

The Role of USGS Science in Offshore Oil and Gas Safety

***Ocean Energy Safety Advisory Committee,
July 13-14, 2011, New Orleans***

**Stephen Hickman, Research Scientist
U.S. Geological Survey, Menlo Park, CA**

With thanks to: Marcia McNutt, David Applegate, Ione Taylor, Anne Kinsinger, Martha Garcia, Donna Meyers, Brenda Pierce, Sonya Jones, Dawn Lavoie, John Haines, Jon Kolak, Herb Buxton, Gary Machlis, Tim Collett, Carolyn Ruppel, Susan Finger, Homa Lee, Uri ten Brink, Jamie Conrad, Jennifer Miselis, Abby Sallenger, Nathaniel Plant, Robert Rosenbauer, Lisa Osterman, Paul Hsieh, Walter Mooney, Phil Nelson, Cathy Enomoto and Mark Sogge

Talk Outline

- The Nature of USGS Science
- USGS Response to the Deepwater Horizon Spill
- Other USGS Activities and Assessments
- Conclusions

The Nature of USGS Science

USGS serves the Nation as an independent research agency, providing scientific understanding of earth, water and biological resource conditions, issues and hazards.

USGS supports the science needs of all other bureaus of Department of the Interior, as well as other Federal, State and Local agencies.

With no regulatory or land-management responsibilities, the USGS has developed a reputation for objective, unbiased science.

USGS leverages its resources and expertise in partnership with more than 2,000 government and tribal agencies, the academic community, NGOs and the private sector.



Talk Outline

- The Nature of USGS Science
- USGS Response to the Deepwater Horizon Spill
- Other USGS Activities and Assessments
- Conclusions

USGS Efforts Related to Gulf Oil Spill



Flow Rate Technical Group

Well Integrity Team

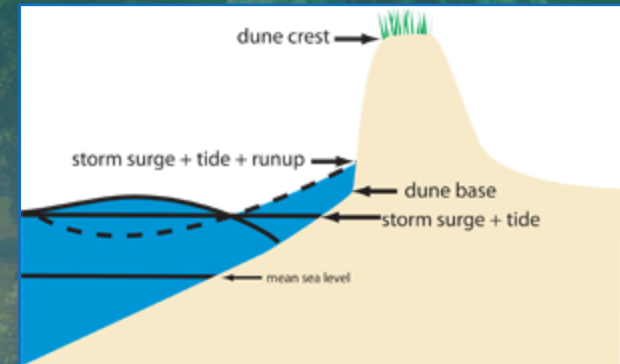
Well Kill and Cementing Team

Residual Oil Assessment Team

Environmental Incident Science Team

Geospatial Information Response Team

Natural Resources Damage Assessment Team

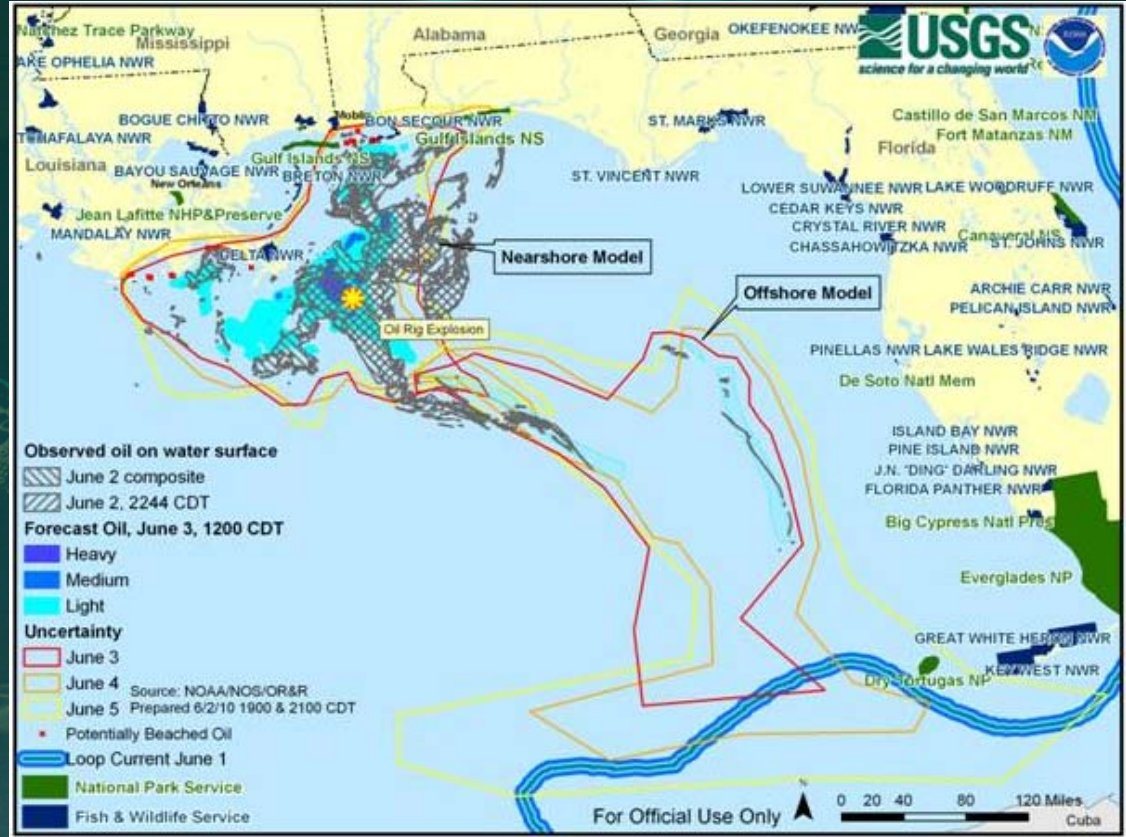


Geospatial Information Response Team

DOI had a huge stake:

- Responsible for managing land and resources on the OCS, where incident occurred.
- ~45 parks and refuges along the coastline.
- DOI manages ~27% of the land along Gulf coast
- Natural laboratories for ecosystem impact.

Oil came close to being carried by Gulf Loop current past Florida Keys.



June 3: Three-Day Projected Oil Movement Forecast

Other GIRT Contributions Included:

- Coordinated distribution of remote sensing imagery, for first response community, NRDA and FRTG.
- Developed database of sampling sites accessed by wide community of users through the Internet.

Lessons Learned from the 1989 Exxon Valdez Oil Spill

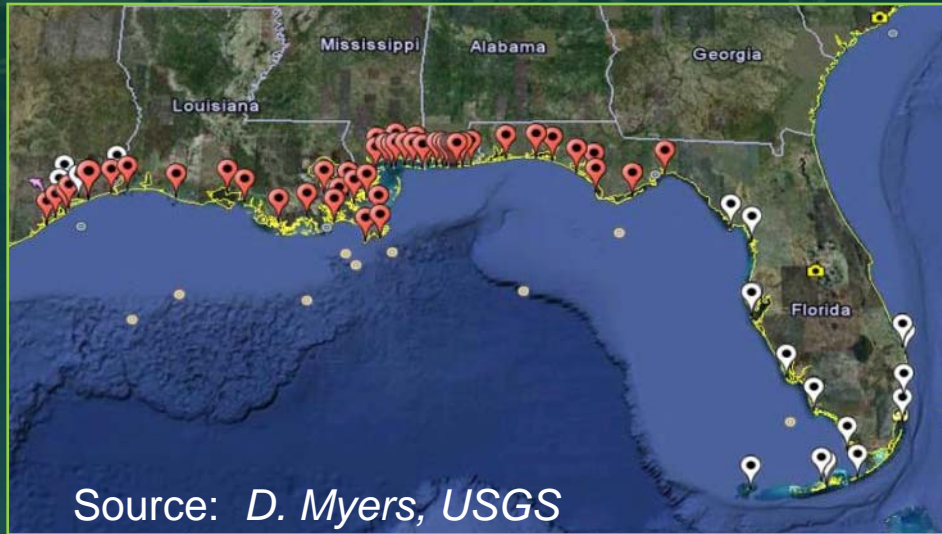


- Think long term regarding impacts and recovery (*1-2 decades*)
- Consider both offshore marine and coastal ecosystems and multiple levels of the food chain
- **Pre-spill data critical for assessing injury to resources and recovery**
- Natural variation in marine and coastal ecosystems will confound understanding of recovery



See USGS Circular 1370, Appendix D: *The Exxon Valdez Oil Spill Experience: Lessons Learned from a Cold-Water Spill in Sub-Arctic Waters*, <http://pubs.usgs.gov/circ/1370/>

Residual Oil Assessment

USGS assisted Coast Guard during *Operation Clean Sweep* by determining residual oil and contaminants remaining after initial clean-up of beaches and marshes, plus effects on water/sediment chemistry, microbes, sediment-dwelling invertebrates and aquatic organisms (see *OSAT reports* at <http://RestoreTheGulf.gov>).



USGS collected & analyzed water, tar-ball and sediment samples at or near Fish and Wildlife Service refuges, National Seashores or State Parks.

-  Locations sampled before *and* after oil made landfall (49)
-  Locations sampled before oil made landfall (70)

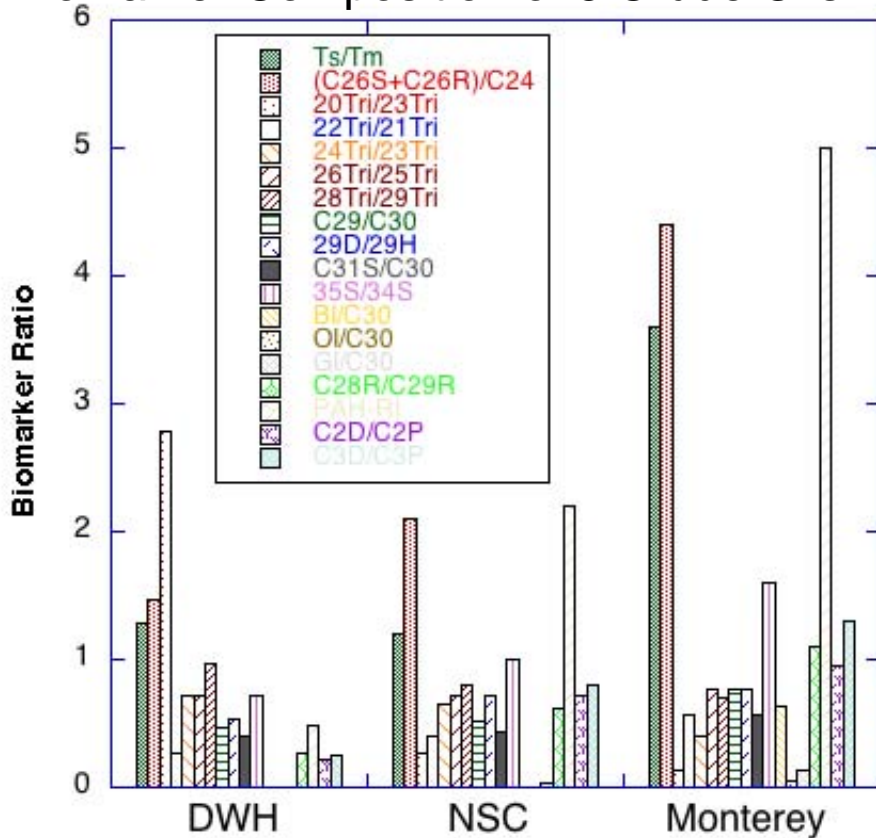


- USGS also provided coastal vegetation photo surveys before landfall, and
- Oversaw remote sensing and production of maps and GIS overlays showing Trust Resources, coastal ecosystems and shoreline conditions.

USGS Oil Fingerprinting



Biomarker Composition of 3 Crude Oils



DWH – Deep Water Horizon
NSC – North Slope Crude
Monterey – Monterey Formation

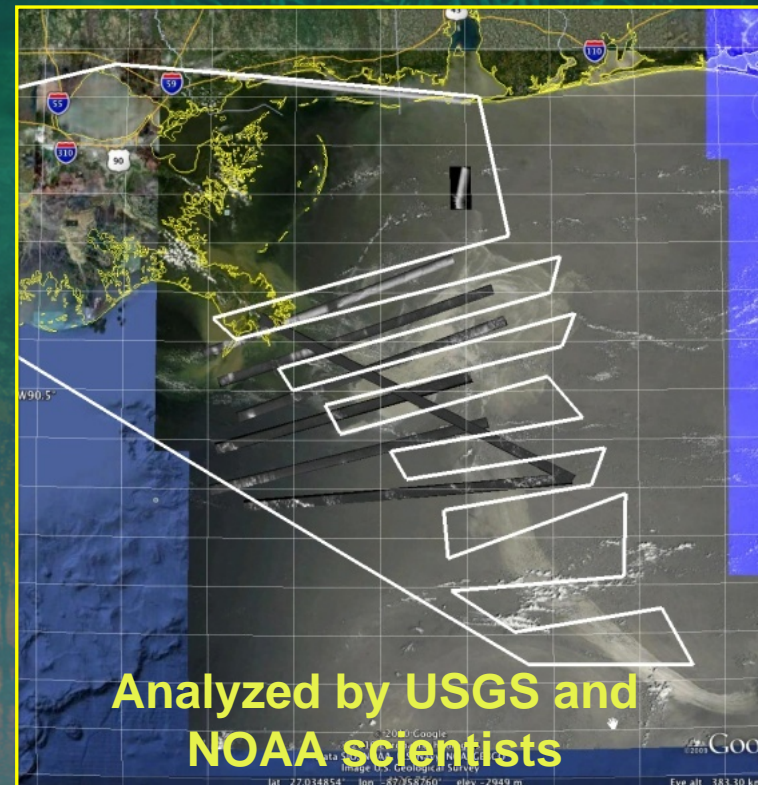
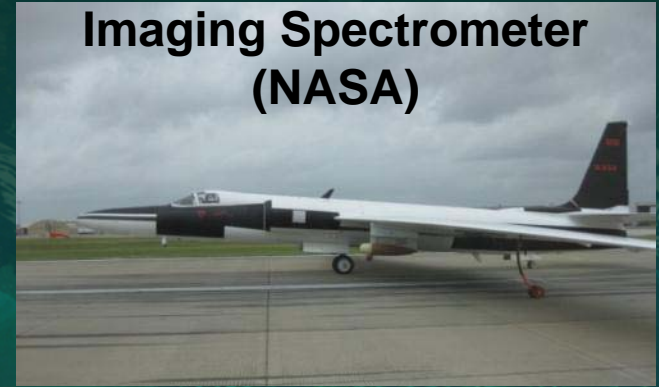
Actions:

- Used bio-chemical signature of DWH oil so that oil found in marine and terrestrial environments could be genetically linked to or excluded from DWH oil today and in the future.
- Used organic/petroleum analyses of pre- and post-spill sediment, oil and water samples to determine presence, source and state of degradation of oil.
- Used organic analyses to link oil composition to airborne (hyper-spectral) imaging results.
- Also, USGS developed a new chemical test for the major surfactant used in Corexit dispersants by BP, allowing government to assess long-term impacts of dispersant use.

Flow Rate Technical Group

- Led by USGS Director Marcia McNutt, involved scientists and engineers from USGS, NOAA, WHOI, DOE, BOEMRE, NASA, NIST, independent experts and university scientists.
- Five teams developed methods to estimate oil flow rates from Macondo well:
 - Mass Balance (surface observations)
 - Acoustic/Sonar Analysis (ROVs)
 - Particle Image Velocimetry (ROVs)
 - Reservoir and Well Modeling (2 teams)
 - Benchmarked against flow rate determined by DOE from closure of capping stack.

Airborne Visible InfraRed Imaging Spectrometer (NASA)



Well Integrity Team (USGS, DOE)

Capping Stack Closed July 15

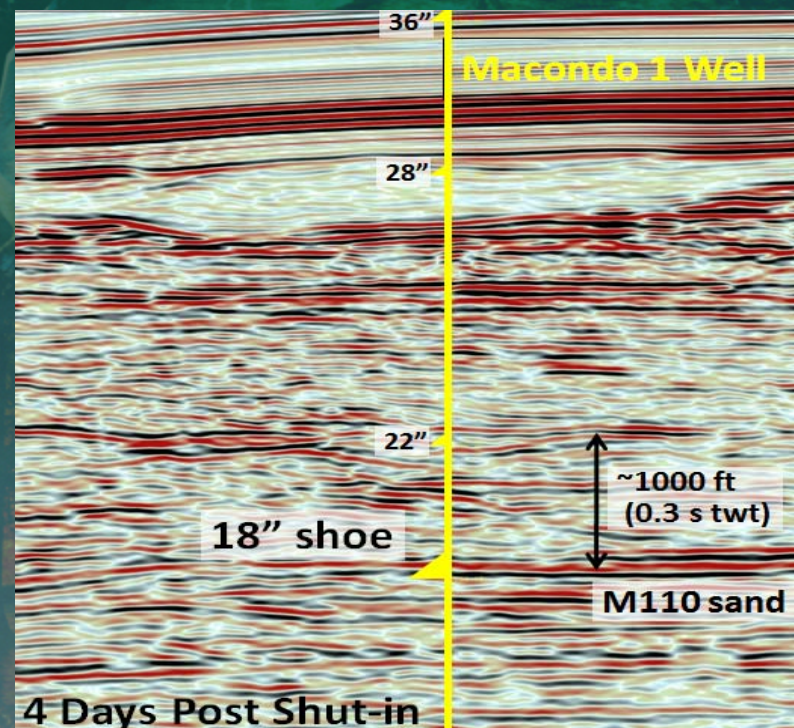
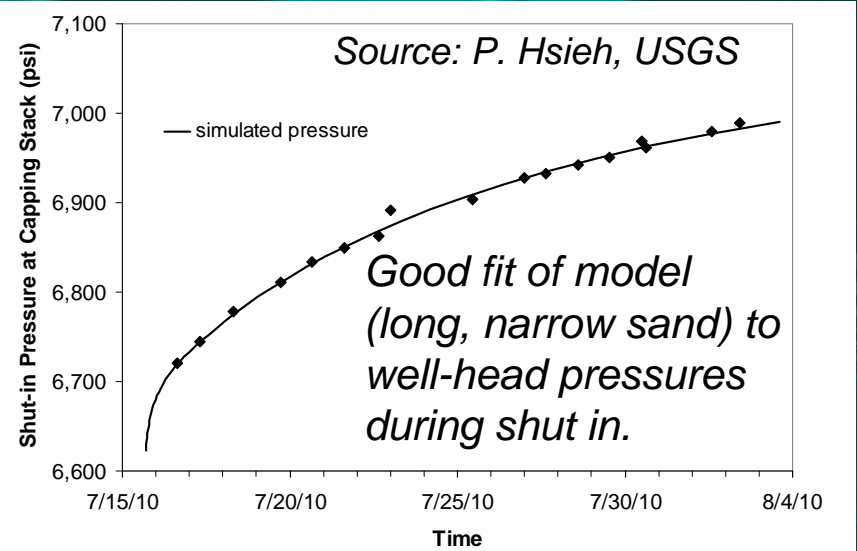
- Analysis of shut-in pressure was consistent with no-leak, high-reservoir-depletion scenario.
- Extensive monitoring (pressure, reflection seismic, sea-surface and sea-floor sonar, ROV visual) continuously analyzed to test for well leakage below sea floor.

Observations During Shut In:

- No anomalies in seismic images.
- No deeply sourced gas bubbles, either in the water column or at wellhead (NOAA & Univ. NH, BP).

Recommendation:

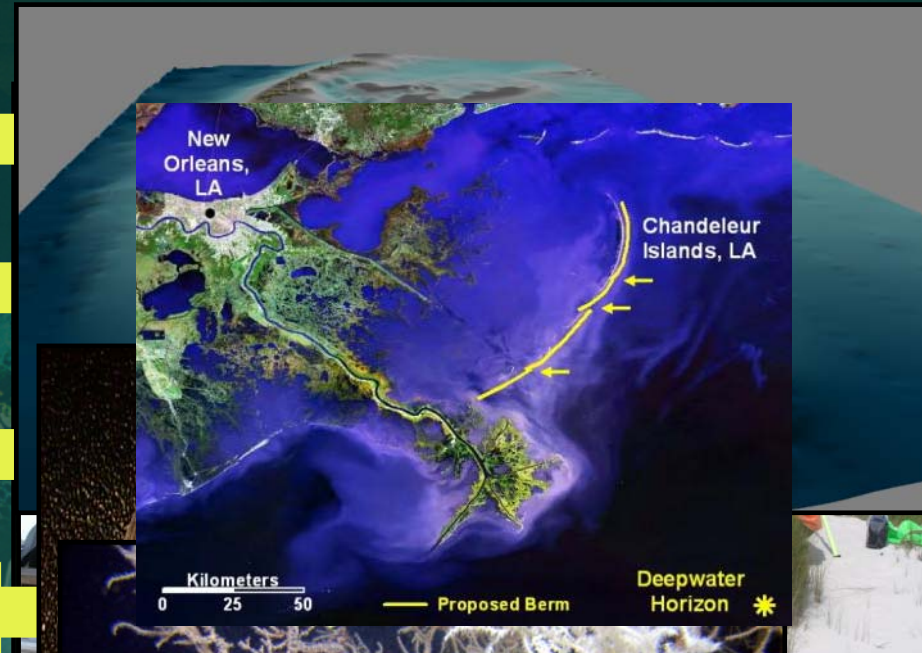
- Well could safely remain shut in from July 15 until final well kill and cementing ops. began August 3.



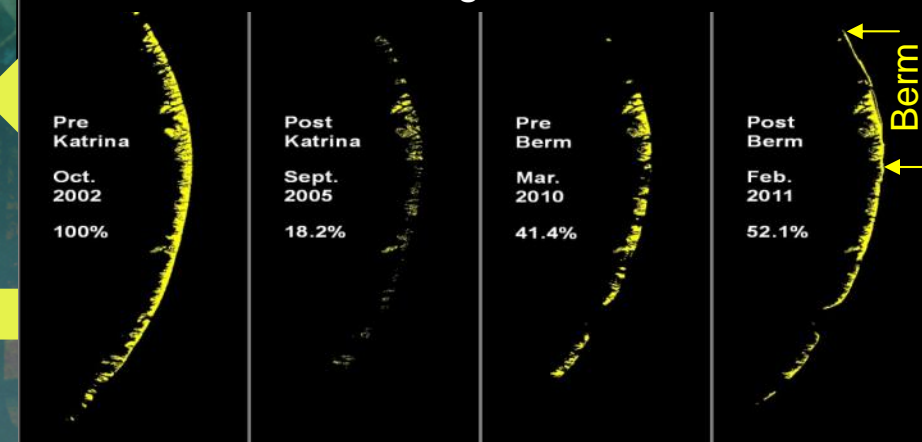
Source:
BP

Other Examples of USGS Research in Support of DWH Spill Response and Restoration

- Provided data and mapping products to identify sand resources and impacts
- Identified risk of oil deposition on barrier islands and back-barrier bays/marshes
- Documented baseline conditions in seagrass habitats in MS prior to impact
- Investigated factors controlling bacterial degradation of oil in coastal ecosystems
- Obtained baseline information on ecology and diversity of deep (>370 m) coral reefs to assess possible effects of oil/dispersant
- Studied impacts of constructing a sand-barrier berm on Chandeleur Islands morphology and local waves/currents.



Surface Area Change: Katrina to Berm

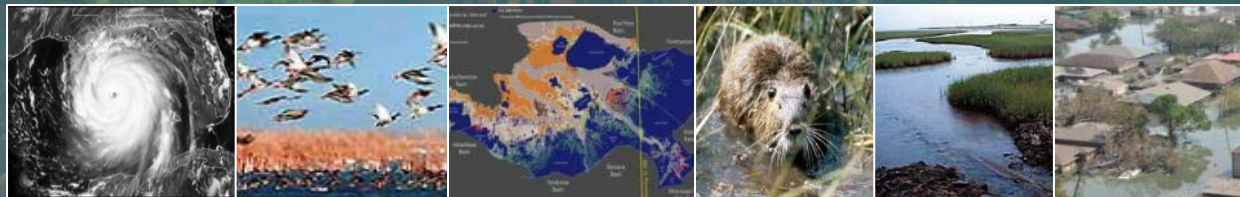


See <http://www.usgs.gov/oilspill/>

Source: J. MISELIS, A. SALLENGER, N. PLANT, US

Continuing USGS Response to DWH Oil Spill

- *USGS Long-Term Science Strategy in Response to the Deepwater Horizon Oil Spill* (Final report from the *USGS Environmental Incident Science Team*, Nov. 2010).
- Discusses core USGS capabilities and how they can be brought to bear to assist resource managers and policy-makers, falling under four themes:
 - Transport and Fate of Oil and Oil Spill Contaminants
 - Impacts of Oil Spill and Response Activities on Fish and Wildlife
 - Impacts on Human Communities
 - Tools to Aid Long-Term Recovery and Assess Future Threats and Risks
- This *USGS Science Strategy* is now being used by the USGS to help with science planning for the *Gulf Coast Ecosystems Restoration Taskforce (GCERTF)*:
- Multiagency initiative led by EPA, involving 5 Gulf states and 11 Federal agencies (see <http://www.epa.gov/gulfcoasttaskforce/>)
- GCERTF is developing a restoration strategy for Gulf Coast ecosystem, including identifying new research/monitoring data and policy actions needed.



Continuing USGS Response to DWH Oil Spill

Long-Term DWH Science Strategy also guiding USGS *Ecosystems* researchers in evaluating long-term effectiveness of two mitigation strategies tried after DWH spill: 1) construction of sand berms in the near shore areas, and 2) release of additional fresh water from the Mississippi River into coastal marshes (oil flushing).

This USGS research effort involves the following new activities:

- Comparing elevation change and sediment redistribution in surface and submerged habitats between the Chandeleur Islands and artificial sand berms, using marine-based LiDAR.
- Identifying factors controlling sediment redistribution around the Chandeleur Islands and the berm, using computer modeling of wave energy and currents.
- Determining impact of oiling and sediment redistribution on vegetation and corresponding impact on sediment mobility/stability of Chandeleur Islands.
- Establishing chemical and microbial baselines and hydrocarbon degradation processes using sediment cores (and pore fluids) from oiled and non-oiled marsh sites in comparison with sea-floor samples from open-water sites.
- Comparing above with distribution of contaminants across the food chain (micro-organisms to predatory fish) to determine if release of fresh water had an impact on the current state of restoration in Louisiana.

Natural Resource Damage Assessment (NRDA)

Goal: Determine injury to natural resources (water, soil, sediment, air, biota and their associated habitat) resulting from the release of a hazardous substance and to insure that those resources are restored at no cost to the public.

USGS Role in NRDAR (*ongoing*):

- Providing support in Scientific Design, Review and Study Implementation, including helping set up Technical Work Groups (e.g., Birds, Sea Turtles, Marine Mammals, Water Chemistry, Offshore & Nearshore Fisheries, . . .).
- Leading all aerial imagery work.
- Conducting laboratory and field studies to evaluate adverse effects of oil on birds, gulf sturgeon and sea turtles, and their habitat.
- Conducting field assessments on deepwater corals, manatees, and the health of marsh vegetation .



Talk Outline

- The Nature of USGS Science
- USGS Response to the Deepwater Horizon Spill
- Other USGS Activities and Assessments
- Conclusions

USGS Gas Hydrate Research

Source: T. Collett, USGS

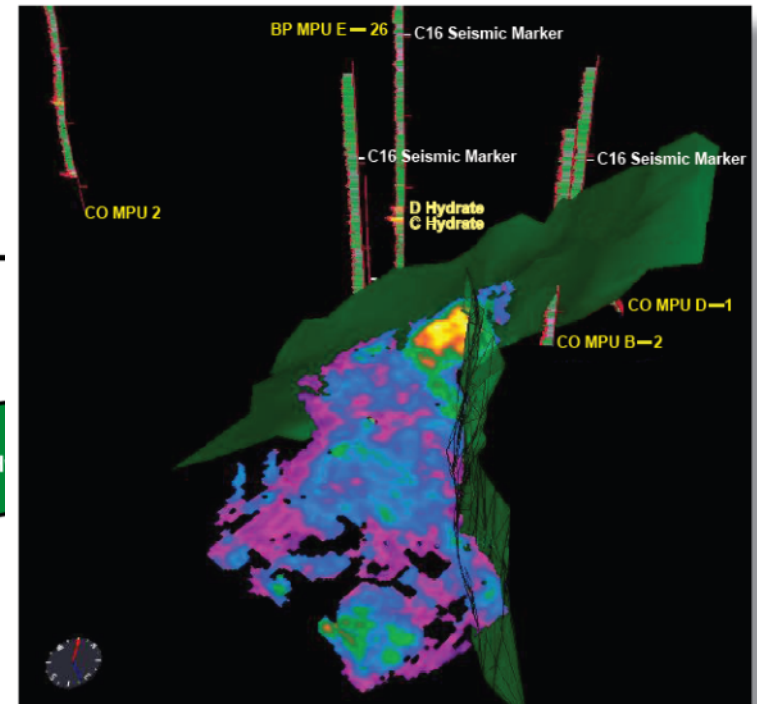
Extensive gas hydrate program, with following goals:

- Document geologic parameters controlling occurrence and stability of gas hydrates.
- Assess volume of natural gas stored in various gas hydrate accumulations:
- USGS conducted first systematic assessment of in-place U.S. gas hydrate resources (1995) and *first-ever assessment of technically recoverable gas hydrates* (2008).
- Analyze the production response and characteristics of gas hydrates.
- Predict natural and induced environmental impacts of natural gas hydrates.
- Analyze effects of gas hydrate on drilling safety.

<http://energy.usgs.gov/OilGas/UnconventionalOilGas/GasHydrates.aspx>

Warmed During Drilling

Warmed During Production



- In a pallet of colors ranging from yellow to magenta; the yellow-imaged portion of the structure contains the thickest and most concentrated gas hydrate).
- Also shown are the bounding faults (in green) and gas hydrate occurrences in nearby well penetrations.
- The well penetrations show downhole-measured geophysical data indicative of gas hydrate occurrence (in yellow).

Warming and loss of seafloor support can also affect subsea pipelines.

USGS Fact Sheet 2008-1073

USGS Submarine Landslides Research

Coastal and Marine Geology Program has an active program studying the geologic setting, size distribution, timing and impact of submarine landslides.

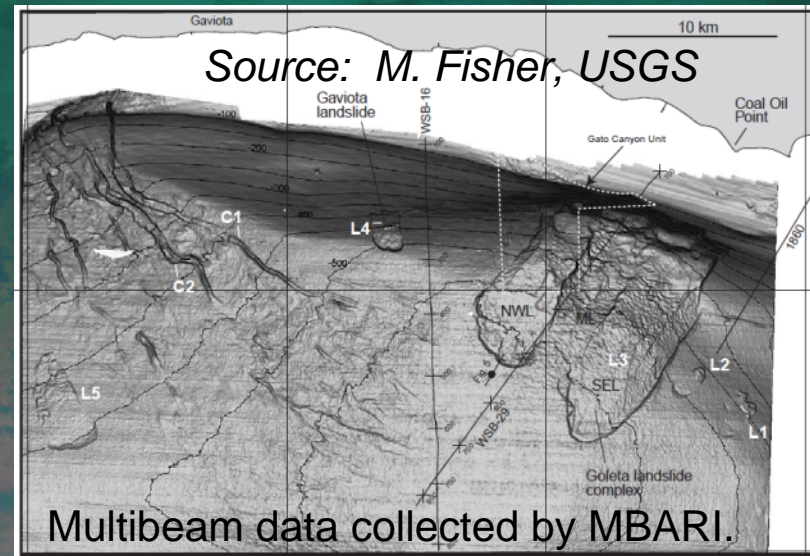
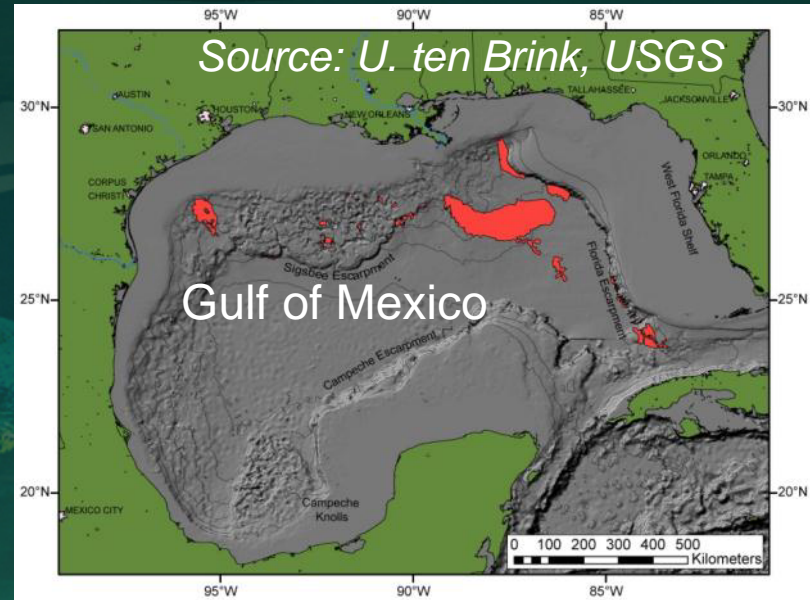
Implications of submarine landslides:

- Hazard to offshore and coastal infrastructure and human life
- Tsunami generators
- Major factor in canyon development, turbidity current generation and the development of continental margins.

Submarine landslides can be triggered by:

Sediment loading, Erosion, Gas and gas hydrates, Groundwater seepage, Carbonate dissolution, Earthquakes, Volcanoes, Diapirism (salt), Human activity.

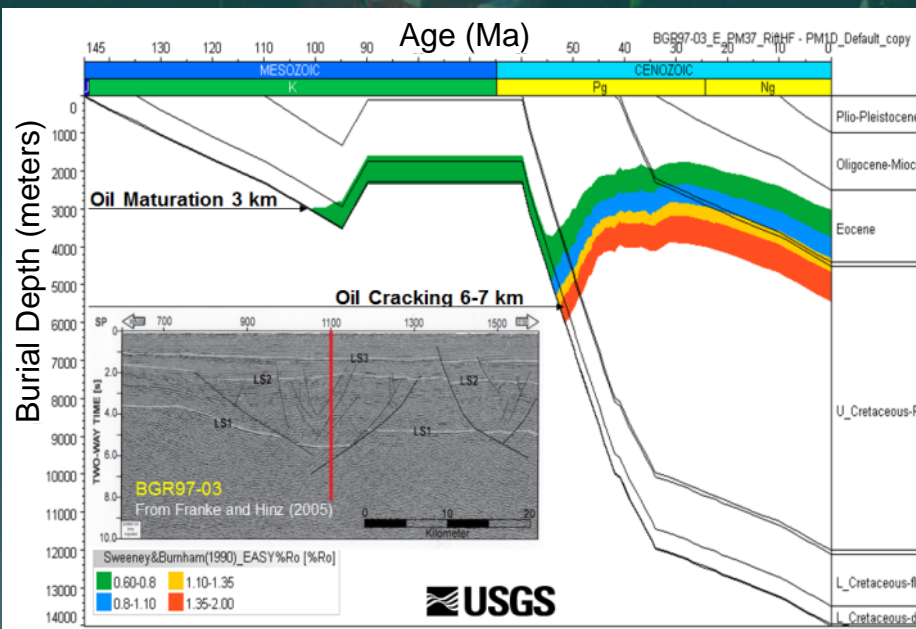
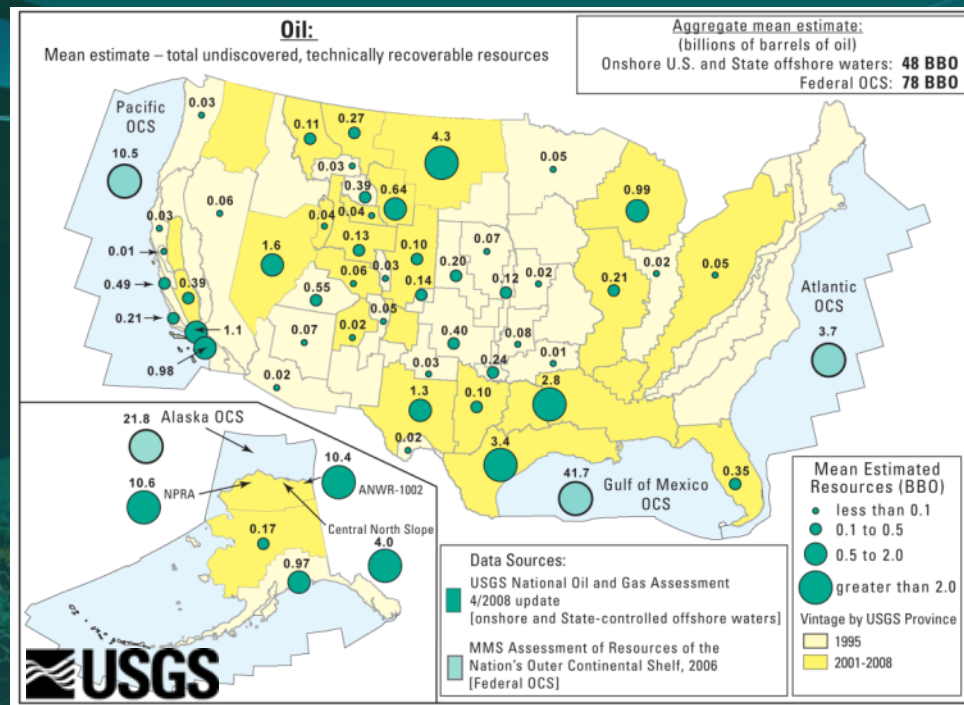
Sensitive to climate change



Santa Barbara Channel

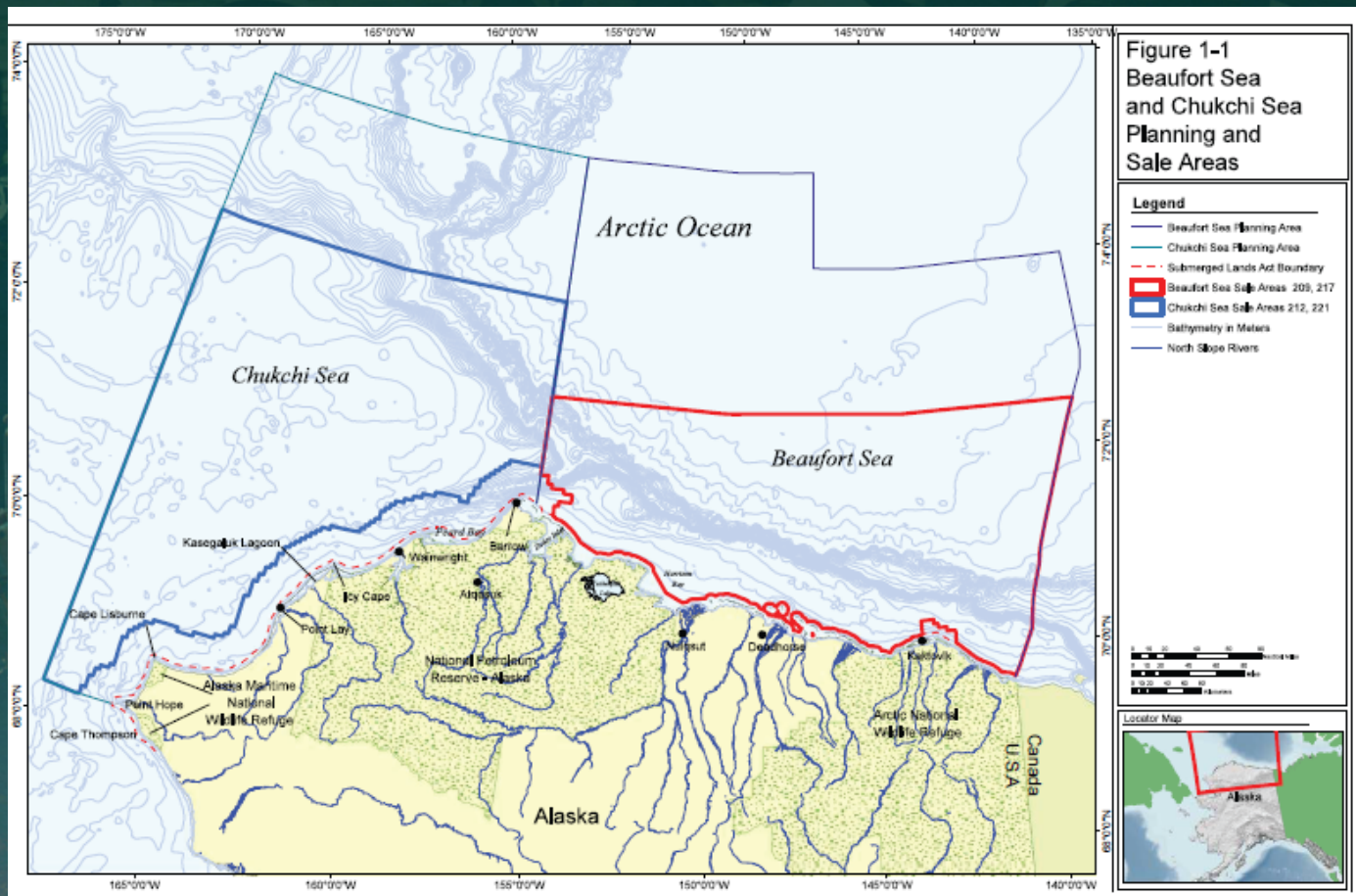
USGS National Oil & Gas Resource Assessments

- **Scope:** Onshore U.S. and State offshore plus International.
- Employ consistent methodology and supporting scientific research: enables national, regional & global comparisons and methodological advances.



Expertise in geological framework studies, geophysical imaging, borehole geophysics, reservoir modeling, geomechanics and hazard assessments can help develop methods for off-shore pressure prediction, subsurface fluid migration modeling, geologic well integrity assessments and spill risk analyses.

An Evaluation of the Science Needs to Inform Decisions on Outer Continental Shelf Energy Development in the Chukchi and Beaufort Seas, Alaska



U.S. Geological Survey Circular 1370, July 2011, 278 pages, edited by Leslie Holland-Bartels and Brenda Pierce

Full Report at <http://pubs.usgs.gov/circ/1370/>

Fact Sheet at <http://pubs.usgs.gov/fs/2011/3048/>

USGS Arctic OCS Study

- **Significant advances: BOEMRE, Industry, USCG, NOAA, EPA and international Input to Risk, Preparedness and Response recognized:**

Information for Effective Oil Spill Risk Assessment, Preparedness and Response advancing, but significant challenges remain

- Critical inputs to spill scenarios (reservoir volume & pressure, oceanography, weather, ecology) would benefit from increased joint planning & data sharing.
- Applicability of laboratory & mesoscale studies to full field conditions remains largely untested, but international efforts are improving the foundation.
- **Although a lot is not known for various locations, times and species:**
- Actions based on best available information. But, could be enhanced by application of *Structured Decision Making* tools, which allow action now, with transparency and incorporation of new science (with uncertainties).
- ***Exxon Valdez* and *Deepwater Horizon* oil spills demonstrate that a suite of spill countermeasures must be available and effective, and these change over the response period of a spill:**
 - Significant questions exist about Response Gap for the Arctic, particularly in ice-infested water. ***This is exacerbated by expected climate change.***

Recommendation: Critically assess data needs that will most effectively increase accuracy of Oil Spill Risk Analysis. Develop means to more quantitatively include ecological insights. Commission an authoritative assessment of “Response Gap”.

USGS Arctic OCS Study

Climate change in the Arctic will have variable effects on key factors in oil and gas development and spill response

- **Climate models show pronounced warming:**
 - **Physical:** Clouds/fog reduce visibility; Icing conditions increase; Precipitation increases; Storms increase in frequency and intensity; Sea-level rises; Ocean circulation patterns change; Sea ice decreases
 - **Ecological:** Ocean acidification -- calcifying organisms, entire food chain; Sea Ice – ecosystem shift; Species responses -- fish, birds, marine mammals
- **International development of Global Climate Models a success. However, these lack sufficient regional “grain:”**
 - More refined regional understanding is essential to clarify what planning and engineering solutions must target in 50 year future.
- **Uncertainties exists on critical topics for which science focus is required:**
 - Physical: storm frequency and intensity, circulation patterns
 - Species’ response to environmental changes; undertake periodic population and distributional surveys

Recommendation: Promote development of fully-integrated Atmosphere-Ocean-Land regional climate models. Address gaps in storm data as soon as possible.

Conclusions

- Science clearly made a difference in the course of the *Deepwater Horizon* spill, involving many scientists and technicians at the USGS working in concert with colleagues from other government agencies, industry and academic institutions.
- USGS science continues to support oil-spill restoration in the Gulf of Mexico, as part of *Operation Clean Sweep* (USCG), through research priorities being implemented in the *USGS Ecosystems and Water Mission Areas*, as part of the *Natural Resources Damage Assessment* process, and through science planning for the interagency *Gulf Coast Ecosystems Restoration Task Force*.
- Lessons learned from the *Deepwater Horizon* and *Exxon-Valdez* spills and ongoing USGS research on land and at sea are informing strategic scientific planning to facilitate safe and environmentally responsible offshore oil and gas development, not only for the *Gulf of Mexico*, but also for frontier areas like the *Arctic Ocean* and the *Atlantic Margin*.