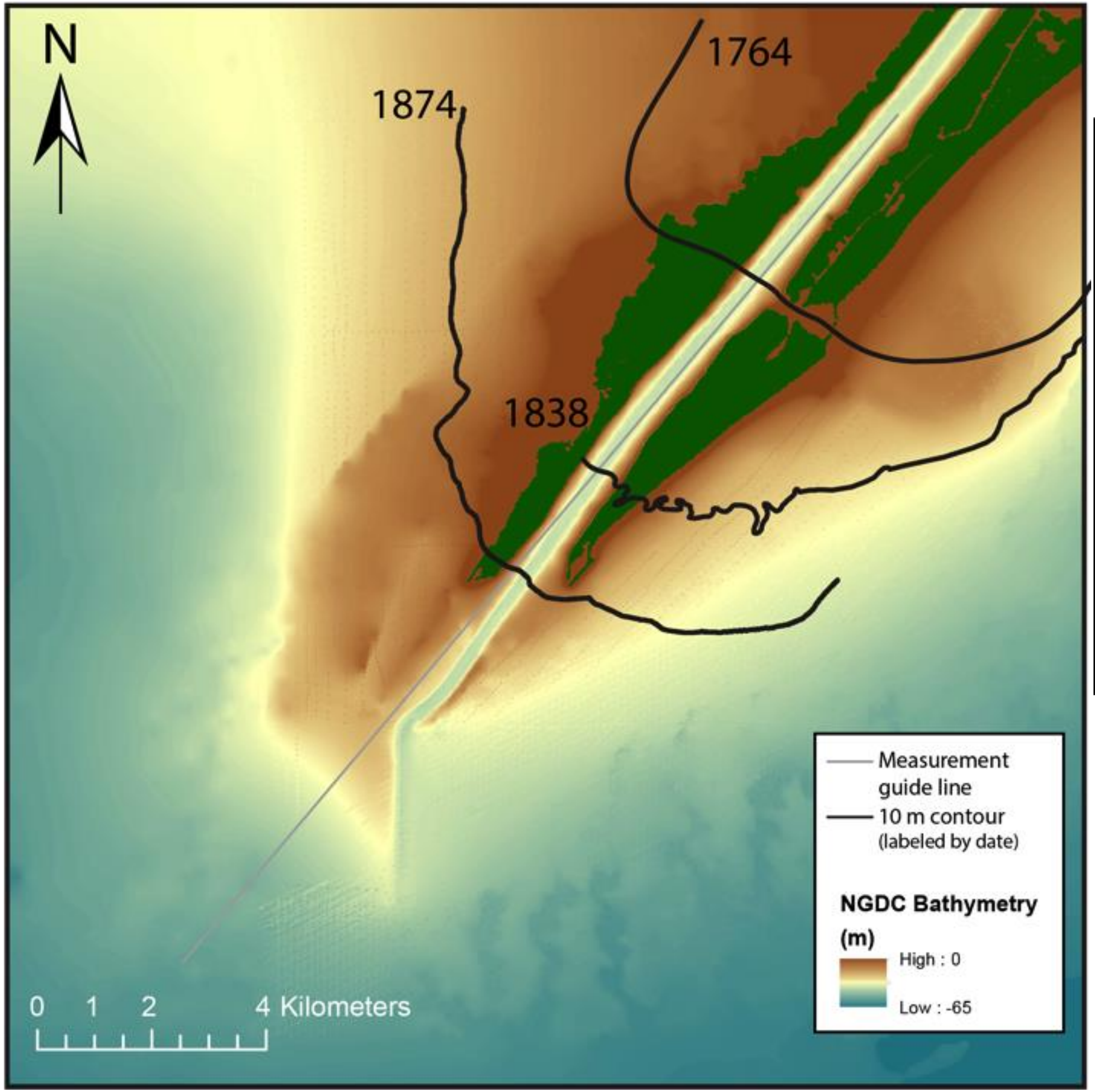


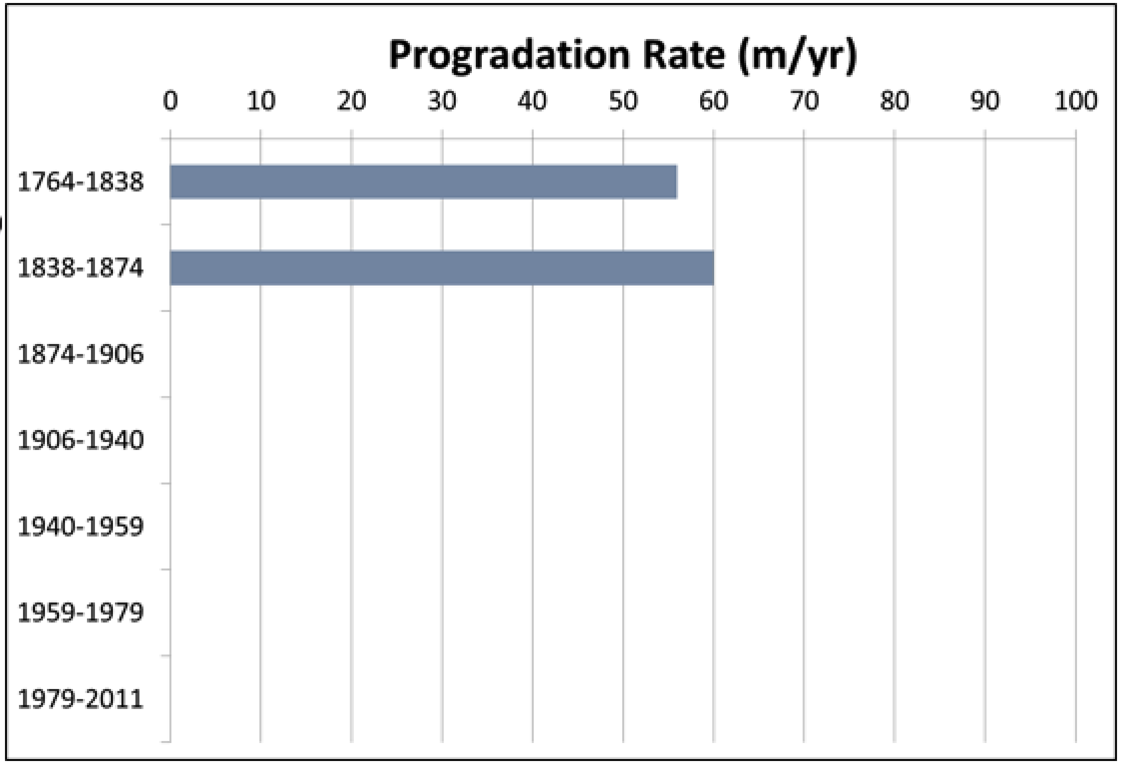
Southwest Pass Progradation



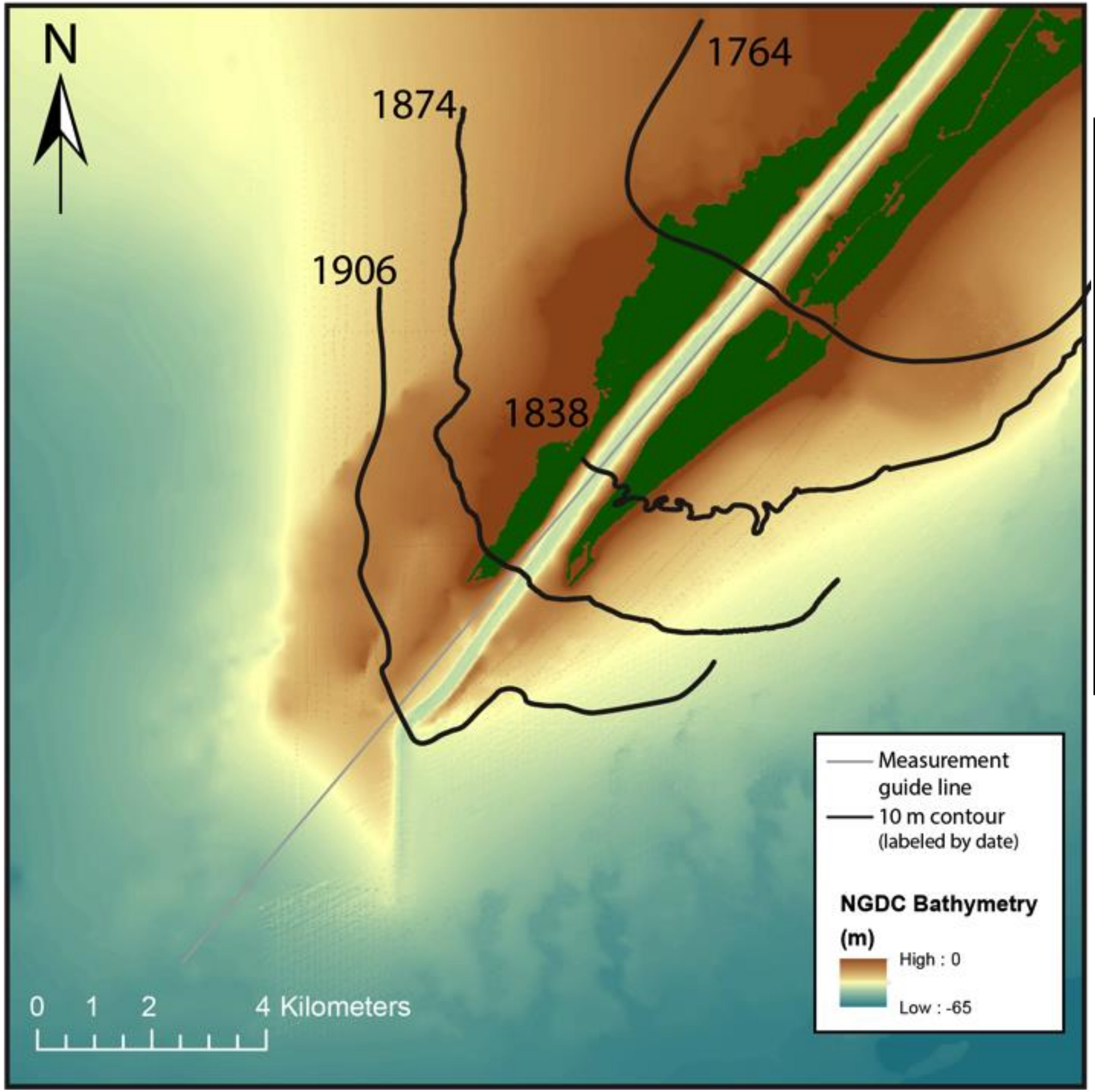


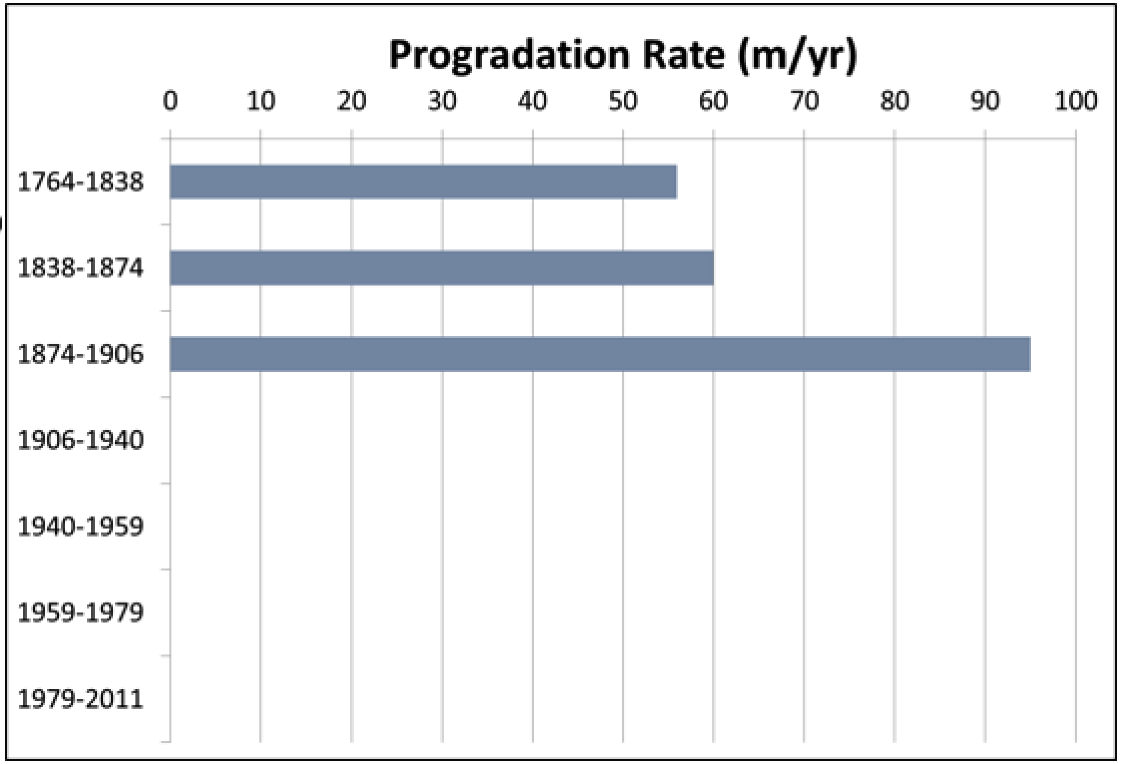
Southwest Pass Progradation





Southwest Pass Progradation





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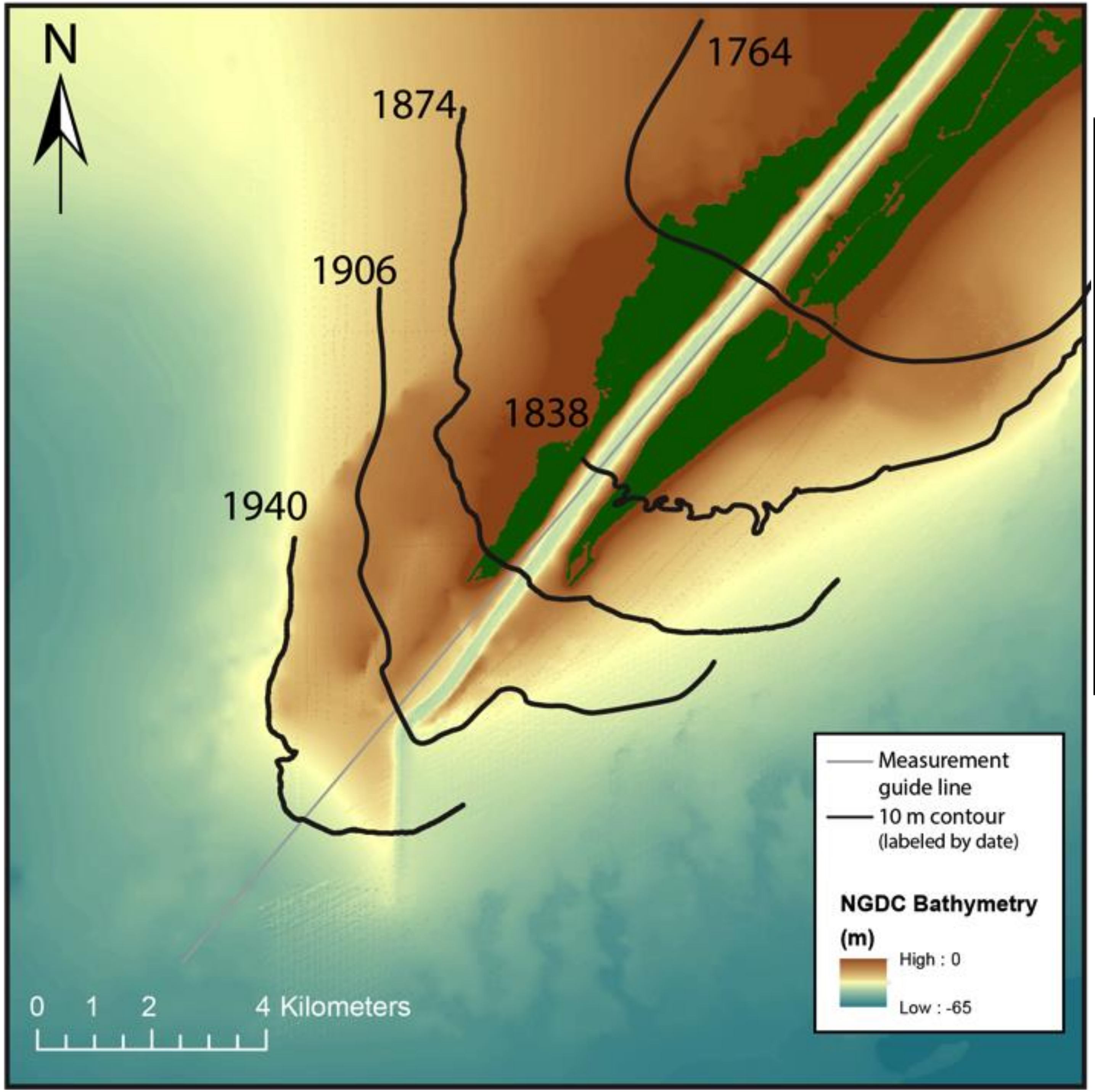

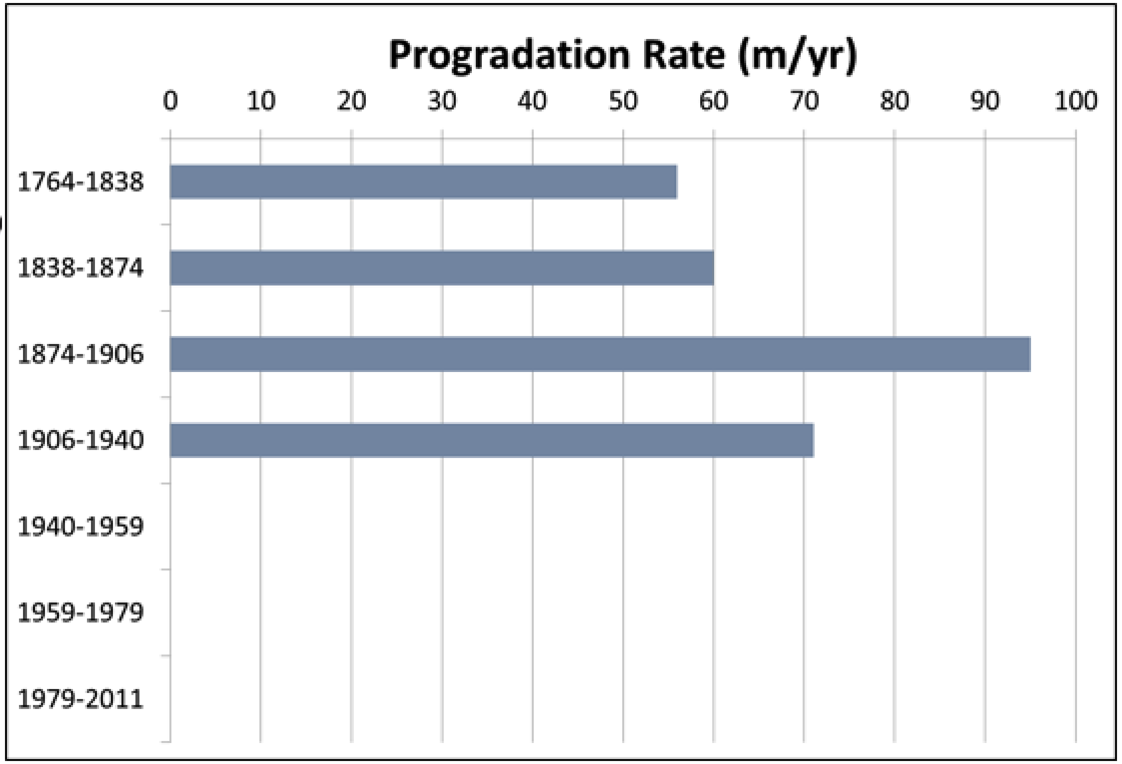

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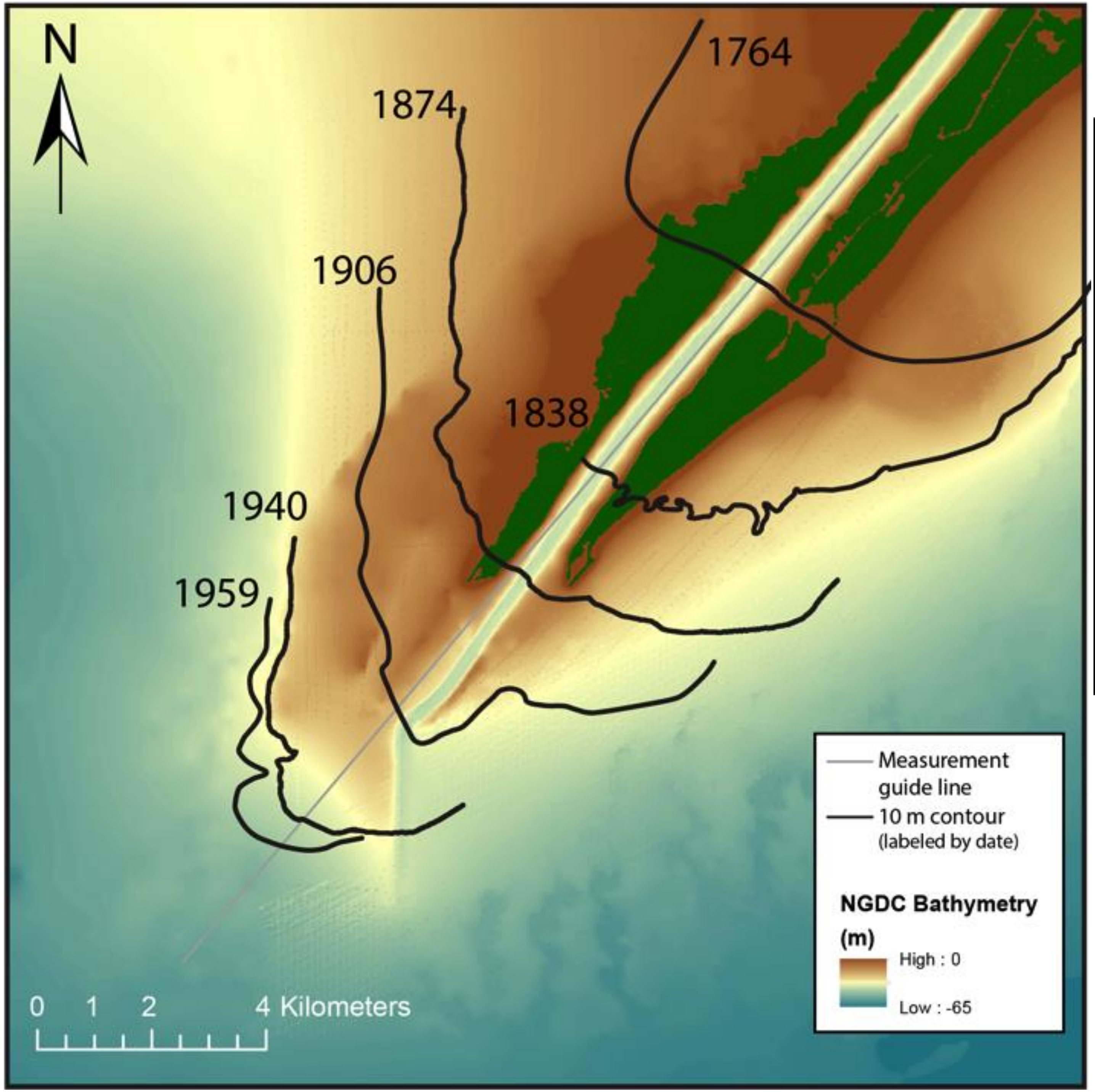
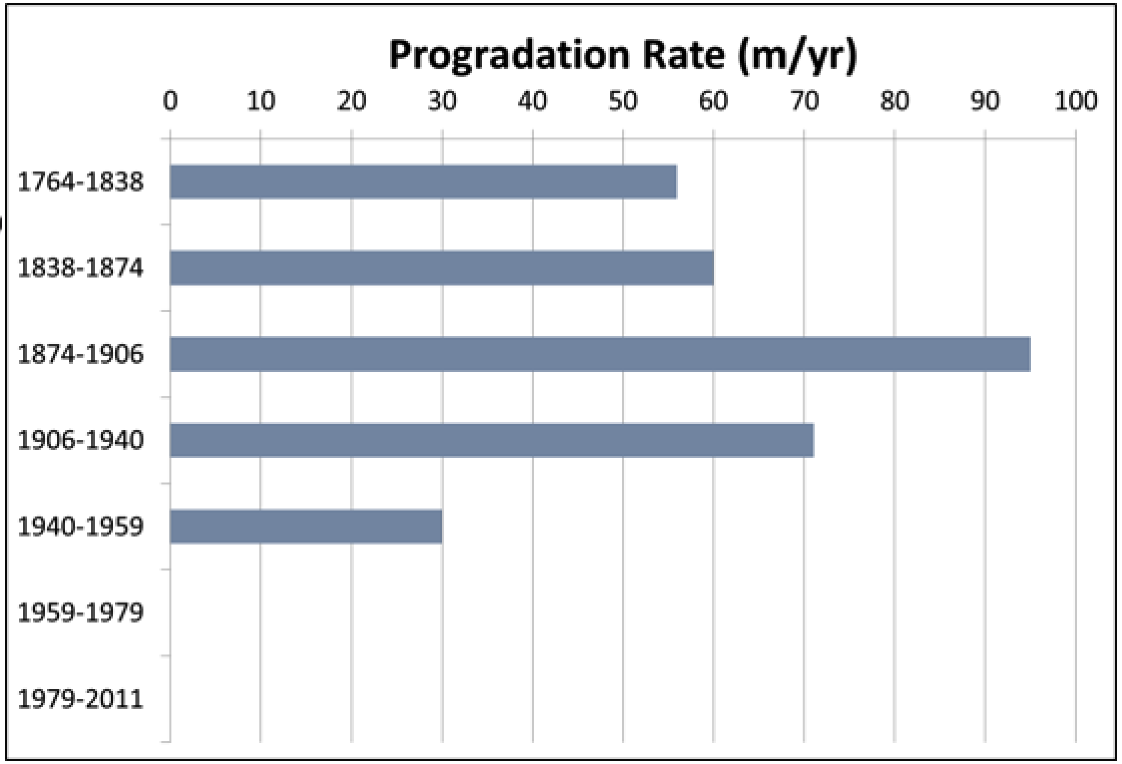
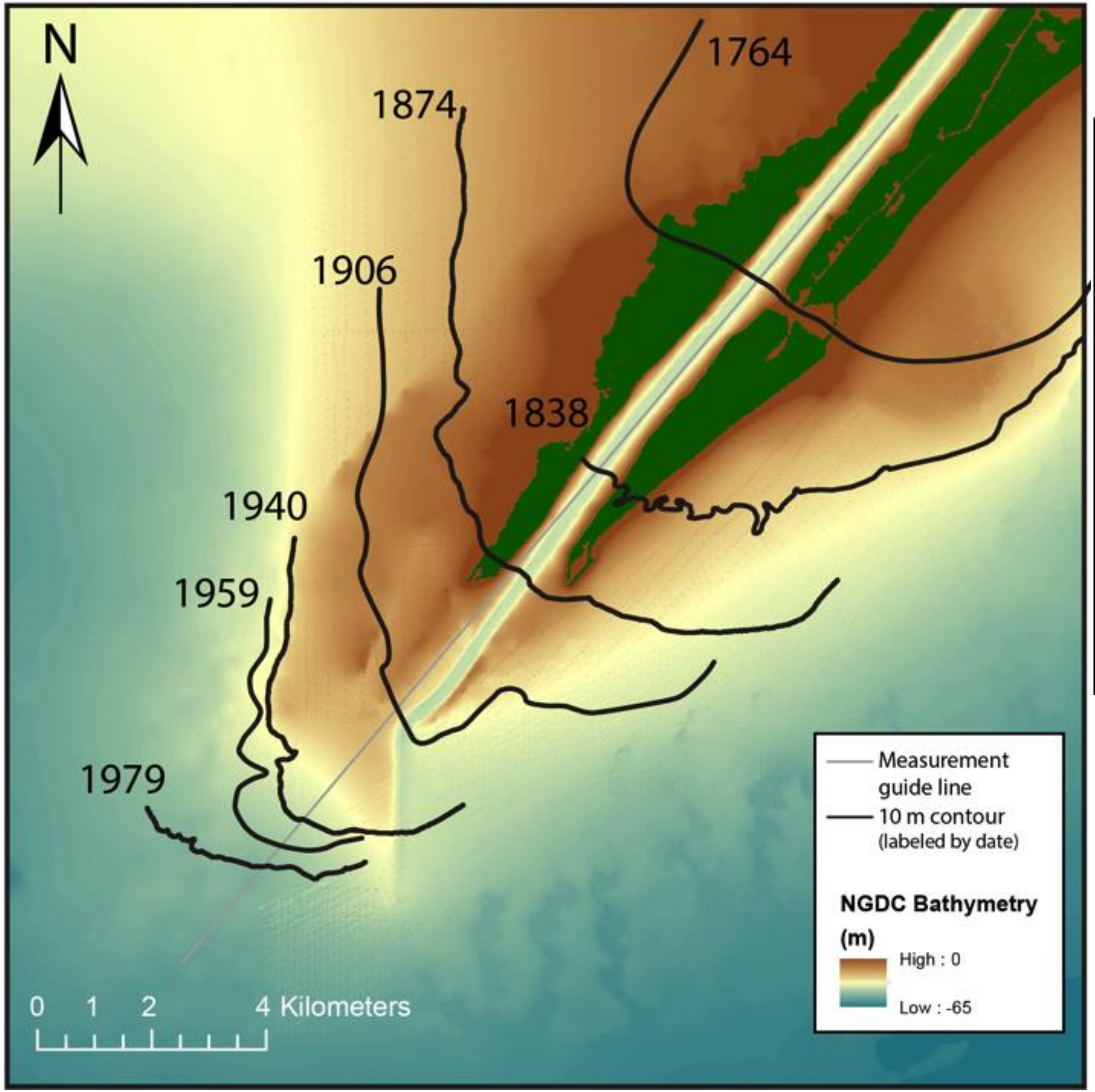
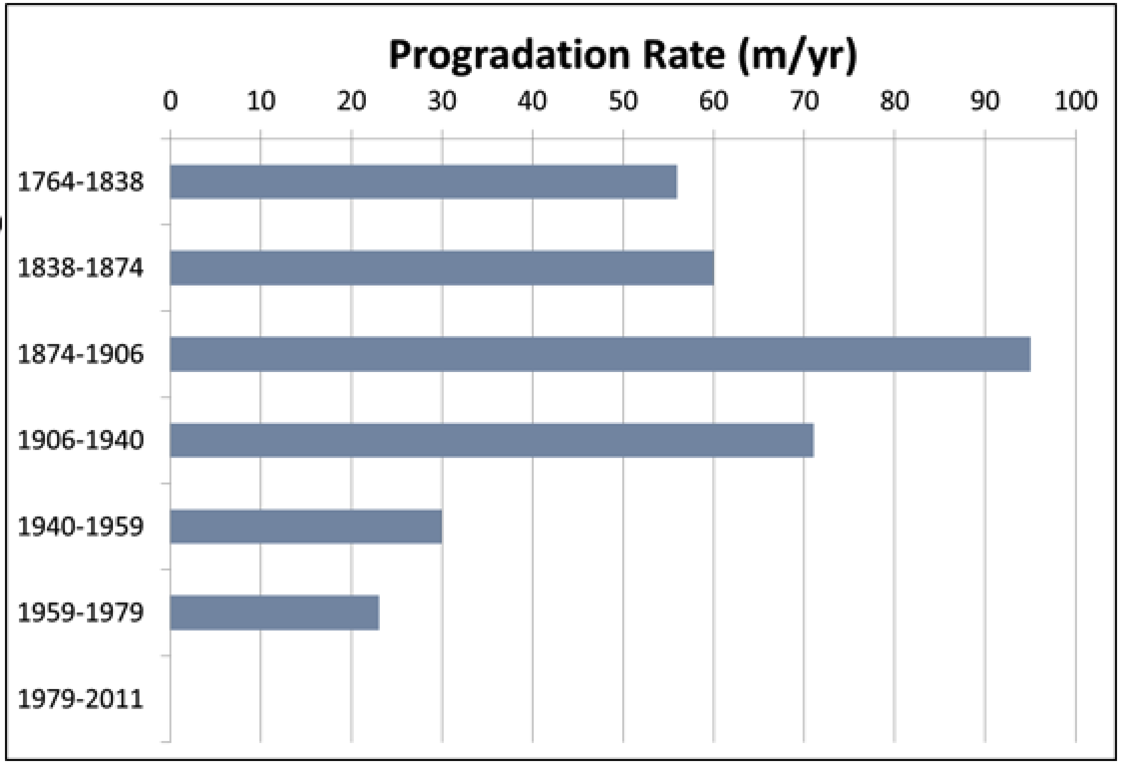


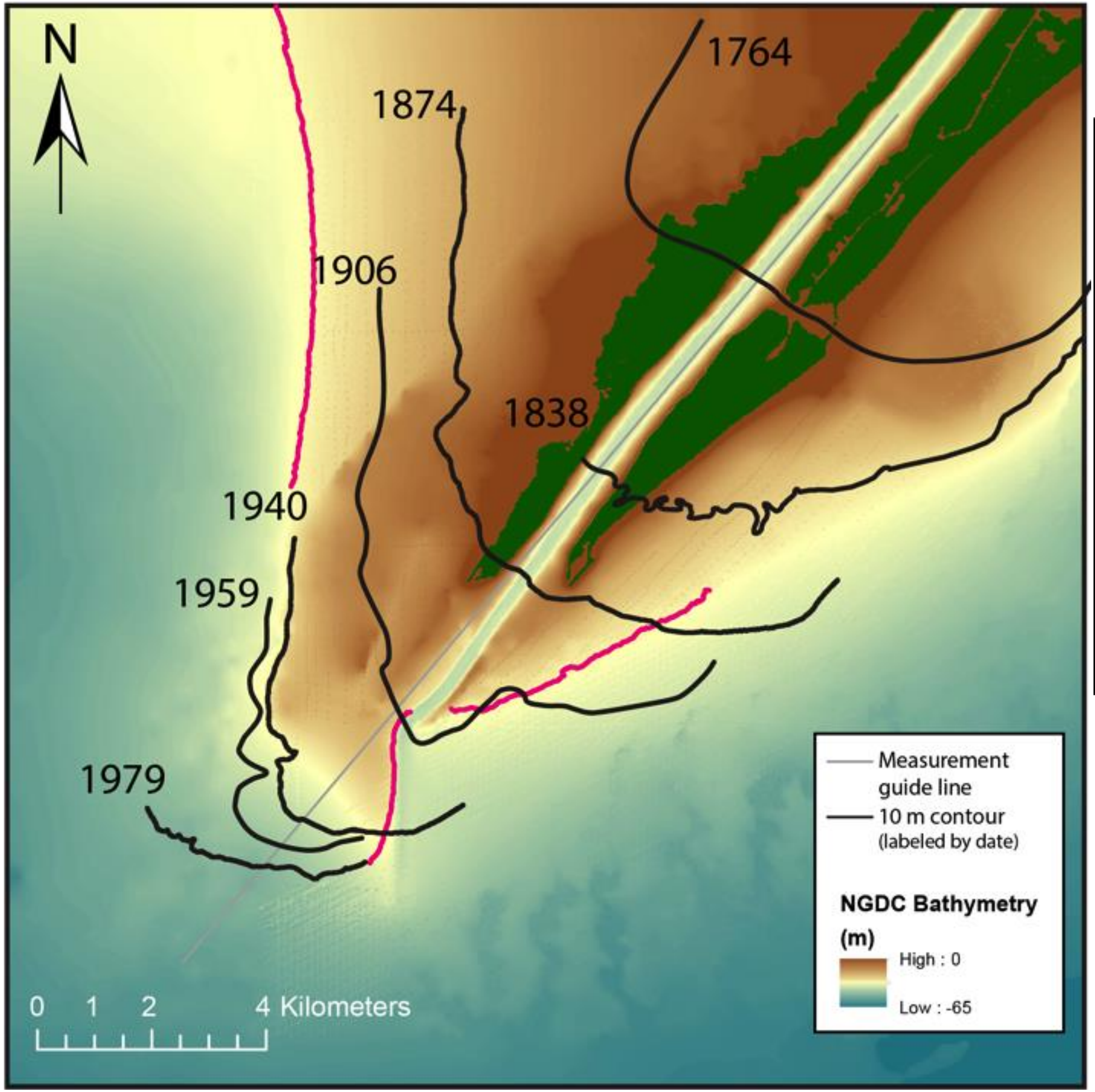


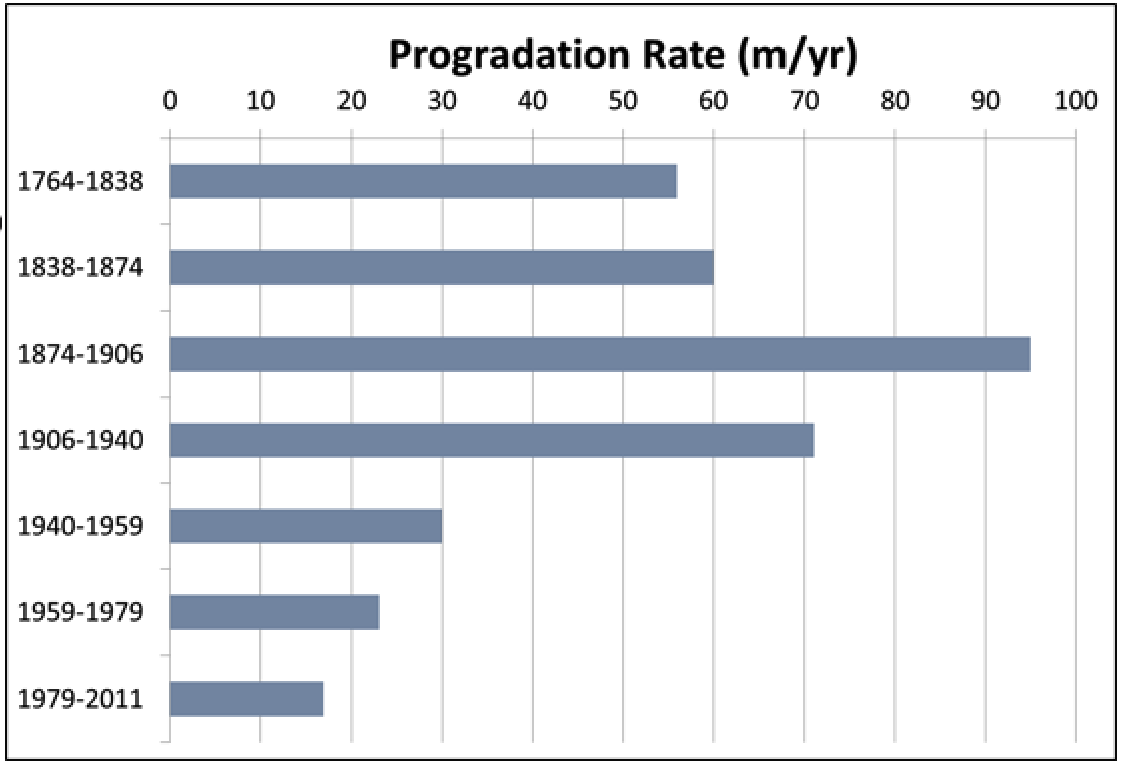


Southwest Pass Progradation

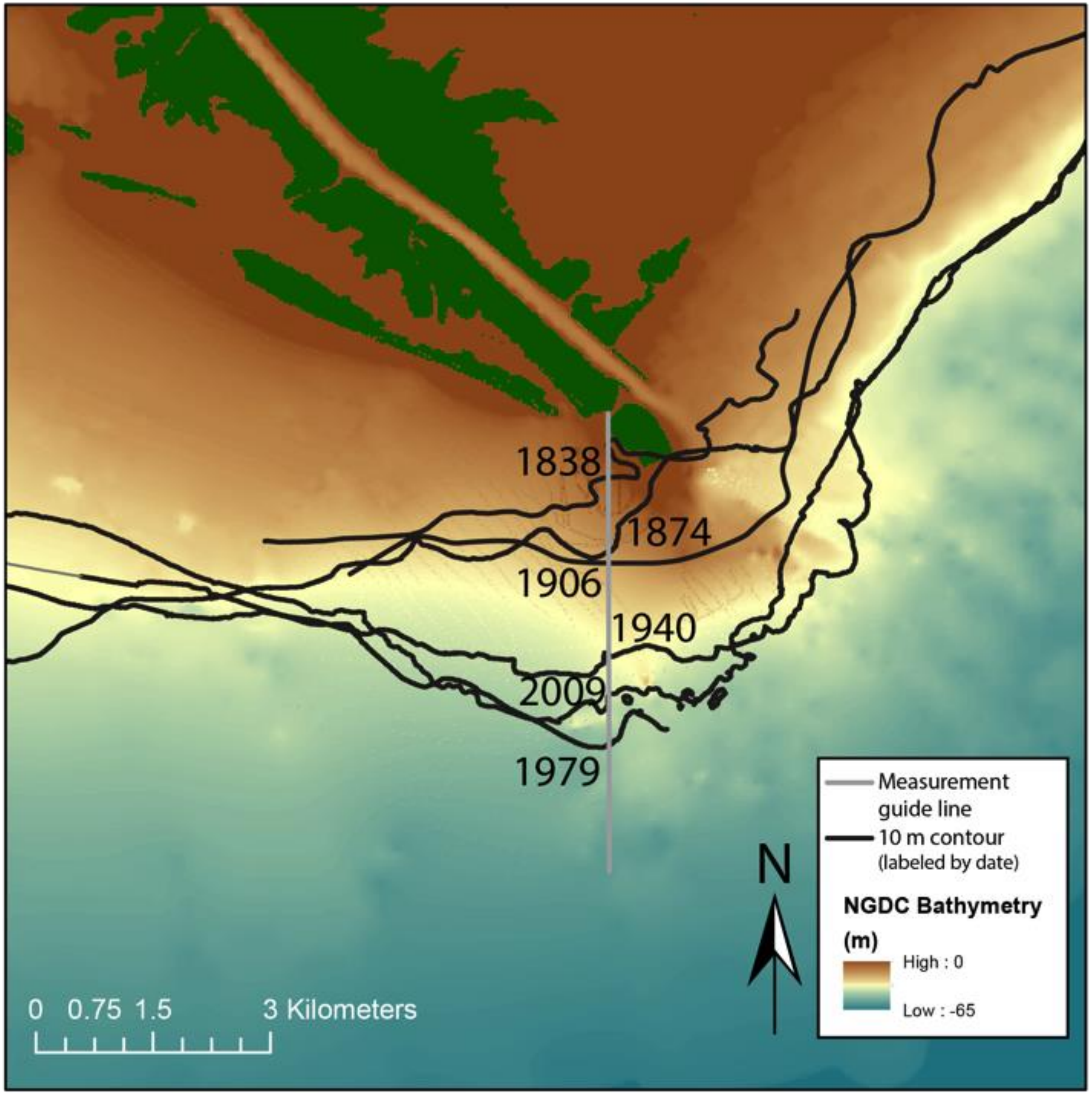


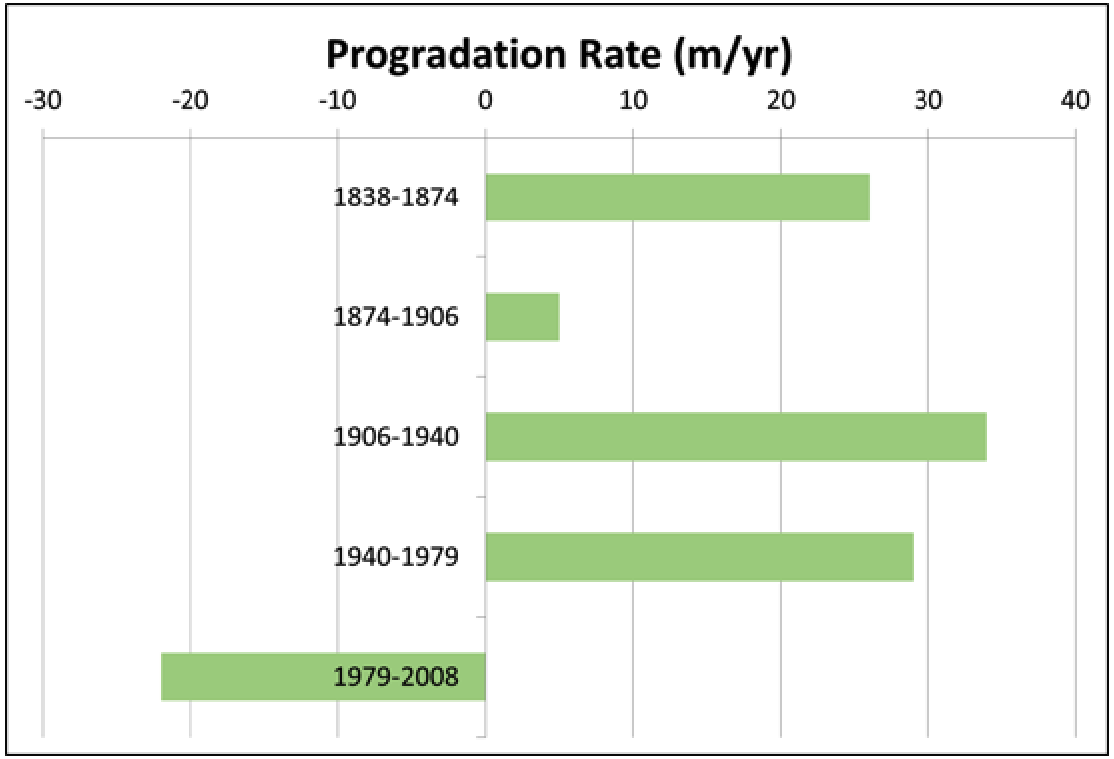
Southwest Pass Progradation



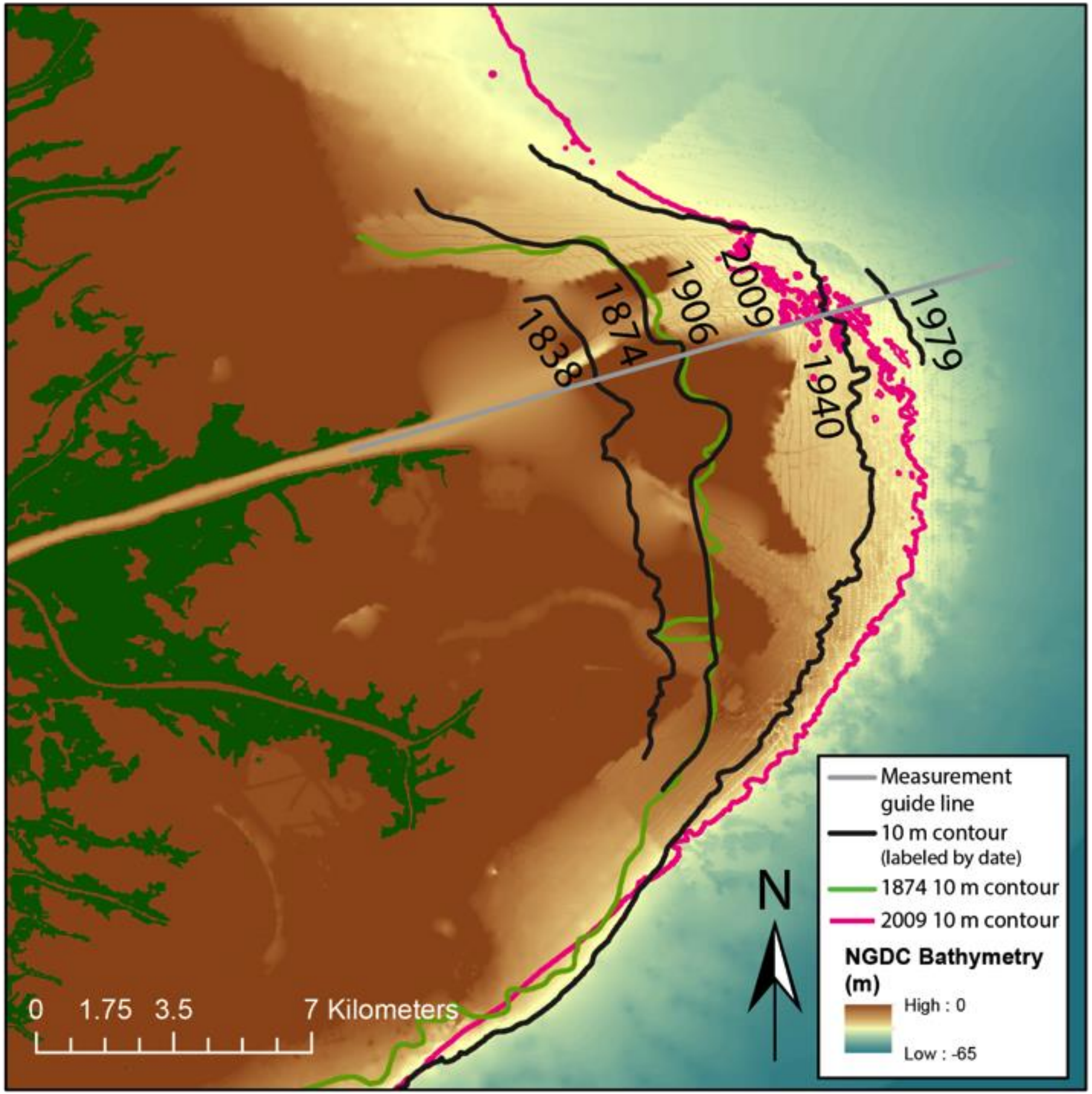


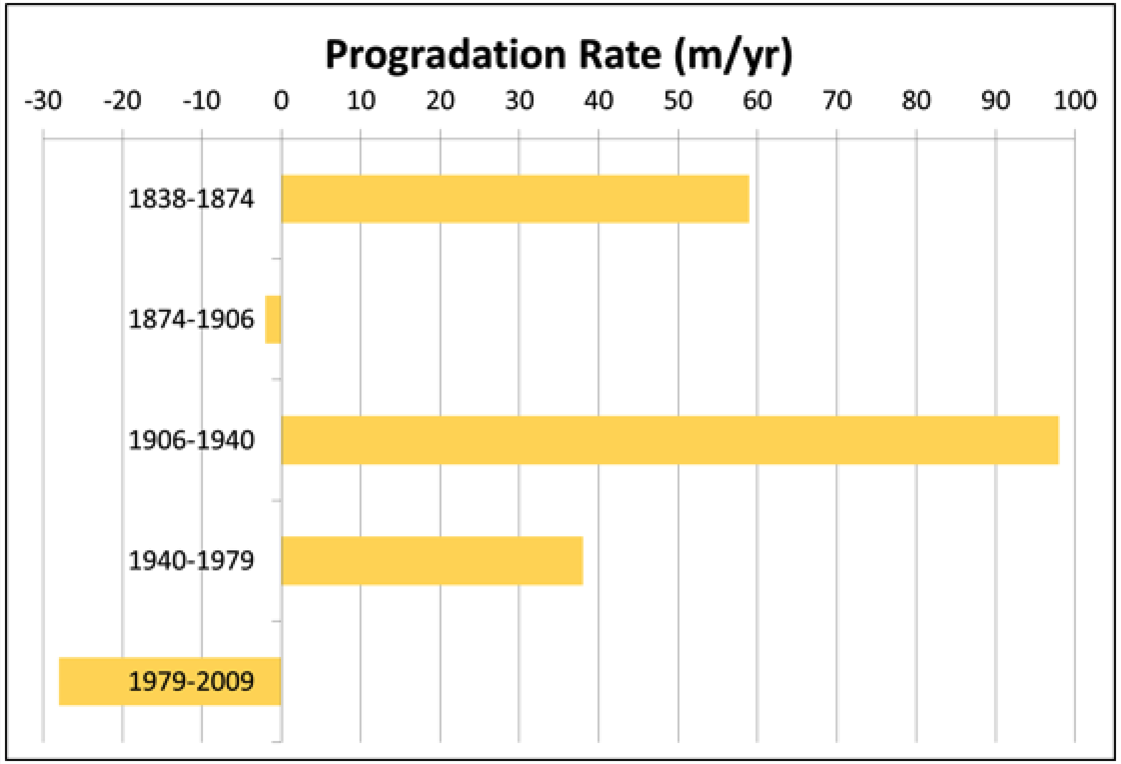
South Pass Progradation

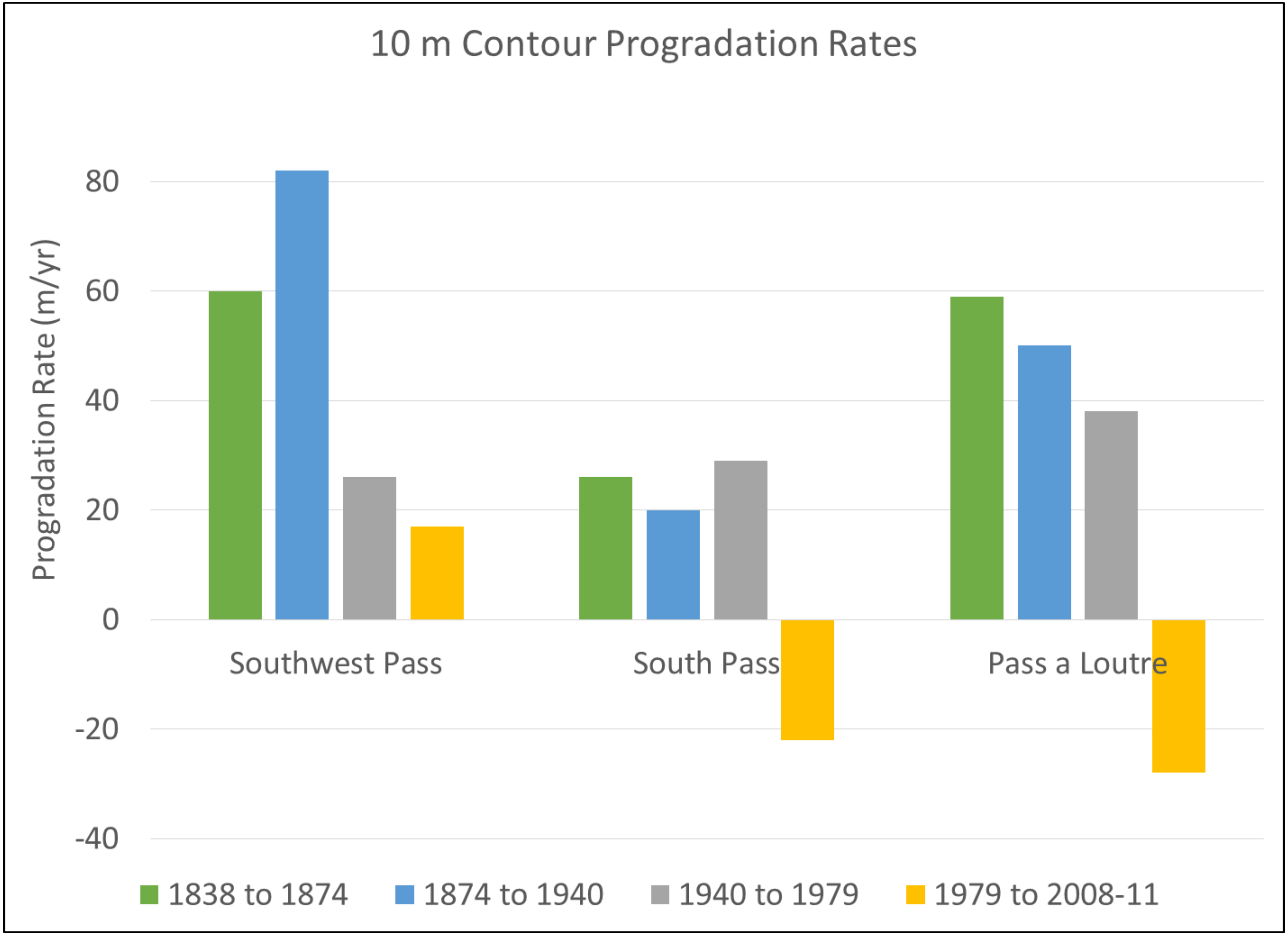




Pass a Loutre Progradation





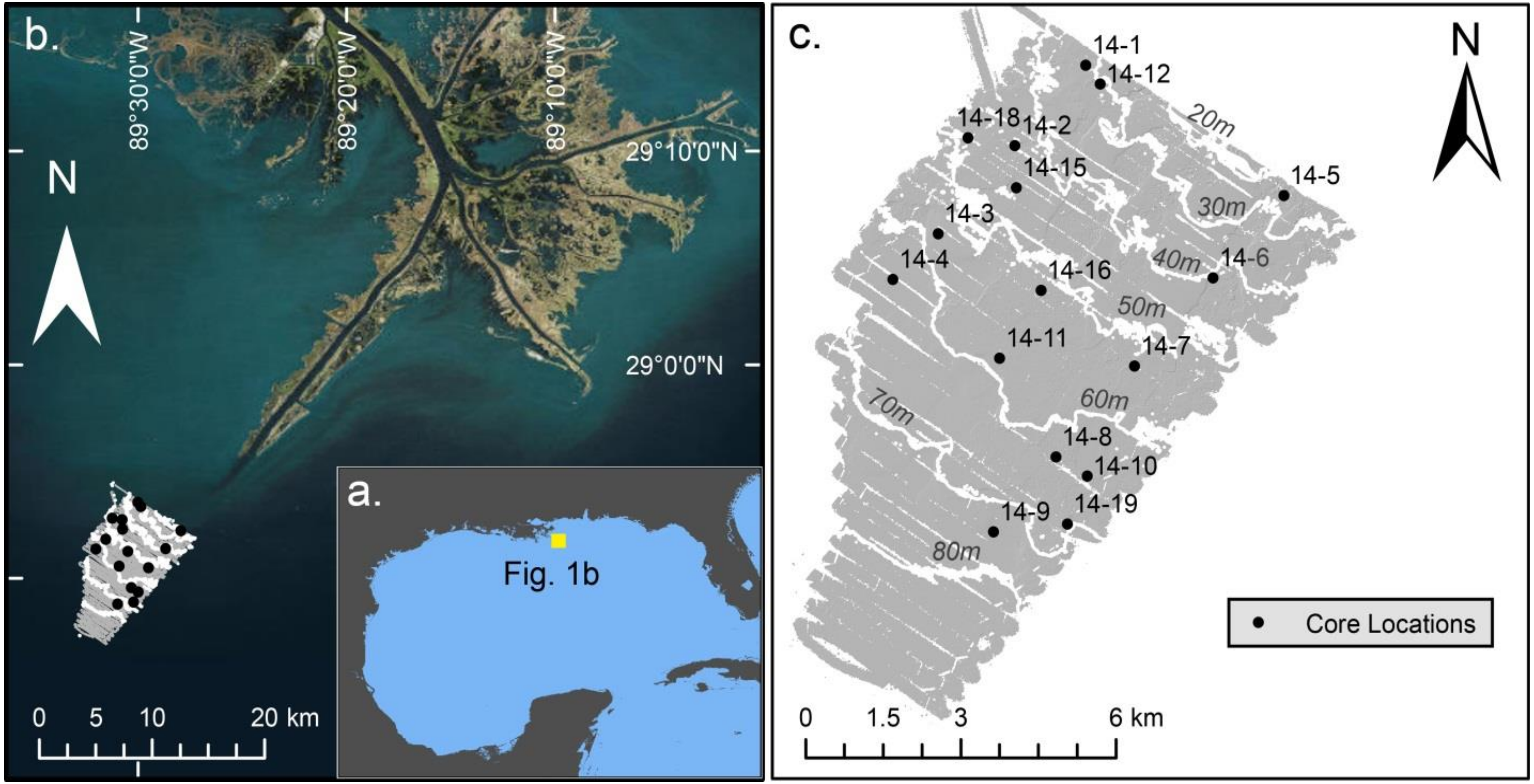


10 m Contour Progradation Rates
Progradation Rate (m/yr)
80
60
40
20
0
-20
-40
Southwest Pass
South Pass
Pass a Loutre
1838 to 1874
1874 to 1940
1940 to 1979
1979 to 2008-11

Pilot Studies 2014 and 2017

- Focus on hot spots for seabed dynamics, off MR passes
- 2014, off Southwest Pass only; Results published in Geology, Geo-marine Letters
- 2017: collaboration with USGS
- Southwest Pass, South Pass, Pass a Loutre; analyses ongoing

2014 Seabed Coring Study



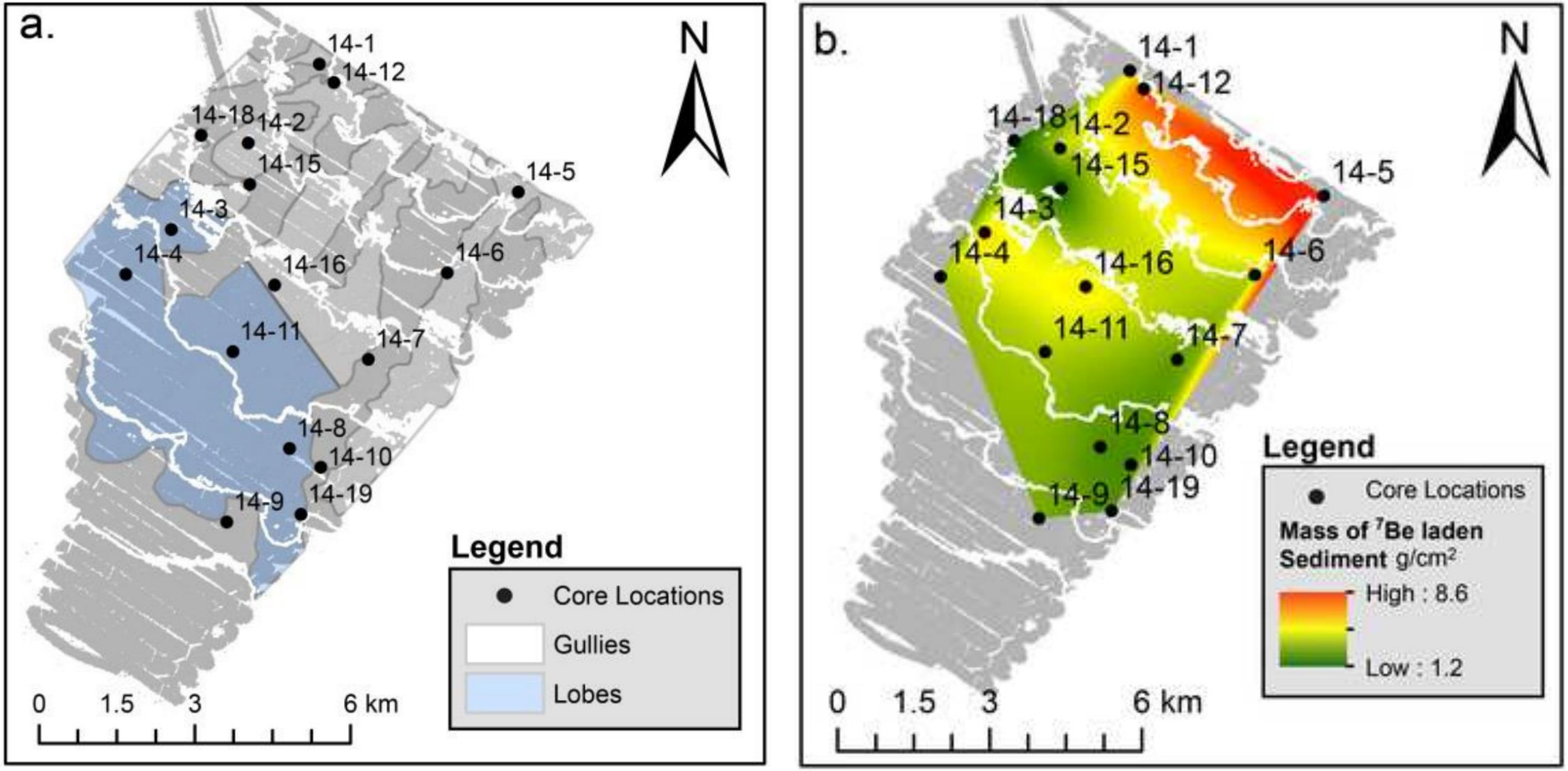
Keller et al. 2016,

Geo Marine Letters

Doi:

10.1007/s00367-016-0476-0

Depositional Environments and ^{7}Be Sediment Deposition



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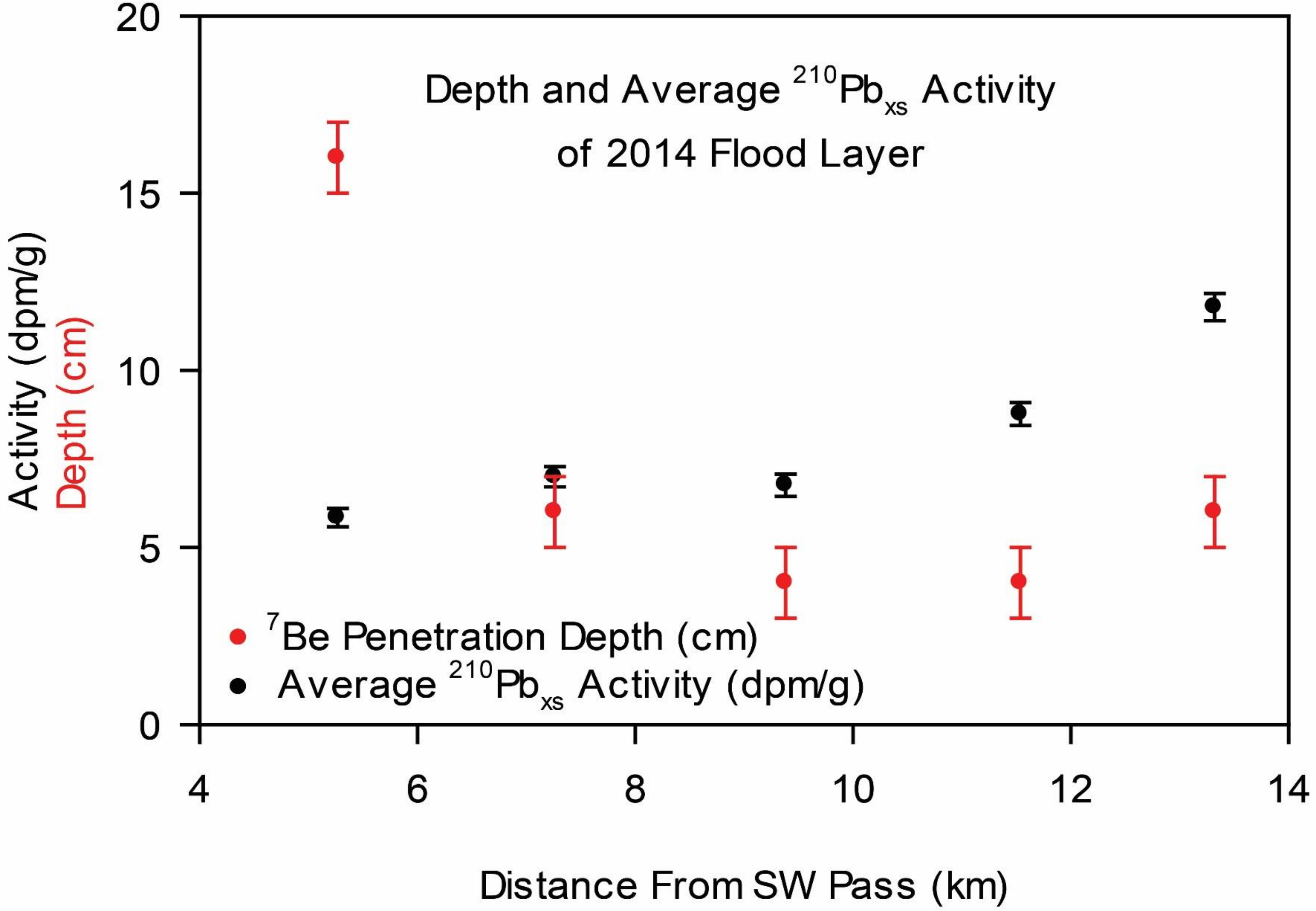
^{7}Be and ^{210}Pb versus distance from River Outlet

^{7}Be: river source

^{210}Pb: primarily marine source

Both scavenged by river sediment.

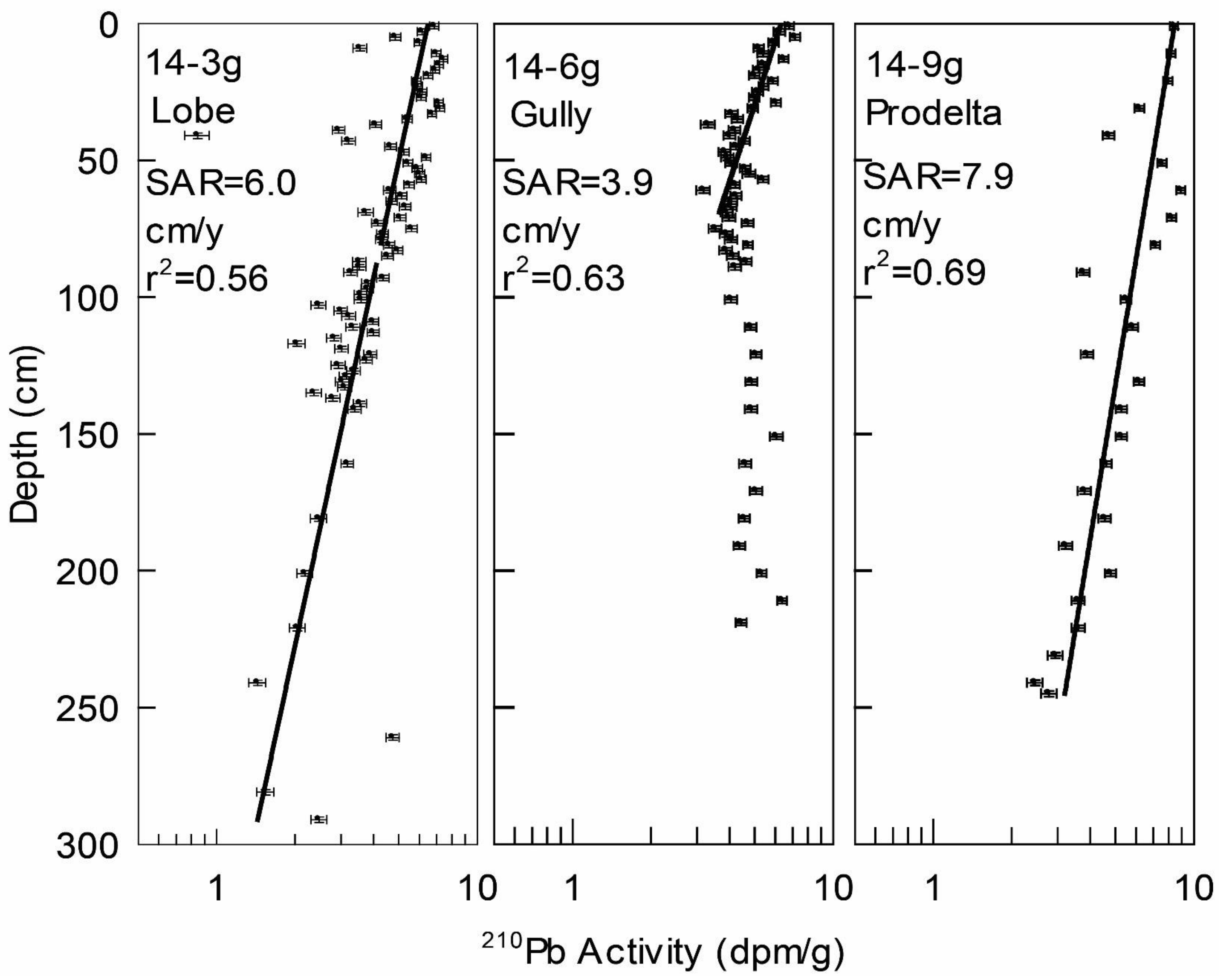
Documents role of river plume in seabed sedimentation



Profiles of ^{210}Pb in long cores

Profiles undulate over cm scales due to scavenging by flood sediments

Over decimeter scales, compare relatively steady activity decline with depth (lobe and prodelta) with abrupt change in gradient (gully core)



Geophysical study:

Comparison of three multibeam surveys

Southwest Pass, important location of

Submarine landslides

2005 (Walsh et al., 2006)

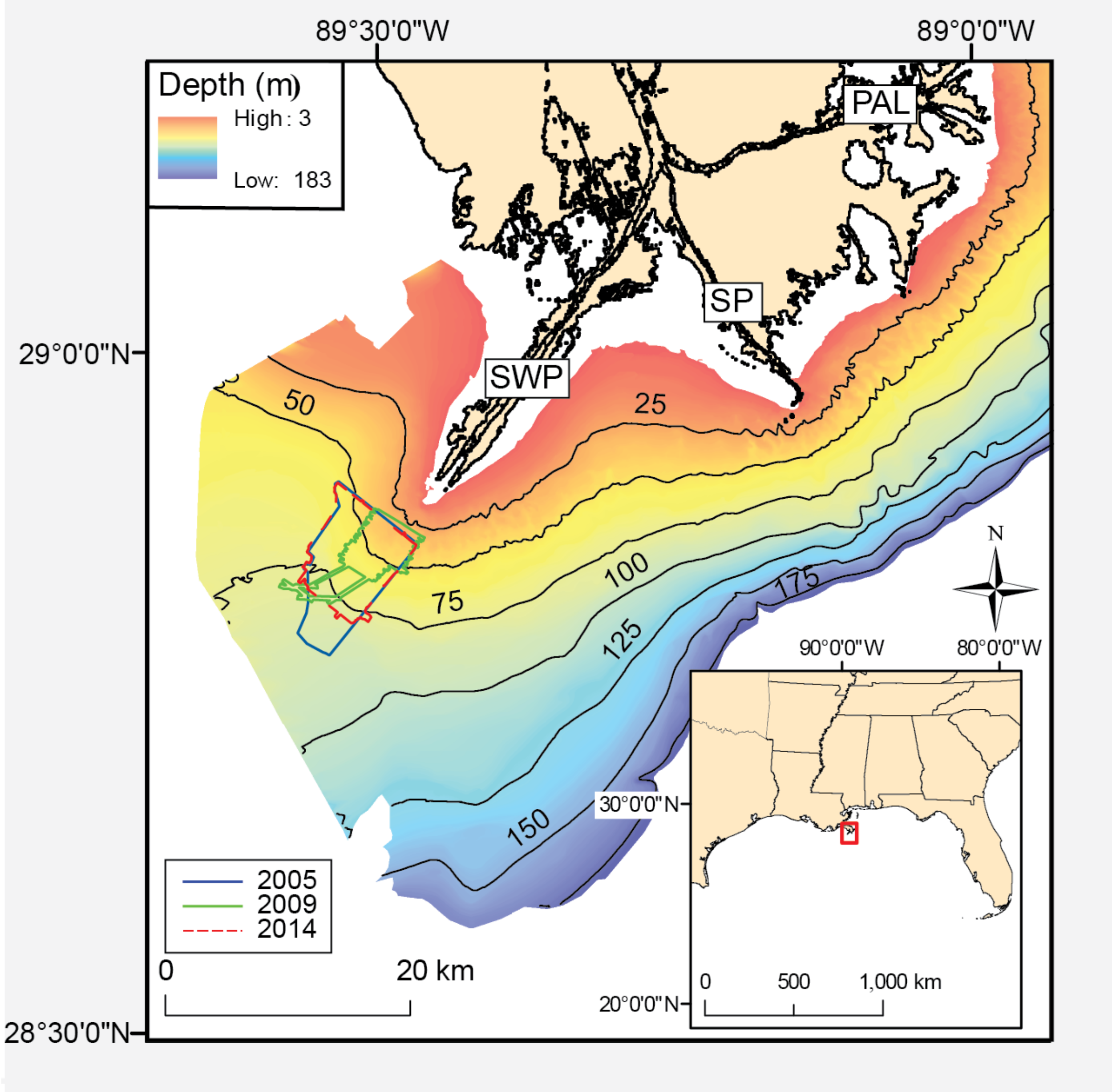
2009 (Fugro Marine Geoservices)

2014 (LSU)

No nearby hurricane strikes 2005-2016

Obelcz et al., 2017

Published in Geology



Difference of Depth Calculations

<u>Here: 2005-2009</u>

Primary Observations:

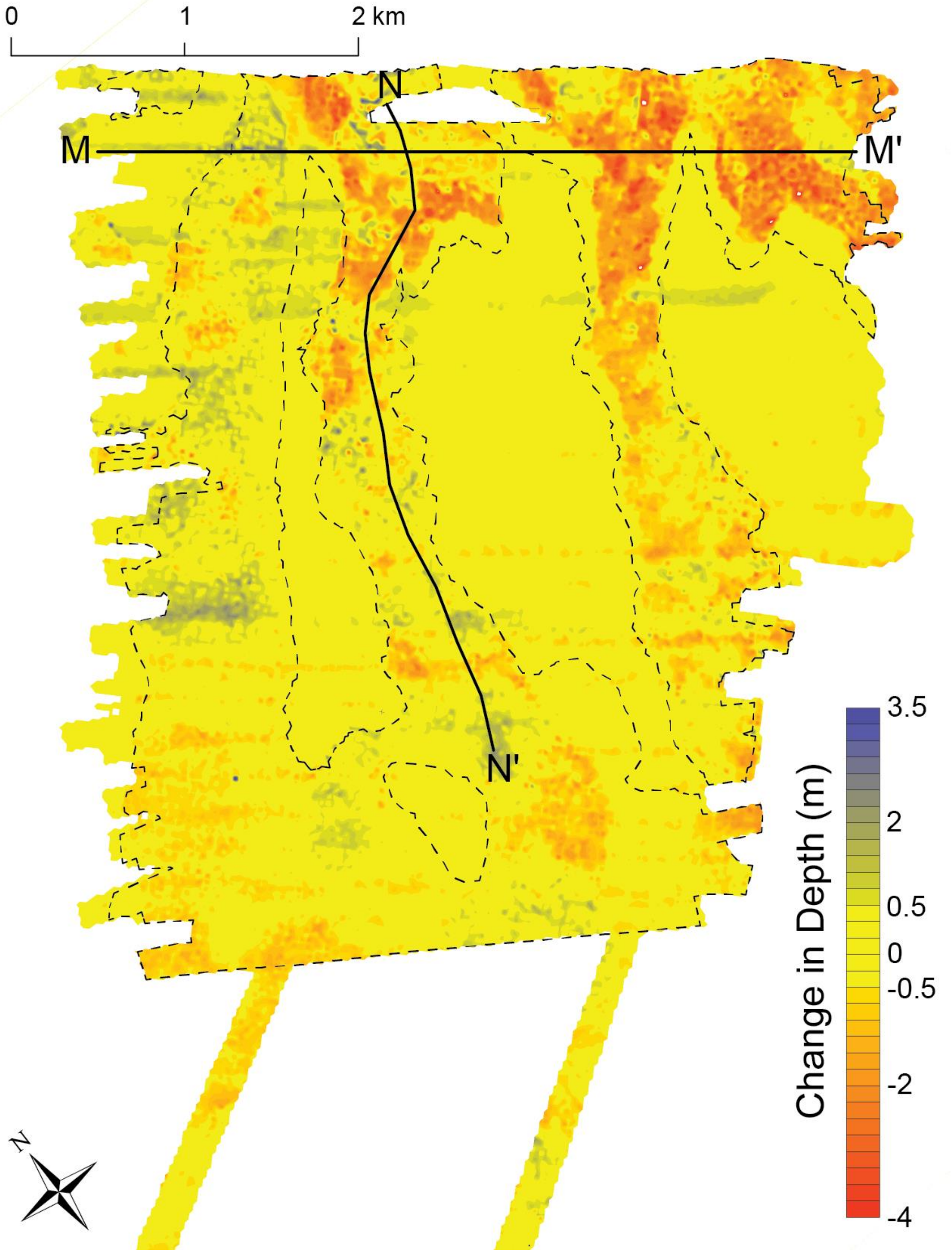
Gullies grow deeper 1 meter per year

Sediment lobes fed by gullies grow shallower 1 meter per year

Gully and lobe with does not change

Seabed bathymetric changes exceed sediment deposition rates

Changes occur without forcing from large hurricanes



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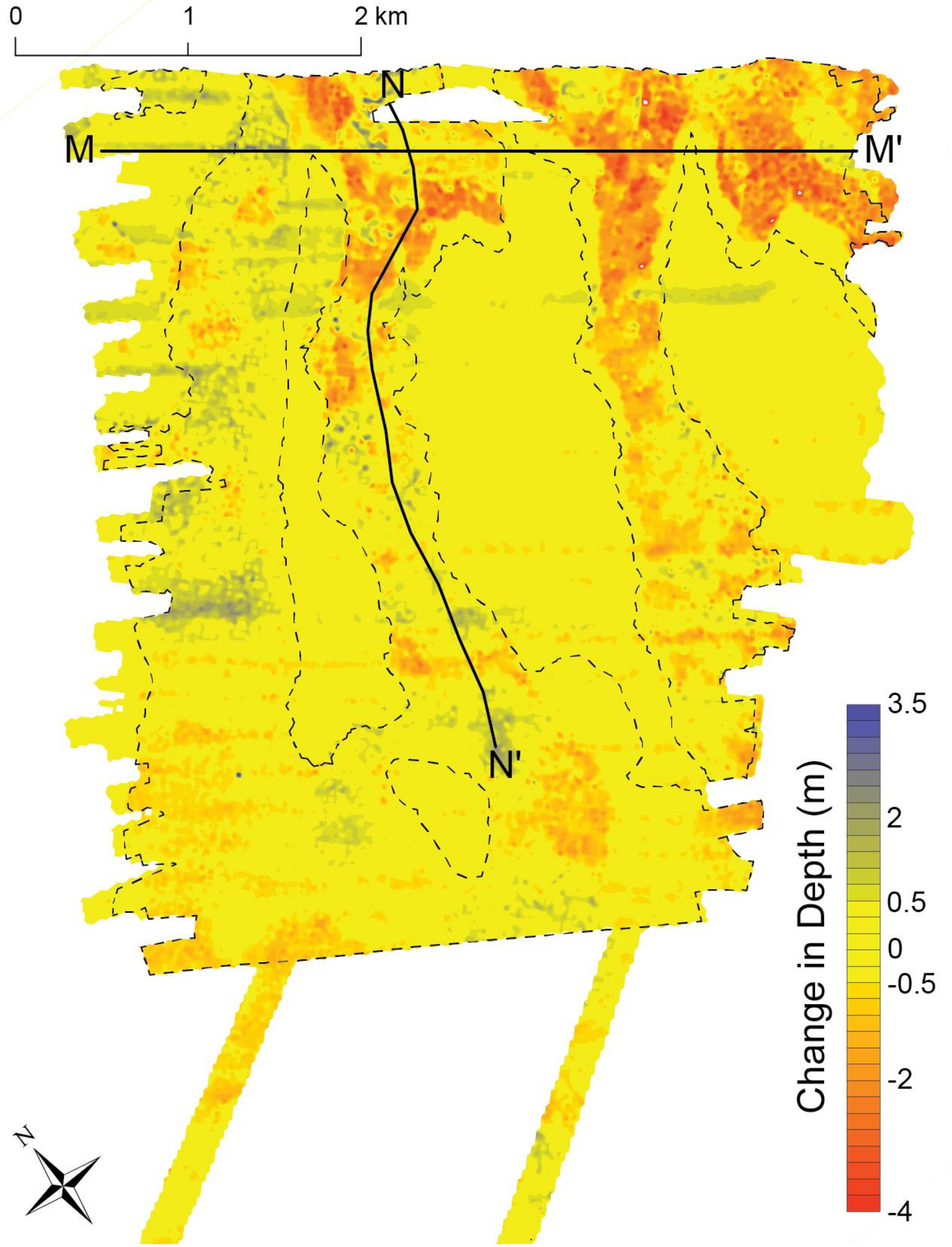
Difference of Depth Calculations

<u>Here: 2005-2009</u>

Modeling of non-linear annual wave climate suggests that *<u>routine winter storm waves</u>* can force observed motion

Sediment-core study to 3 m sediment depth shows no gravity flows within the last 10 years.

SO, the detachment plane for observed movement must be deeper than 3 m in the seabed.



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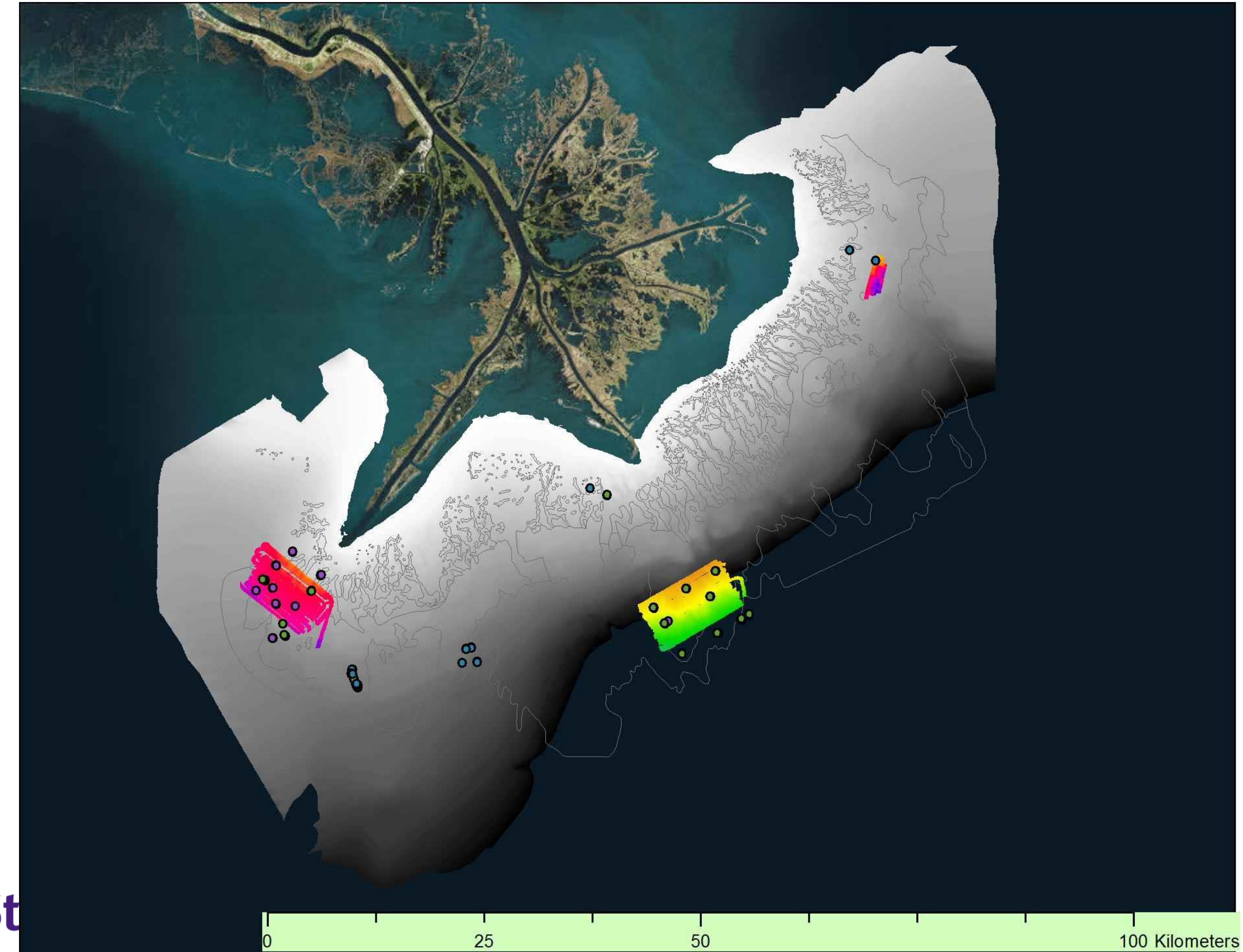
Pilot Study 2017

- R/V Point Sur
- USGS mapping to identify sampling targets
- 16 science crew, 24-h operations
- 134 sampling deployments over 7 days
- LSU, UNO, SDSU, University of Bremen (Germany), NRL-Stennis

2017 Sampling

- Focus on small areas
- <10% of > 2000 km^2 study area
- Attempt to be sample representative seabed types, based on USGS mapping data



2017 Press Coverage

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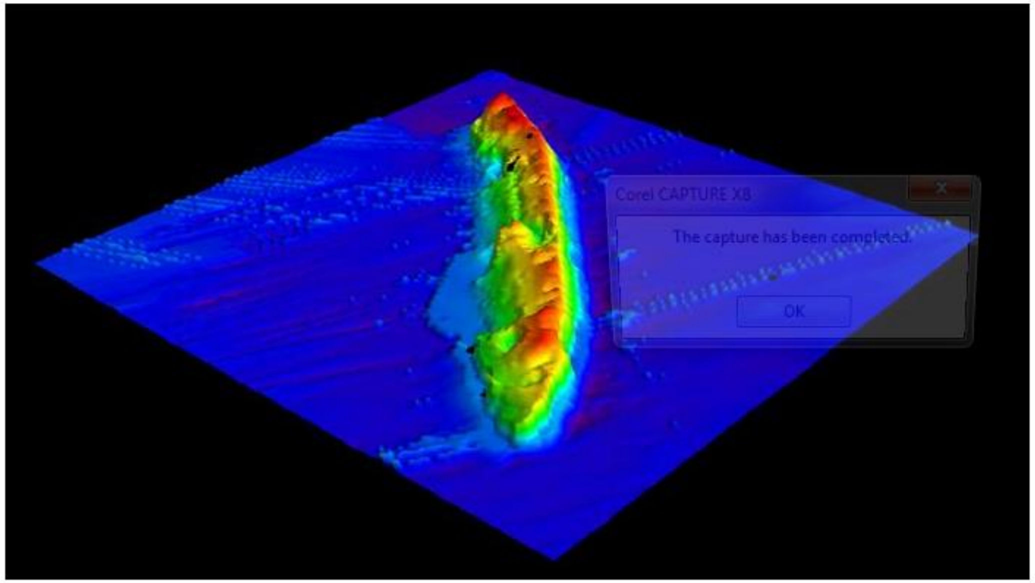

A sonar image of the wreck of the *Virginia*, an oil tanker that was torpedoed by a German submarine in the Gulf of Mexico during World War II. Jason Chaytor/USGS

The Germans torpedoed a ship during World War II. The wreck is now revealing secrets about underwater mudslides

By **Zahra Ahmad** | Aug. 21, 2017 , 10:34 AM

In 1942, in the midst of World War II, the oil tanker *Virginia* was anchored off the mouth of the

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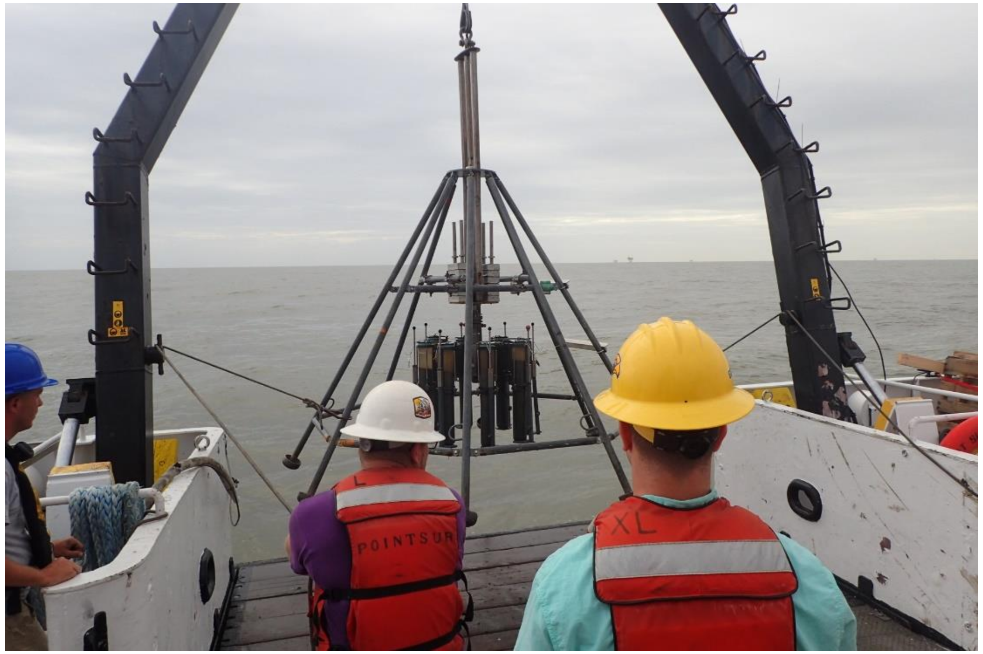
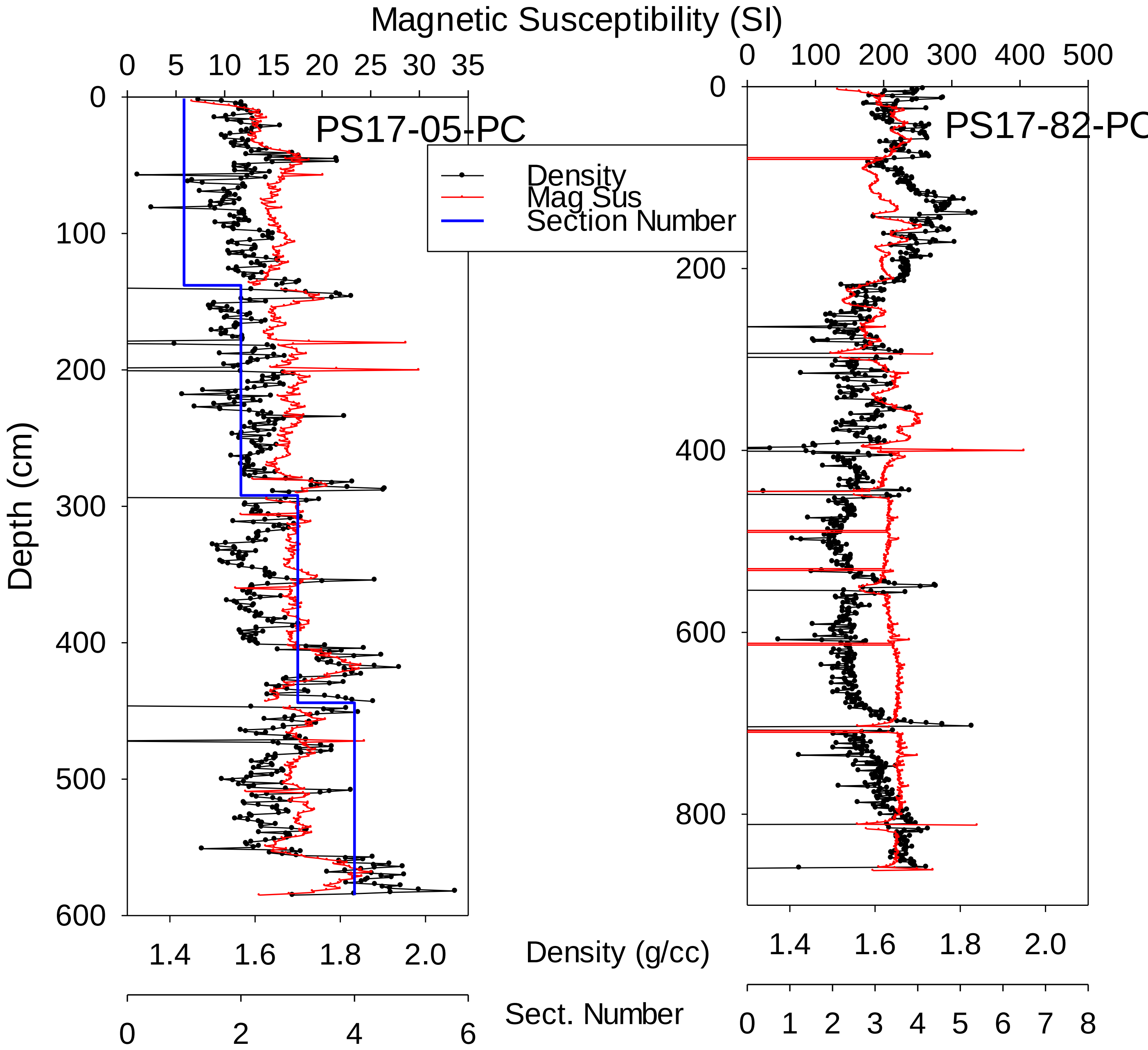
2017 Tools: Coring and Cone Penetrometer

- piston corer: direct sampling to ~9 m
- Ocean Instruments multicorer (sediment surface, 0-0.6 m)
- Free-fall cone penetrometer (seabed strength to 8 m)



Preliminary Logs of Physical Properties: near outlet versus deep water

- Up to ~9 m recovery, 31 stations
- Gaps in data from gas pockets
- Deeper water sediments have higher Magnetic Susceptibility
- Densities comparable
- Density generally controlled by consolidation state and grain size



Major Findings to Date

The subaqueous delta is diminishing in volume, due to declining sediment load to river outlets. Land loss has been recognized for decades, but ours is the first documentation of submarine changes.

During periods without major hurricanes, sediment transport in the upper 3 m of seabed is controlled by plume delivery, not mass transport. This is the first geochronological measurement of short-term sediment dynamics in gullies, prodelta, and sediment lobes

Also during periods without major hurricanes, sediment mass transport is occurring along failure planes in the seabed below 3 m sediment depth. Only mass transport due to major hurricanes has been previously documented conclusively.

We hope to expand to wider regions of the delta in the next few years.

Limits to Existing Data and Knowledge

Huge area, limited data, no regional studies since 1970’s

Tools for present study do not allow us to study the most critical processes, where the action is occurring (limited by available resources, not existing technology)

For example: major submarine landslides can excavate seabed to > 30 m subbottom depth, but our physical sampling is presently limited to < 10 m subbottom depth

We do not know exactly when, why, how fast, or how deeply sediments move during active sliding

Role of biogenic gas production and influence on submarine landslides likely critical, but knowledge is based on a handful of relatively primitive studies from the 1970’s and 1980’s (compared to modern technologies)

What Next?

Comprehensive Mapping and sampling study, seabed and subsurface, to subbottom depths that encompass geologically active regions

Track flow activity using seabed instrumentation

Study role of gas in triggering submarine landslides: in-situ measurements, recovering pressurized cores

Develop new generation of modeling tools that allow integration of physical and biogeochemical processes to test hypotheses, explore field data

Requires substantial expansion of research team, capabilities

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