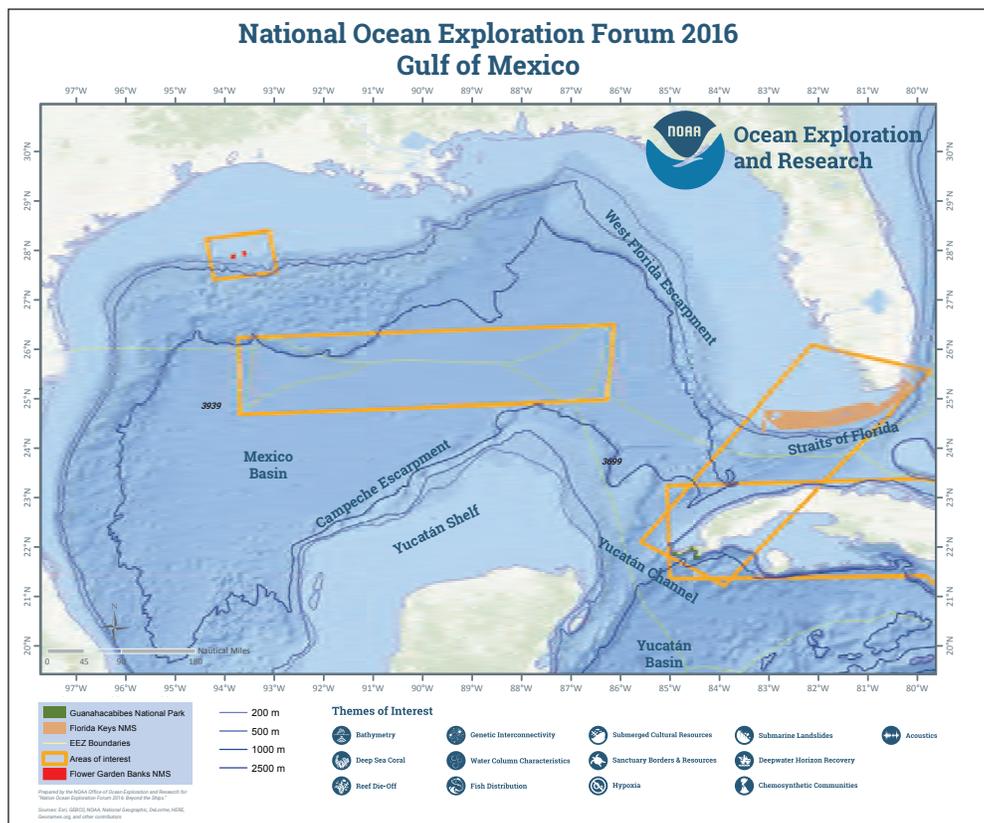


Gulf Campaign Scenario

INTRODUCTION: Two independent Breakout Groups met in two sessions to consider emerging technologies to enable ocean exploration campaigns that may occur in the Gulf of Mexico in the next decade. A map of the notional campaign scenario area is presented below. VADM Scott Van Buskirk (Oceaneering International, Inc.) and Dr. Nancy Rabalais (Louisiana State University) led one group while Dr. Tony Knap (Texas A&M University) and Victoria Tschinkel (1000 Friends of Florida) led the other. Other forum participants moved among the several Breakout Groups during the course of their discussions. Lists of participants and their provisional group assignments made at registration are available ([click here for Breakout Rosters](#)). Following are a narrative of the discussion and summary slides delivered by each Gulf of Mexico Breakout Group.



Gulf of Mexico Breakout Group led by
VADM Scott Van Buskirk (Oceaneering International)
and
Dr. Nancy Rabalais (Louisiana State University)

Those geographic areas that already had some level of exploration and deployed instrumentation had an advantage over areas with little ocean exploration such as the Gulf of Mexico. The Gulf is not well explored except for some discrete areas like the Flower Garden Banks Marine Sanctuary, seep areas, and a few other topographic features. There has been no dedicated campaign compared to areas such as the Southeast and Mid Atlantic US Bight areas, or, more recently, the Arctic.

We started with Russel Callender's suggestions about extending the Flower Garden Banks Marine Sanctuary system to the east to include other topographic features, then taking that concept around the shelf margin to the southern tip of Florida and finally exploring for connections between the Florida Keys and the north coast/west tip of Cuba. We did not stay specifically with that focus. Nonetheless, potential partnerships with Cuba (and Mexico) were magnetic.

The Cuba opportunity had so much attraction that the focus became the Yucatan Straits and the Straits of Florida, and for a while included marine sanctuaries and national parks in Florida and Cuba. We continually shifted emphasis until settling on the movement of water from and through the Yucatan Channel and Florida Strait into the Gulf of Mexico, as a "follow the water" exploration, a different look at the exploration concept. We discussed establishing "gates" to follow parcels of water as they flowed through Strait and the Yucatan Channel. We spent a great deal of our time discussing the idea of Gulf Stream flow through the Florida Strait; currents, water quality, acidity, and the ability to integrate data gathered:

- Look at shallow and deep connectivity
- Deal with high current speeds
- Build Cuba institutions for a viable future.
- Consider fiber-optic cables (with installed/attached ocean sensors) for enhanced connectivity to Cuba.

- Capitalize on established international connections in the Gulf (e.g., Harte Institute, CiiMAR-GOMC, Lounsbery grants, USF student exchanges in geology), but extend the opportunity beyond this established community of regional scientists.

Further collaborations among the U.S., Cuba, and Mexico could include an exploration “box” in the Yucatan Channel; high visibility for each country. We noted that Cuba has some of its own priorities, viz., oil and gas exploration and production and coral recruitment and health.

We further noted that bringing new technologies to an international exploration effort must consider standing national technology export restrictions.

A common theme throughout the two-day Forum and within our group was the continued value of multi-beam mapping in unexplored bottom waters. Especially critical is backscatter information to characterize living communities.

The geography of this area, its interesting marine life, proximity to shorelines, and its international appeal drew comments about the value of citizen science in this area.

Further, understanding it important to gain an understanding of the major ocean currents in these straits and in eastern and southern areas of the Gulf. Here the Loop Current and its spin-off eddies are especially interesting in understanding general biology, juvenile spawning areas, MPAs, hotspots for fisheries and recruitment, and coral communities for conservation.

Our breakout group saw the importance of adapting vehicle and sensor technologies for deployment from ships of opportunity; commercial traffic entering and leaving the Gulf. A corollary is developing sensors that are easy to deploy and also cheap and disposable, but still accurate. Expendable bathythermographs (XBTs) are examples of sensors that could easily be deployed by crews on commercial vessels.

Important is identifying the information gaps to better understand the Gulf. Examples include: identifying connectivity between biological communities, measuring how water moves, and understanding how that movement supports connectivity.

We agreed with the [Forum discussion paper by Jennifer Miksis-Olds and Bruce Martin](#) that the Gulf was a good candidate to test out and deploy acoustic technologies to characterize biodiversity and help create ambient seascapes.

Key parameters in a Gulf exploration campaign

- What is in the water, in situ, temperature, dissolved oxygen, CTD, turbidity, chlorophyll, nitrates, phosphate, pH
- Microbiome
- Macrobiome using nets, continuous plankton recorder, passive acoustic monitoring
- Hydrocarbons and in situ methane, VOC, dissolved gases,
- Biomass of larger fauna, e.g., fish, acoustics
- Water column eDNA analysis
- Currents
- Marine archaeology

Technology ideas

- Anticipate and plan for acquisition, aggregation, and archiving of large data sets
- Disposable sensors; size, weight, and power designs that are key to economical data collection
- Tagging/instrumenting megafauna
- Near-term existing technologies, especially broad area queuing to identify target areas
- Midterm (3-5 years) expect deployment of now pre-operational technologies, e.g., swarm, high-resolution mapping (X Prize)
- Out-years (5-10 years) low size/weight/power (SWaP), seabed monitoring, big data assimilation
- More telepresence (presume mobile telepresence capabilities) for targeted projects

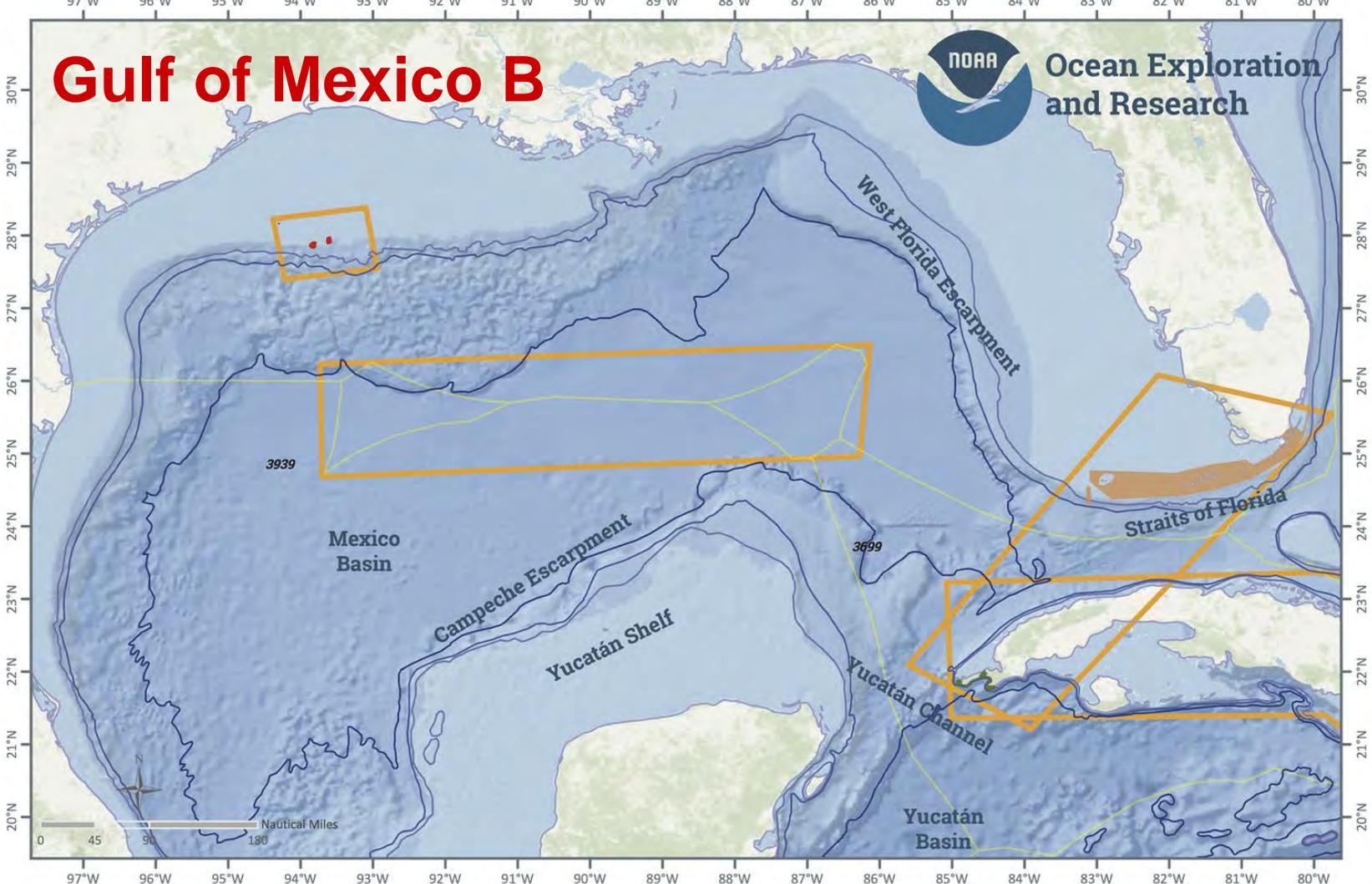
Slide presentation

The Gulf Breakout Group led by VADM Van Buskirk and Dr. Rabalais presented the following PowerPoint slides at the 2016 National Ocean Exploration Forum.

Gulf of Mexico B



Ocean Exploration
and Research



CONNECTIVITY

*explore and characterize the connectivity of the
Gulf of Mexico*

Overarching questions

What are the physical and chemical connections between the Yucatan Strait, Gulf of Mexico, and Straits of Florida?

What is the connectivity of habitats in the Gulf?

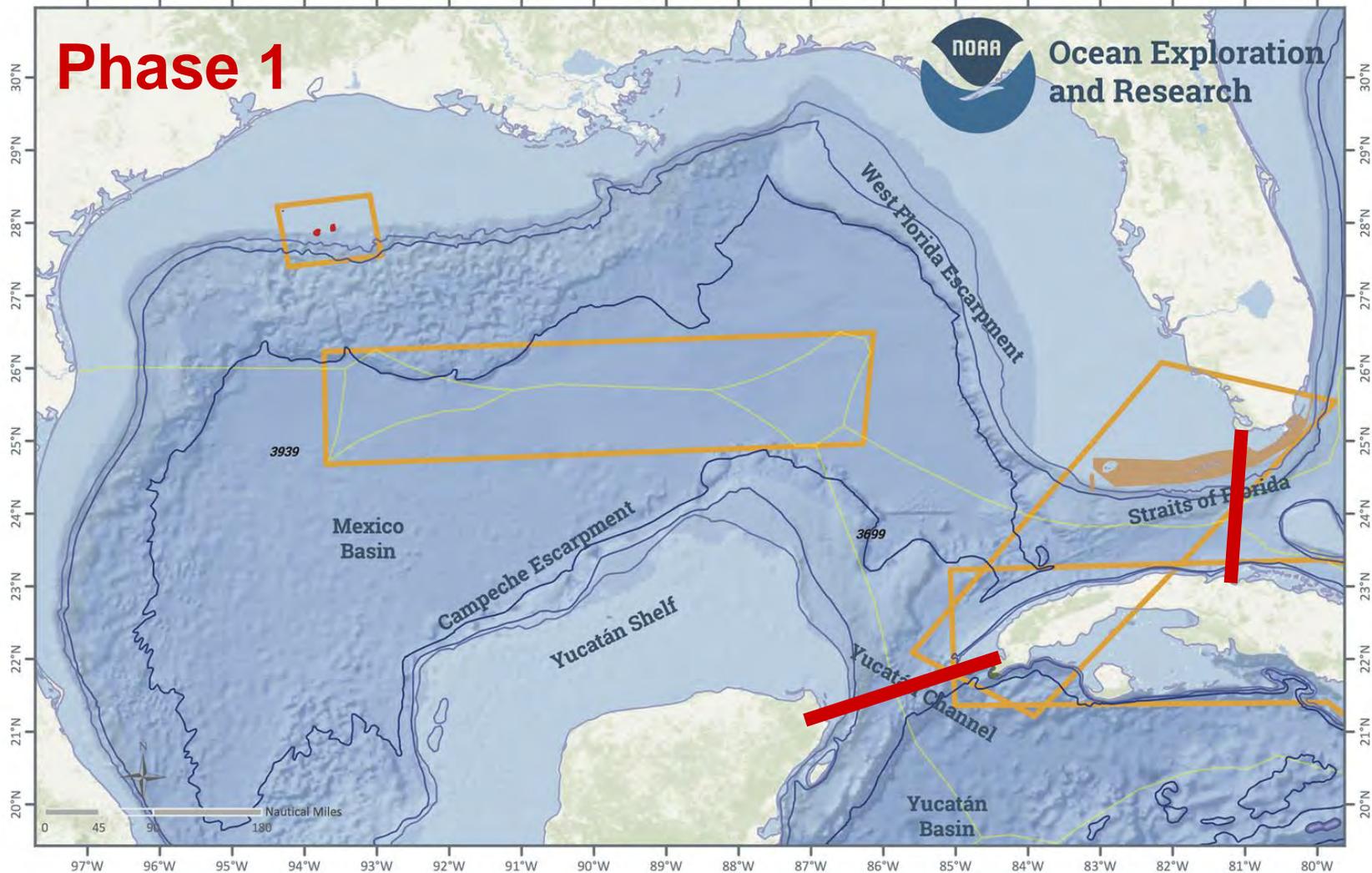
What are the historical and cultural connections around the Gulf of Mexico?

How can we enhance connectivity between Gulf countries?

Phase 1



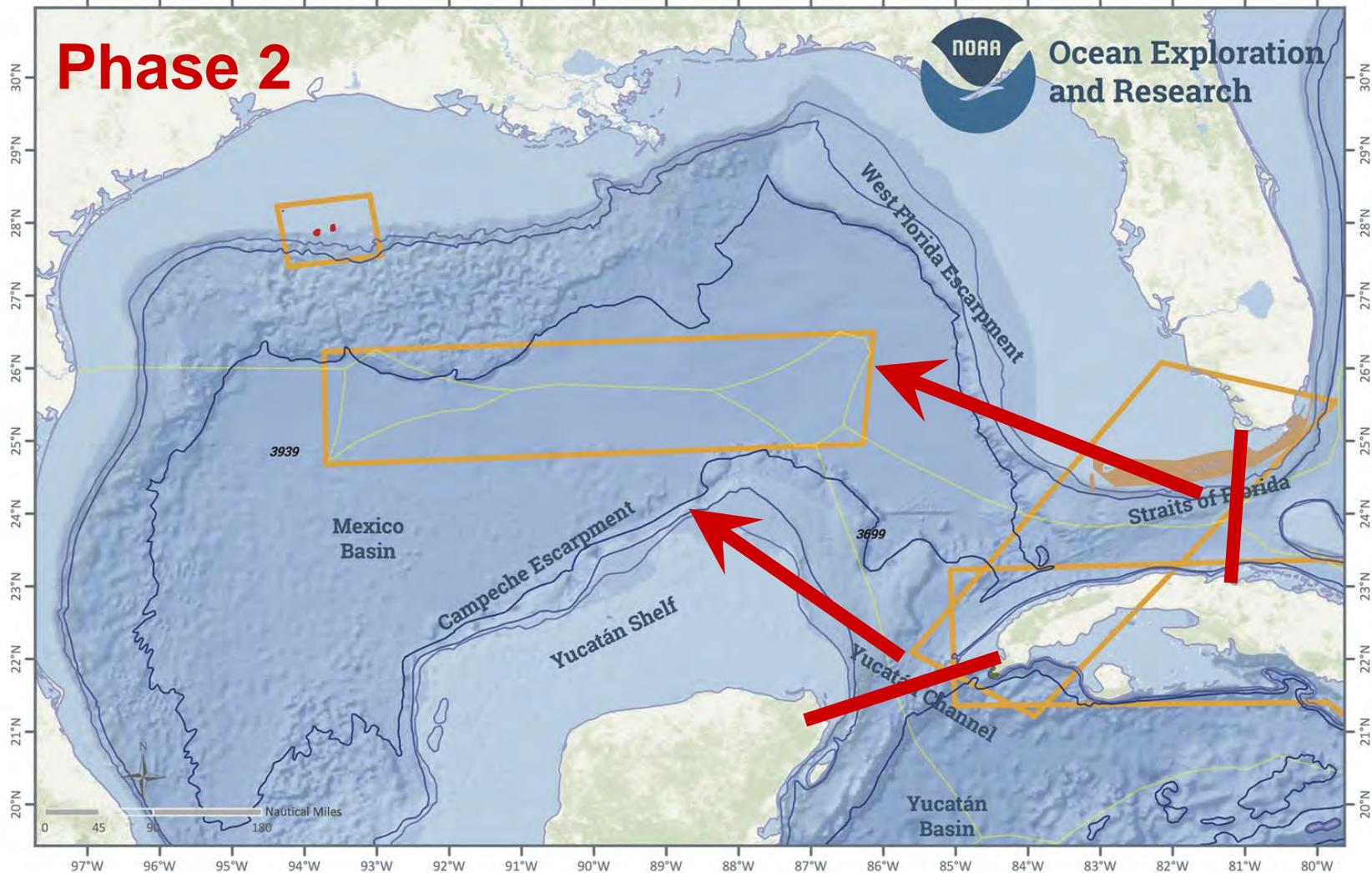
Ocean Exploration
and Research



Phase 2



Ocean Exploration and Research



Key Parameters

- Seafloor mapping
- Physical, chemical, & biological properties of water
- Distribution & connectivity of micro & macro biology
- Distribution of archaeological sites (shipwrecks & palaeo)
- Consider operational constraints (e.g. high current areas)

subseafloor - seafloor - mid-water - surface

Key technologies

- **Seafloor mapping** (e.g. multibeam, backscatter, images)
- **In situ sensing** (e.g. temp, DO, CTD, pH, acoustics, etc.)
- **Continuous in situ sampling** (e.g. microbiome filtering, dissolved gas, plankton, eDNA)
- **Discrete sampling** (e.g. rocks, bio, water, etc.)
- **Remote sensing** (e.g. SST, chl)
- **Platforms** (e.g. ships, vehicles, moorings, cables, satellites, rubber ducks)
- **Telepresence** where appropriate
- **Software development and data analysis** (e.g. artificial intelligence, machine learning)
- **Emerging technologies and those not yet imagined**

Tech Timeline

Anticipate and plan for acquisition of **large data sets**

Near-term (2-3 years): Use existing technologies to collect baseline information (e.g. multibeam echosounders, ADCPs, vehicles, data infrastructure, etc.)

Mid-term (3-5 years): bring existing pre-operational technologies online to dig deeper (e.g. swarm technologies, AI, ML)

Far-term (5-10): technologies that do not exist yet to identify connections and processes (e.g. low-cost sensors, long-duration vehicles & sensors)

Stakeholders & Leveraging

Stakeholders

Mexico, Cuba, possibly Bahamas, USA (State Dept, NSF, NOAA, BOEM, etc.)

US Federal agencies NGOs (e.g. academic institutions)

Industry (oil & gas, shipping, cruise lines, fisheries, recreation, etc.)

Leveraging opportunities

Existing data and institutions already working in the Gulf

NAVO autonomous vehicle range

GoMRI, GoMA

Funding

US Federal - Congress & exec agencies – National Program?

International partners

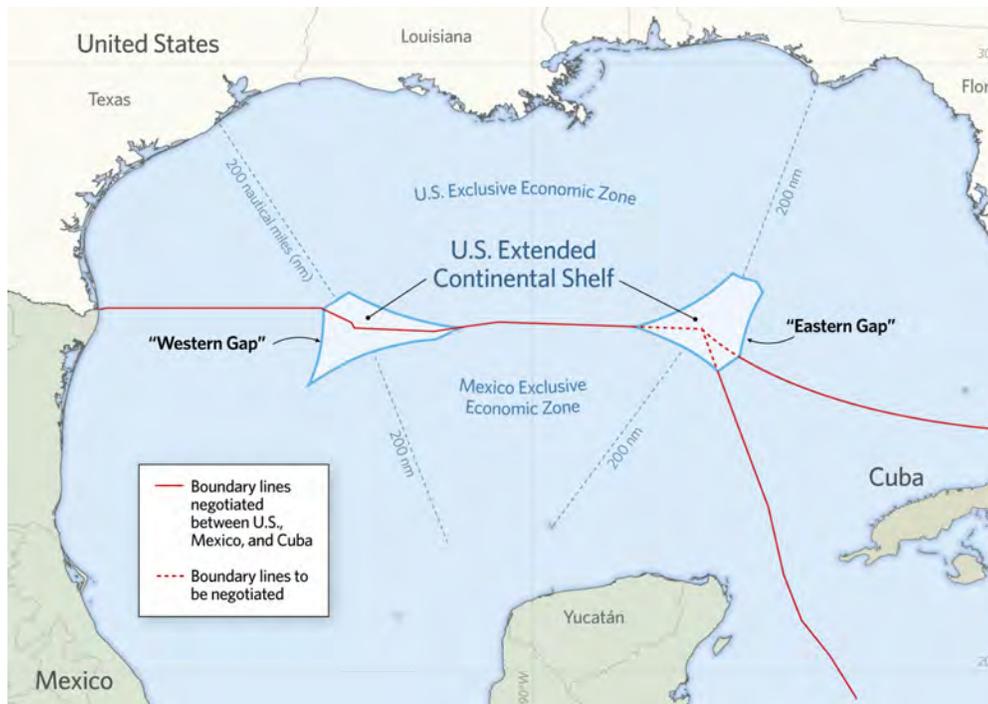
For technology development, ONR, X Prize, corporate sponsors (e.g., O&G, cruise lines)

Private foundations & individuals

Crowdfunding for particular initiatives?

Gulf of Mexico Breakout Group led by
Dr. Tony Knap (Texas A&M University)
and
Victoria Tschinkel (1000 Friends of Florida)

The Gulf of Mexico has two gaps, approximately 200 miles offshore, referred to as “Doughnut Holes” where national jurisdictions meet up. These areas are too far from shore for commercial fishing activities, and there is neither oil and gas exploration (at least not yet) nor evidence of any seeps, so the area remains largely unstudied. Exploration of this area should be of multinational interest as well as an excellent opportunity for the U.S. to collaborate with Cuba, Mexico, and Spain. Exploration of these areas will contribute to our understanding of the Gulf system in its entirety, our “urban sea,” and in particular, will offer the opportunity to work in portions of the Gulf that are relatively unimpacted by man’s activities.



Two areas in the Gulf extend beyond the exclusive economic zones of the U.S., Mexico, and Cuba.

The water depth in the area of interest is around 3000 m and as far as we know is likely to be mostly abyssal plain, although corals might be present. The “Doughnut Holes” should be rich in archeological artifacts from Spanish shipwrecks and possibly of the early humans of the Western Hemisphere. There could be deep corals.

The physical characteristics of these two areas are vastly different, and thus the biology, chemistry, and geology would presumably be quite different.

- The eastern gap is dominated by the Gulf Loop eddy with current speeds up to 4 knots, with massive inputs from the Caribbean in the loop. When a loop eddy breaks off, this becomes a biologically remote circular community.
- The western gap is where the Gulf Loop eddies die and deposit material in that area, including sediments from the Gulf itself but also those entrained from the Mississippi.

In summary, the “Doughnut Holes,” unimpacted by the Deepwater Horizon Spill, offer pristine, quiet waters not too far from land but located in an urban ocean that would provide an excellent test bed for new technologies, including evolving acoustic technologies and eDNA sampling and analysis, and a demonstration area for modern open ocean exploration. The results of this exploration would provide a priority baseline to understand the effect of industrial development activities for the future, and offer an opportunity for sharing these discoveries with Mexico, Cuba, and Spain.

Recommendations

1. Preliminary to developing a detailed proposal for this exploration, we would search the following and other sources for relevant information:

- Mapping, seismic, and physical: Bureau of Ocean Energy Management, National Association of Drilling Contractors, U.S. Navy, and the International Association of Geophysical Contractors.
- Biological: National Marine Fisheries for landing logs, by-catch reporting for marine mammals and sea turtles, individual researchers working along the Gulf Coast, Ocean Biogeographic Information System.
- Wind and current: NOAA National Environmental Satellite, Data, and Information Service, NASA and US Navy for satellite information and NOAA National Data Buoy Center

2. We advocate a phased series of exploration efforts to refine thinking during the work, and to make use of technologies that are evolving, over approximately five years. We should start with benthic mapping of the area and finding ways to process biological samples more efficiently to make better use of biologists' time. Remotely operated vehicles could be deployed relatively early to determine major physical and biological differences between the two gaps.

3. As soon as the appropriate vehicles are available, we would characterize the areas further using passive and active acoustics to form a general map, to look for anomalies that might be further explored, such as bottom-dwelling marine life, potential archeological sites, and open-water pelagic and benthic life.

One of the particular innovations of this exploration would be to unite acoustic surveying with biological surveying, including use of eDNA and improving reference sources. Following an extensive literature review and a detailed assessment of currently available datasets in the region, we propose to use both active and passive acoustic technology deployed strategically throughout the region of interest to identify specific areas worthy of more detailed exploration effort. Areas of extreme interest for further consideration would be ecological hot spots, novel oceanographic or bathymetric features, or areas targeted to explore rapid change over time as eddies transit through the region. Innovation in underwater recording technology now permits the remote monitoring of animals and the environment without the need for human observers, the physical presence of an ocean observation vessel, or adequate visibility and sampling conditions. Passive acoustic monitoring is an efficient, noninvasive, and relatively low-cost alternative to hands-on exploration and is providing a wealth of information about regional sound sources (biologic, anthropogenic, geophysical), animal behavior, ecosystem dynamics, biodiversity, and impacts of human activity. Active acoustics have been used extensively to map the distribution of planktonic and nektonic species in the water column (Foote and Stanton, 2000).

Passive acoustic monitoring is performed using autonomous recorders that are left on the seabed or in the water column for up to one year to capture seasonal signals and patterns. The recordings allow us to characterize and observe marine habitats without the confounding effects of human presence or sampling biases. Indicators of habitat quality and biodiversity that have been developed for terres-

trial applications but are now being adapted to marine habitats and soundscapes are an important area of new research. Rapid acoustic analysis of a habitat's soundscape using high-level indicators such as the acoustic complexity index (ACI), acoustic entropy index, or acoustic dissimilarity index is providing a quantitative way to assess biodiversity and compare soundscapes of different areas.

There are now two commercial products (Canadian and Norwegian) that support long-term, remote deployments for measuring acoustic backscatter. Temporal and vertical spatial distribution of zooplankton in the water column can be measured with echosounders. By recording acoustic backscatter from at least two frequencies, the differences in backscatter between the two frequencies can be used to distinguish between different scatterers in the water column (Watkins and Brierley, 2002). It is possible to distinguish between the following broad taxonomic categories based on size discrimination: small mesozooplankton (e.g., copepods, chaetognaths), large mesozooplankton (e.g., euphausiids), and swim-bladdered fish, as well as provide estimates of in situ numerical densities of animals in some cases (Lawson et al., 2004; Warren et al., 2003). This type of data provides information on ubiquitous features (i.e., deep scattering layers) that occur throughout a study region, and more intermittent features (e.g., organisms that have a patchy distribution or move in and out of the study area). The power of combining passive and active technology is that it provides a more detailed picture of trophic interactions, ecosystem relationships, and pre-prey interactions than can be developed using only one of the technologies.

The more detailed sampling directed by the initial acoustic surveys would be a great chance to compare eDNA results and references to the biodiversity indicators obtained with the acoustics. The comparison would bring greater value to both.

4. Emphasis will be placed on the study of benthic organisms with the understanding that many of the Gulf species have been previously identified and that reference collections can be relatively easily assembled. Biological investigations will promote more advanced noninvasive methods, such as acoustical information described above. Intense focus needs to be placed on developing efficient sampling methodologies for onboard ship analysis and eventually other more modern, automated platforms.

To date, it has not been possible to concentrate these samples efficiently for onboard biological analysis or to preserve and concentrate

large numbers of samples by autonomous machines. There are challenges in all parts of this procedure: collecting, concentrating, preserving and lysing cells, applying reagents, removing particulates and applying extraction chemistry, and sterilizing samplers between runs. The ultimate advance of this area of exploration would be to provide a pilot study to improve sampling technologies and to use eDNA to determine species diversity and abundance, while at the same time enlarging reference collections.

5. We propose to employ physical sampling by means of advanced technologies and telemetry or archiving as appropriate. Remote instrumentation use is developing rapidly. Buoyancy gliders now routinely explore oceans for up to three months at a time. Wave-powered vehicles can stay in the ocean for about six months if they are well protected from fouling. There are a variety of newer vehicles being produced including small remotely controlled ships that can deploy instruments on their own. Mooring systems with surface buoys are well developed, and migrating pods such as profilers can now stay out for a year and crawl between depth and the surface at set sampling regimes. The data can be transmitted to shore by satellite, providing real-time sensing of the ocean.

Ideally, autonomous underwater vehicles would be very useful. However, short battery life does not allow for much exploration in the depth of this water, so using a survey, research, or exploration ship for the baseline study would be advantageous.

New sensors for nonphysical parameters are being developed, but there is still great need for new sensors that measure rates of oceanographic processes. Large pelagic organisms are used extensively in Arctic regimes and migratory fish such as large tuna have also been used. The idea of using telepresence to see the ocean through a “whales eye” is appealing and should be pursued.

6. Concerning the need to change the organizational structure for ocean campaigns, we considered an organization that could efficiently and responsibly amass, contract, and spend pooled funding from different government agencies, NGOs, and the private sector. One such organization is the National Fish and Wildlife Foundation (NFWF), which was created by the federal government but is legally fully private. For example, NFWF is administering the \$2.54 billion Gulf Environment Benefit Fund. It does not seem possible to run an exploration program with enthusiastic public support and participation

unless a single agency or new entity could provide these functions. We suggest that the Consortium Ocean Leadership (COL), or another appropriate forum, take on the responsibility of hosting a discussion on this topic.

Educational opportunities that effectively engage the public are essential in the modern world. Virtual reality viewing from cameras mounted on mammals, turtles, or even tuna constitutes one opportunity to spark public interest in the deep ocean. The publicity from a triumvirate of countries could also focus interest in this area. It would be good to have school children from the cooperating countries work together as part of the exploration. In addition, early determination of an archeological or historical component of the exploration would surely provoke enthusiasm in practitioners and citizens alike.

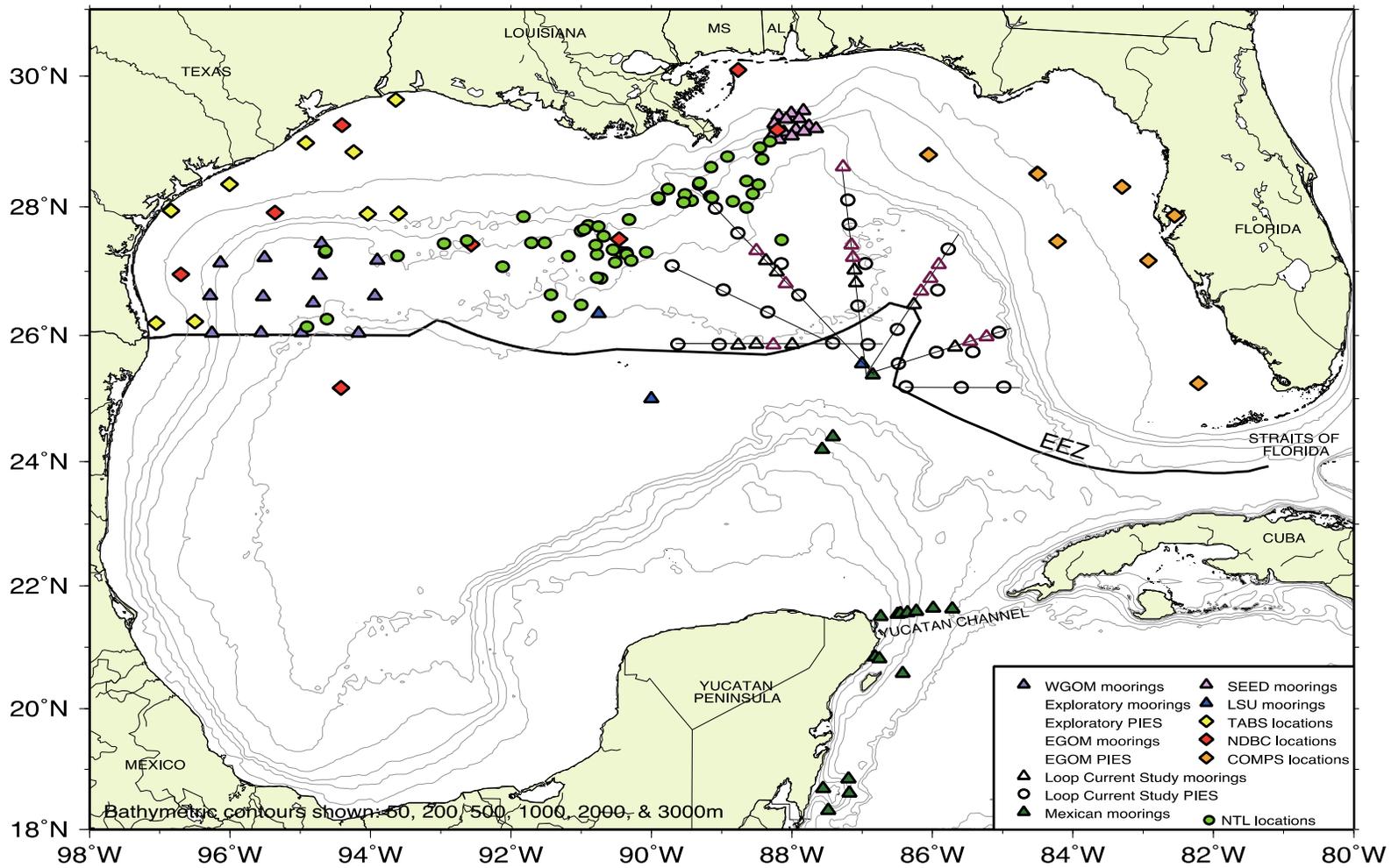
References

- Foote, K.F., and T.K. Stanton. (2000). Acoustical methods. In *ICES Zooplankton Methodology Manual* (ed. R. P. Harris, P. H. Wiebe, J. Lenz, H. R. Skjodal and M. Huntley). Academic Press, London.
- Lawson, G.L., P.H. Wiebe, C.J. Ashjian, S.M. Gallager, C.S. Davis, and J.D. Warren. (2004). Acoustically-inferred zooplankton distribution in relation to hydrography west of the Antarctic peninsula. *Deep-Sea Res Part II* **51**, 2041-2072.
- Warren, J. D., T.K. Stanton, P.H. Wiebe, and H.E. Seim. (2003). Inference of biological and physical parameters in an internal wave using multiple-frequency, acoustic-scattering data. *ICES J Mar Sci* **60**, 1033-1046.
- Watkins, J.L., and A.S. Brierley. (2003). Verification of acoustic techniques used to identify and size Antarctic krill. *ICES J Mar Sci* **59**, 1326-1336.

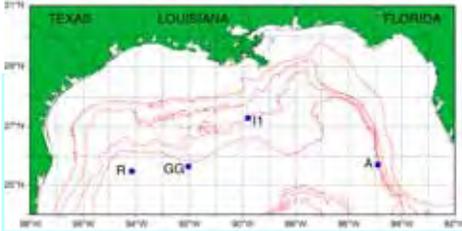
Slide presentation

The Gulf Breakout Group led by Dr. Knap and Ms. Tschinkel presented the following PowerPoint slides at the 2016 National Ocean Exploration Forum.

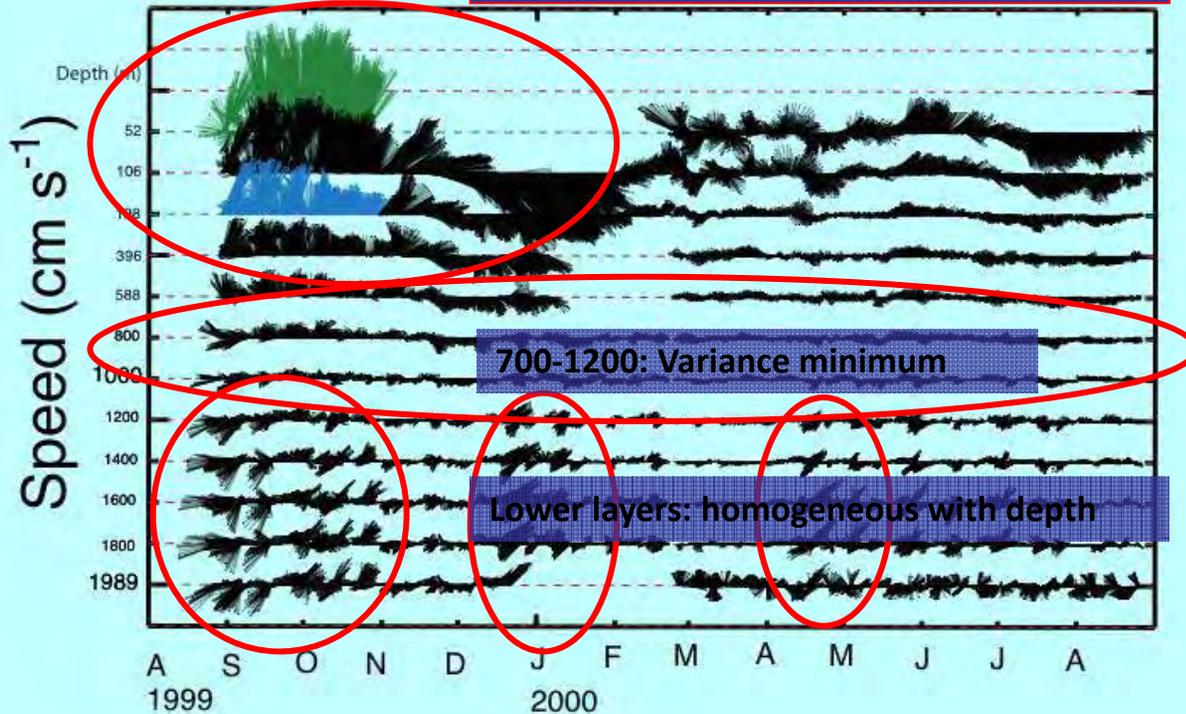
The Gulf of What ???



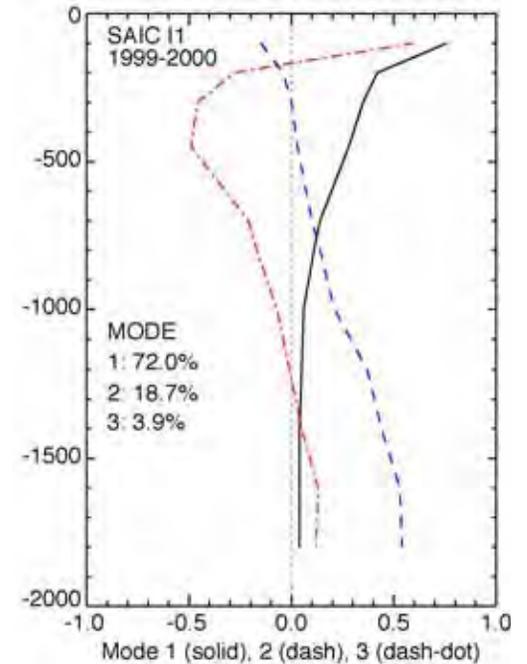
EIS Extension I1: Northeast of Green Knoll



Upper layers: exponential decay with depth



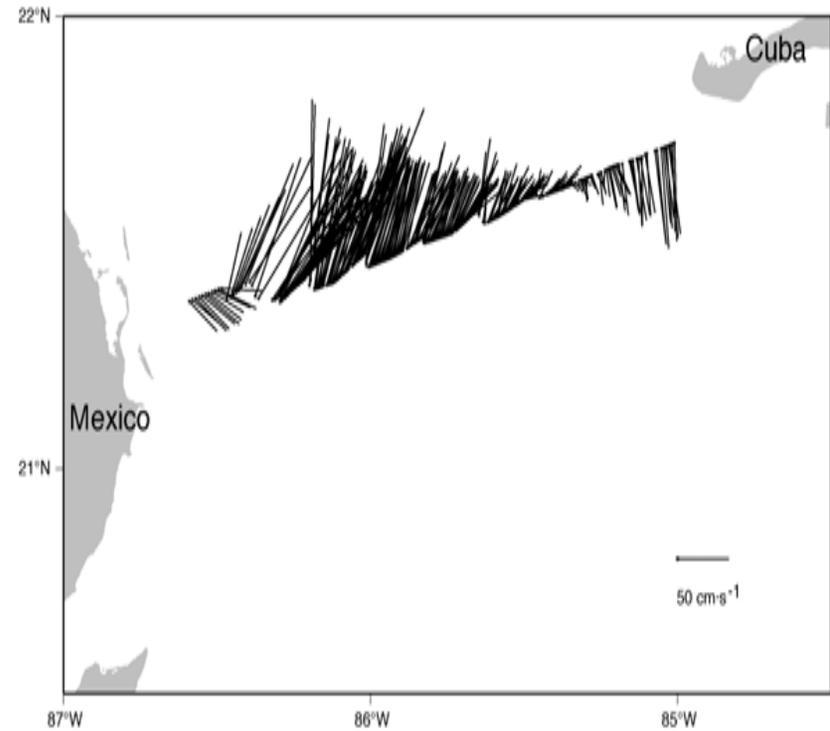
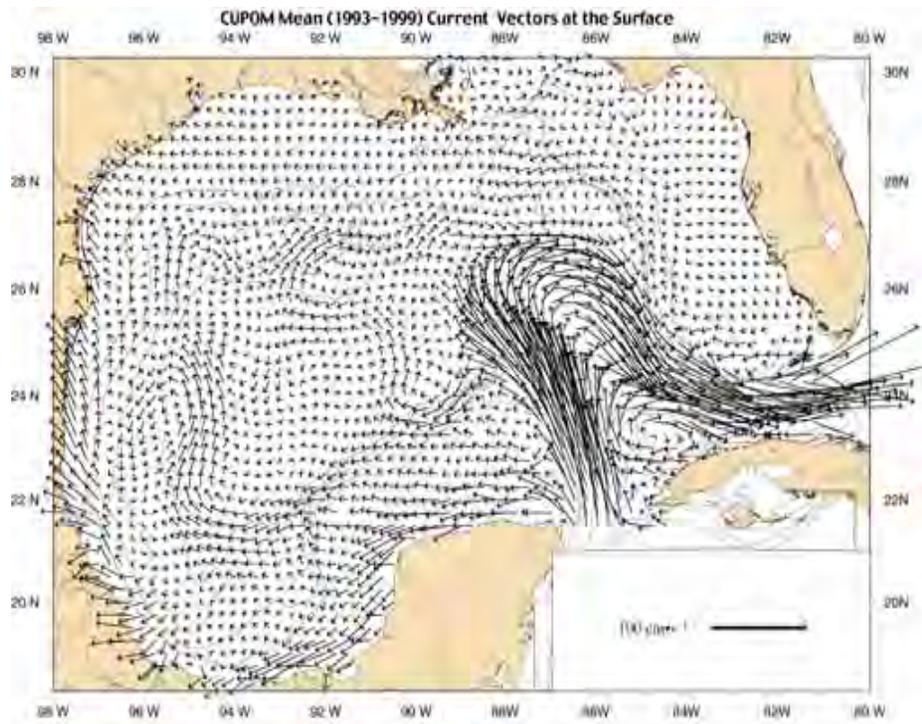
Vertical EOF



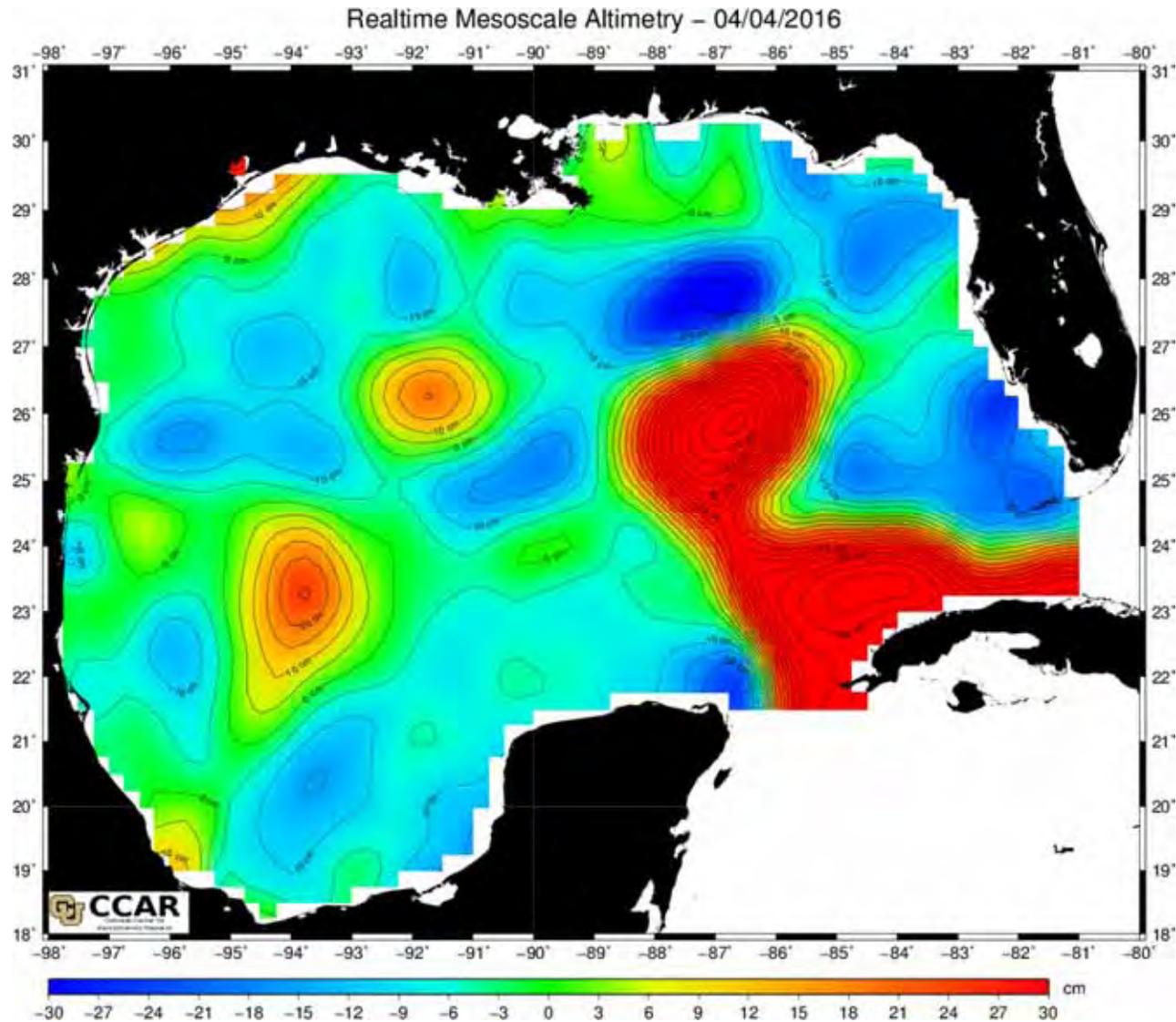
Eddy Juggernaut

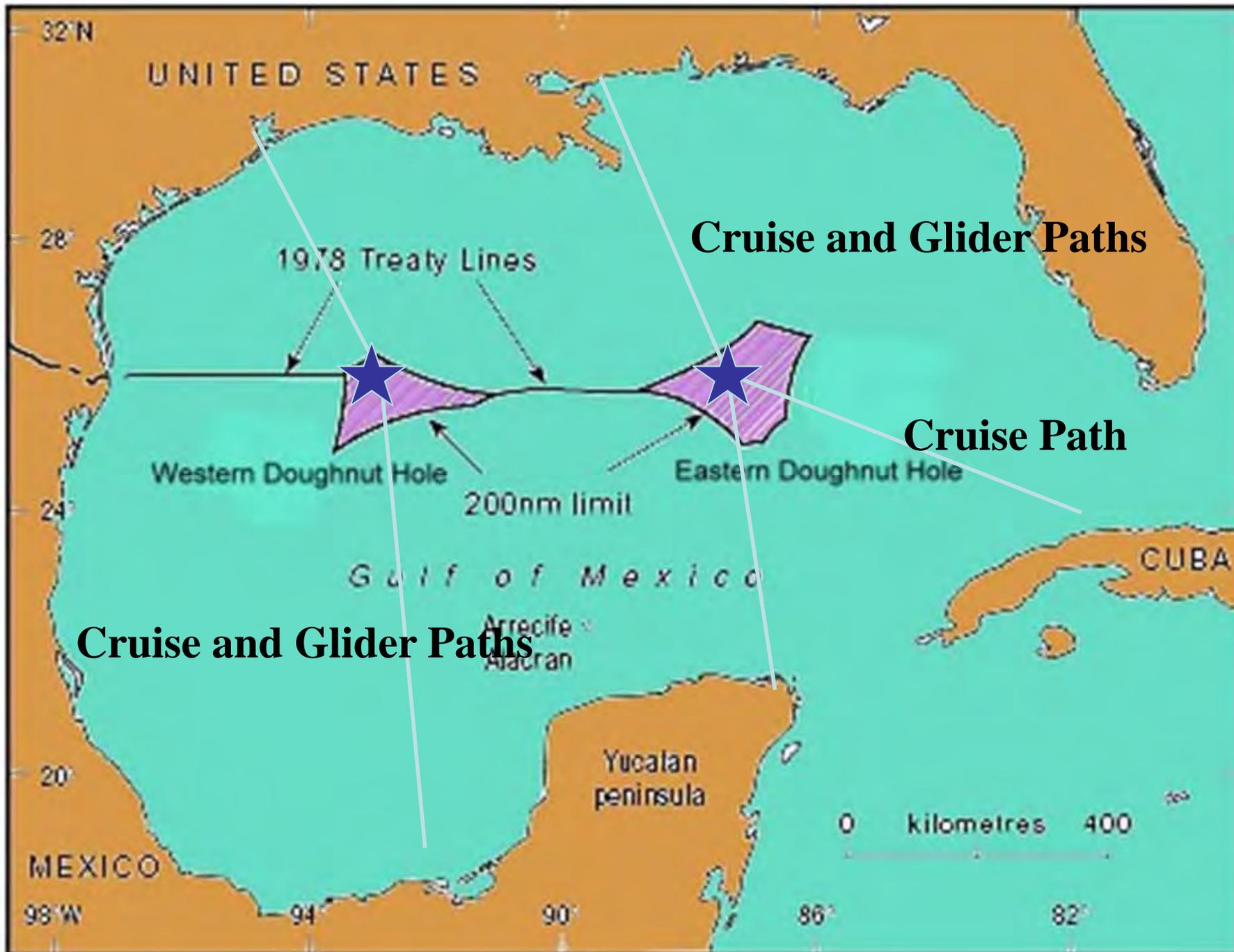
Hamilton and Lugo-Fernandez, GRL 2000
Nowlin, Jochens, DiMarco, Reid 2002

Yucatan Channel velocities



Sea surface height Topex





Cruise and Glider Paths

Cruise Path

Cruise and Glider Paths



Why Explore the Doughnut Holes?

- When Deepwater Horizon happened – we didn't have the environmental information we needed. Here is an area that wasn't damaged we can explore.
 - Pristine, Quiet Waters in an Urban Ocean
 - Test bed for new technologies
 - Demonstration area for exploration
 - Provide baseline for future development
- This is an area where we know a big meteor hit.
- GoM is a valuable resource that needs to be sustainable – life support system.
- Multinational cooperation – US, Mexico, Cuba and Spain

Public Engagement

- Cruise ship measurements
- Camera's on mammals/turtles/tuna– virtual reality educational opportunity
- Untapped Ocean Resources

Find out what we know

- What Seismic mapping exists?
 - BOEM, industry, Navy, IAGC
- Biological Samples
 - Tracy Sutton, Mitch Sogin, Tammy Frank
 - Fisher log-book data
 - OBIS.org (marine mammal surveys, sea turtles)
- Physical
 - BOEM, A&M Atlas, U. Miami, Nav O
 - Satellite (SST, surface currents, winds)

Mapping

- Multi-beam from a ship - If available, use research vessel (likely in the Gulf in 2019)
 - Nautilus or Okeanos
- Use ASV-deployed AUVs
- Broadband multi-beam (in R&D stage now)

Biological Sampling

- CTD cast from ships while mapping (if available)
- Use broadband passive acoustics to get characteristic of a region – all trophic level except phytoplankton
- Put an array down if you have a defined hotspot – such as a shipwreck.
- Pilot for how to use eDNA in this deepwater environment and add to reference libraries
 - Run the test in-situ (look for innovative technologies) and preserve samples for land testing
 - Adaptive sampling

Chemical Sampling

- pH, nitrates, dissolved gas, methane, hydrocarbons,
- Get a sense for the magnitude of the variations – glider to transit continuously through the first year with the use of ASV.

Physical Sampling

- CTD and ADCP from ASV
- Mooring with ADCP to capture the variability beneath the surface.
- Sensors attached to Tuna/Turtles/Mammals (Pressure, Temperature, GPS, for example)

Organization and Funding

- National Ocean Exploration Program – greater organizational plan (interagency setup for planning these campaigns – NIFWIF model)
 - Opportunity to blend money from different sources
 - OceanLeadership to lead this effort
- What assets (people, equipment, \$) are available and how do you access them to have a pool of resources

Gulf of Mexico Issues

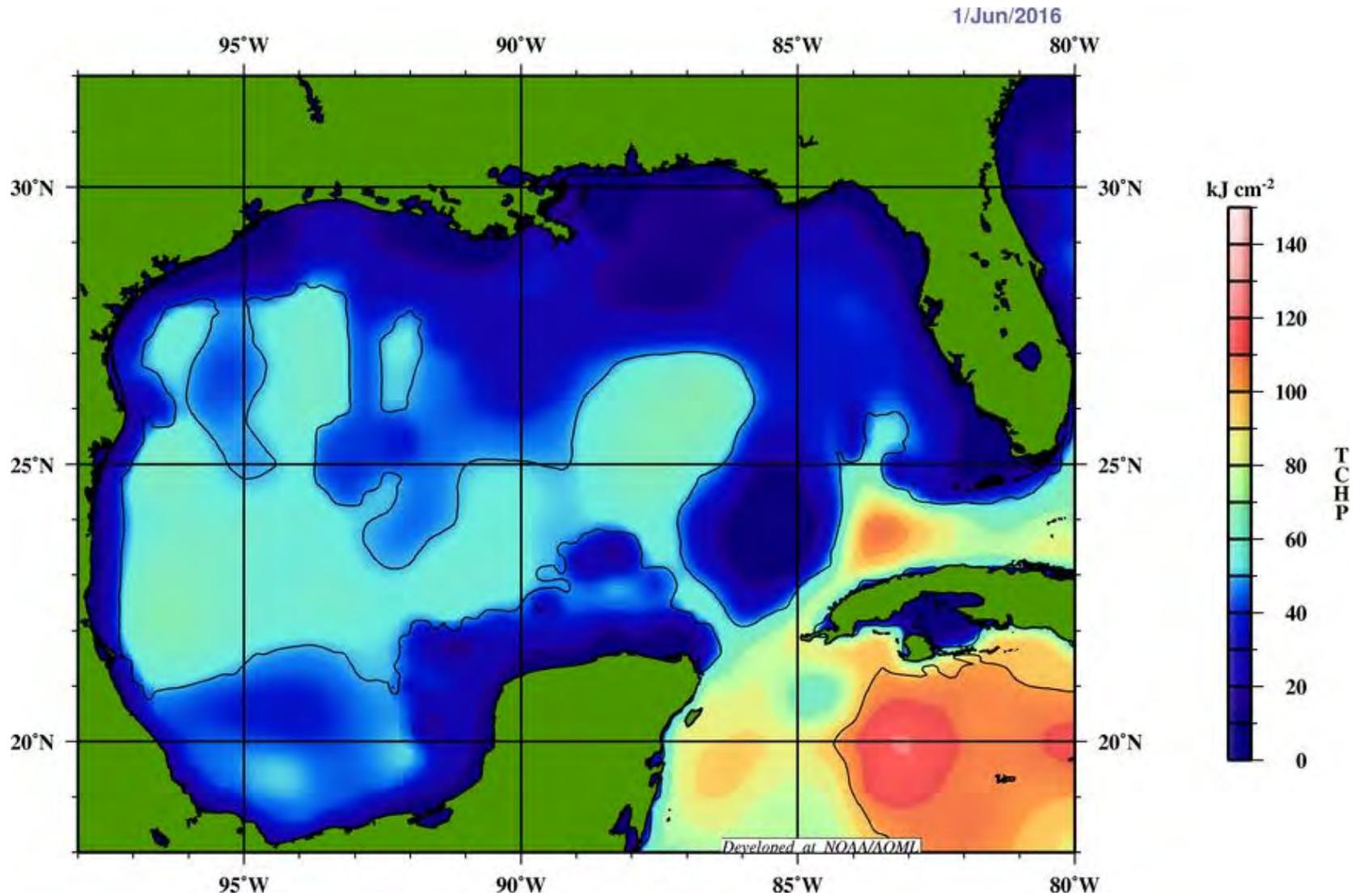
- Sea level rising
- Coastal Subsidence increasing
- Upper ocean heat content increasing
- Atmospheric moisture content rising - Downpours – flooding – misery
- Hypoxia increasing ($<2\text{mg O}_2/\text{L}$)
- Harmful Algal Blooms
- Ocean Acidification (reefs, larvae – affecting fisheries)
- Oil releases ?

Also the longest Drought of major hurricanes ever in the GoM – over 10 years.

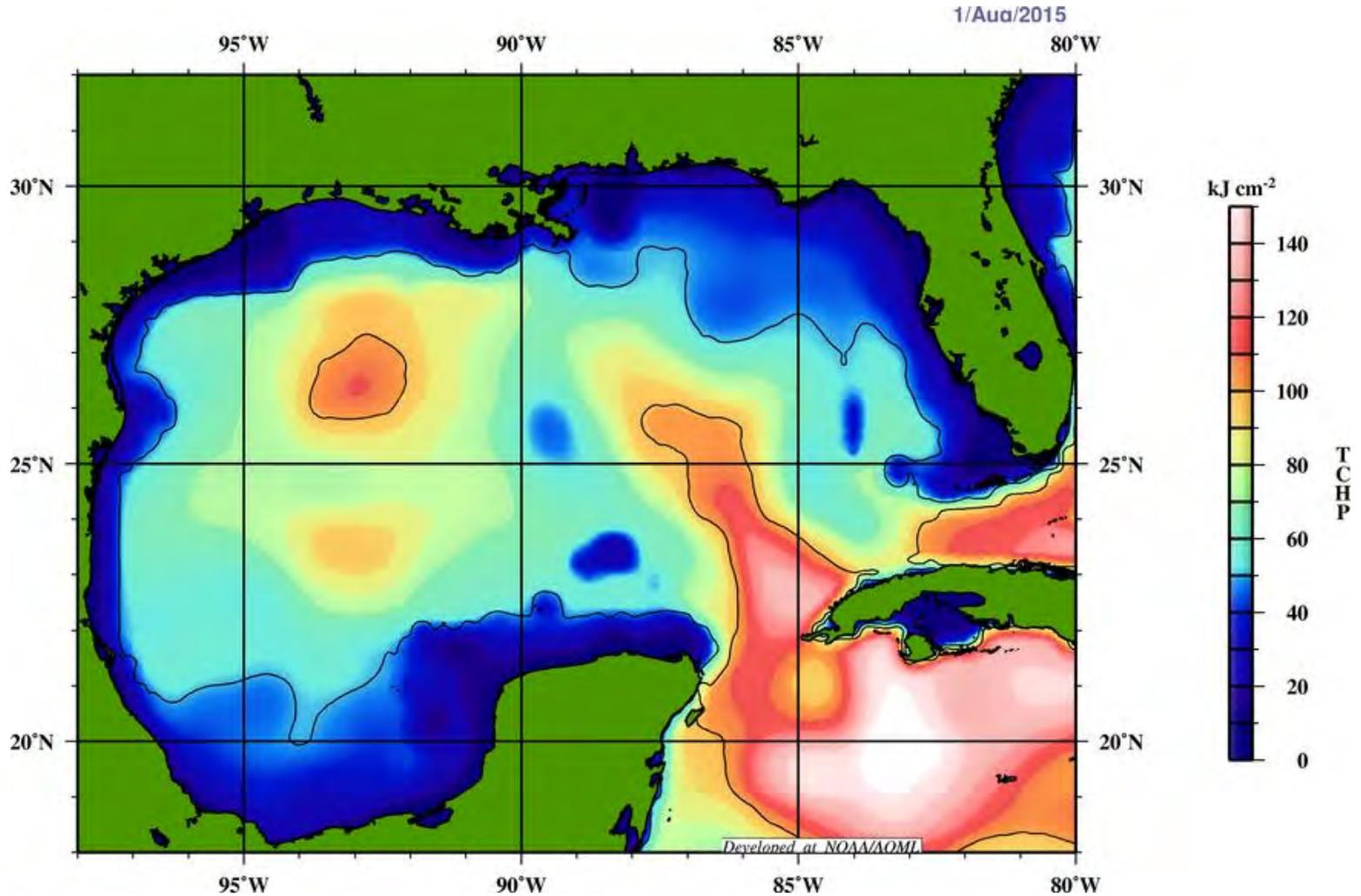
Existing Technologies at GERG



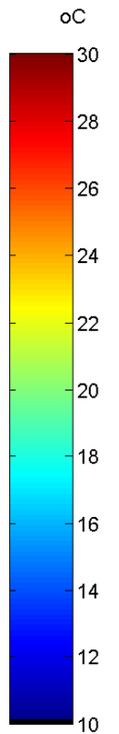
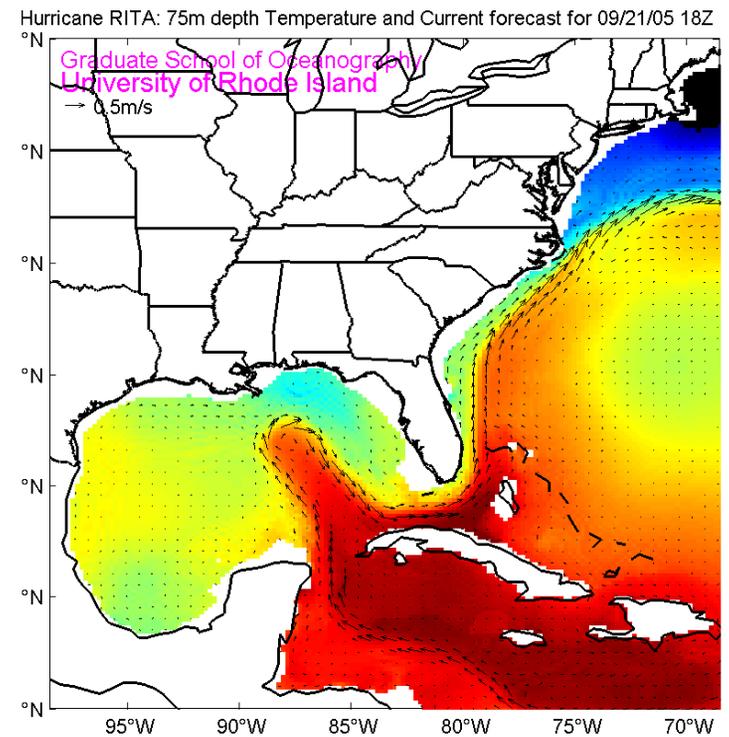
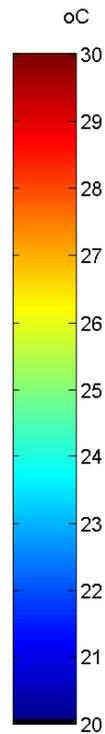
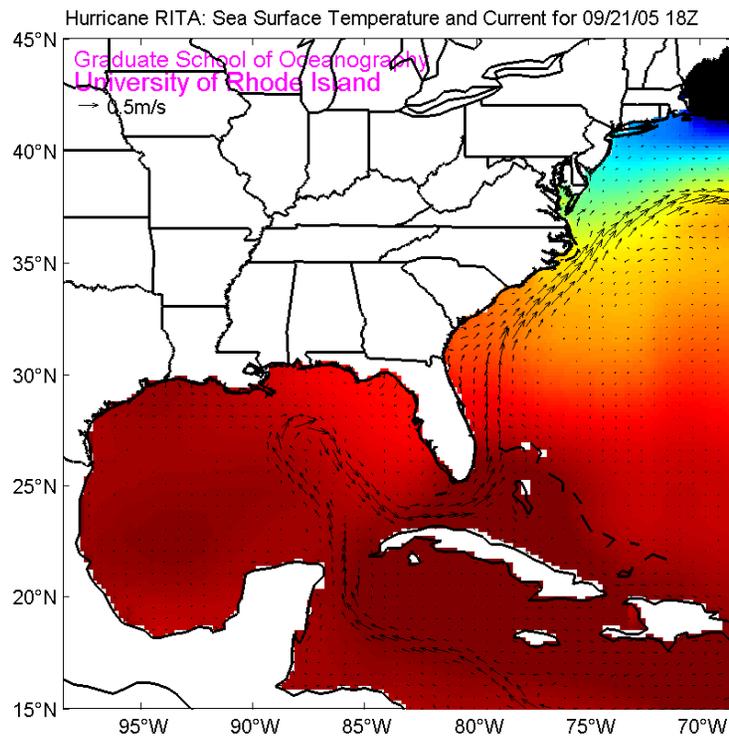
Tropical Cyclone Heat Potential Jun1 2016 (AOML)



Tropical Cyclone Heat Potential Aug1 2016 (AOML)

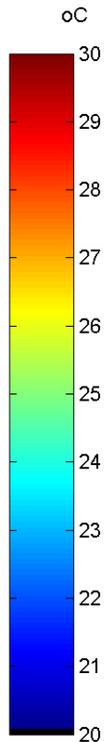
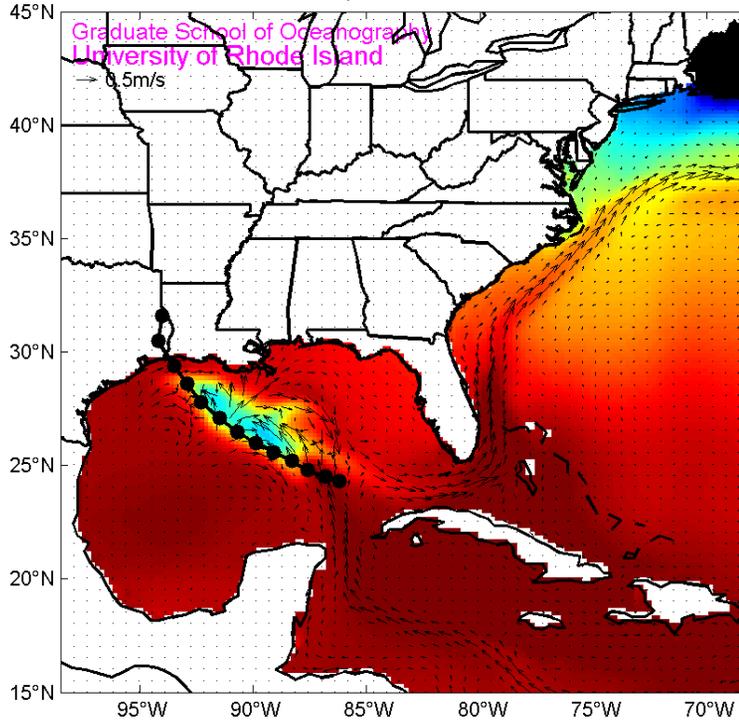


Gulf of Mexico prior to Rita

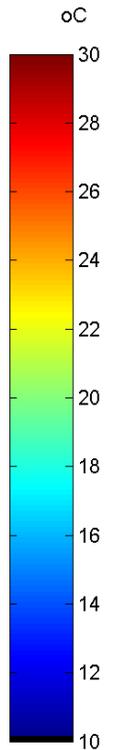
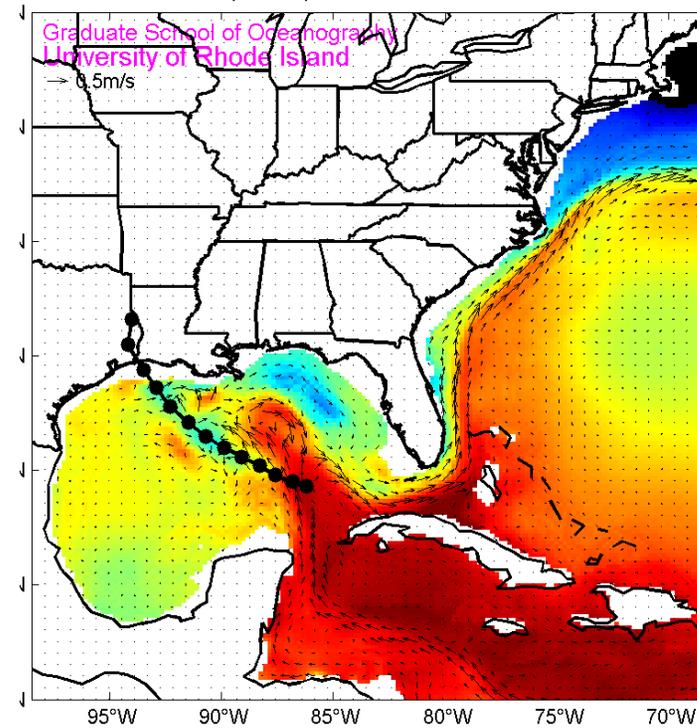


Hurricane Rita

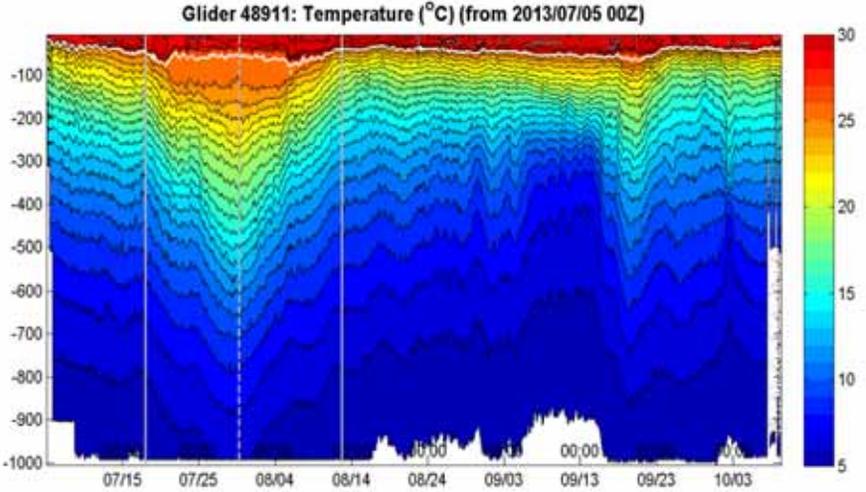
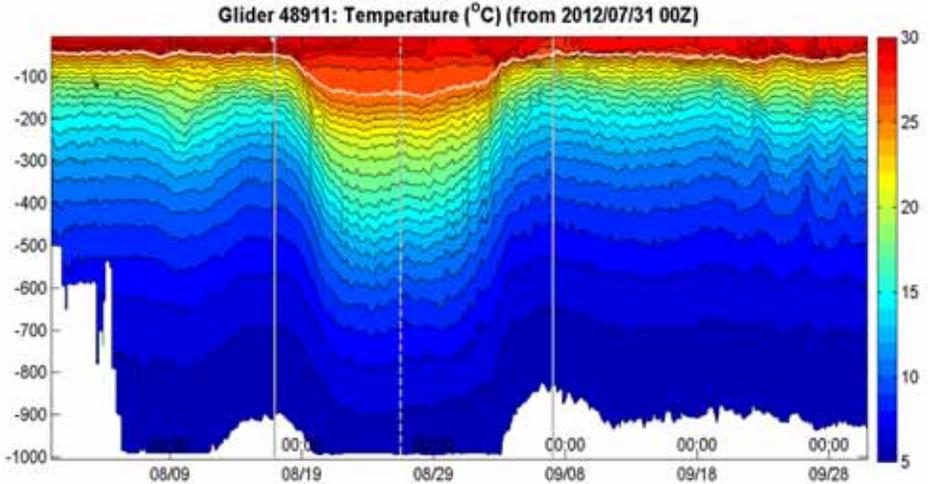
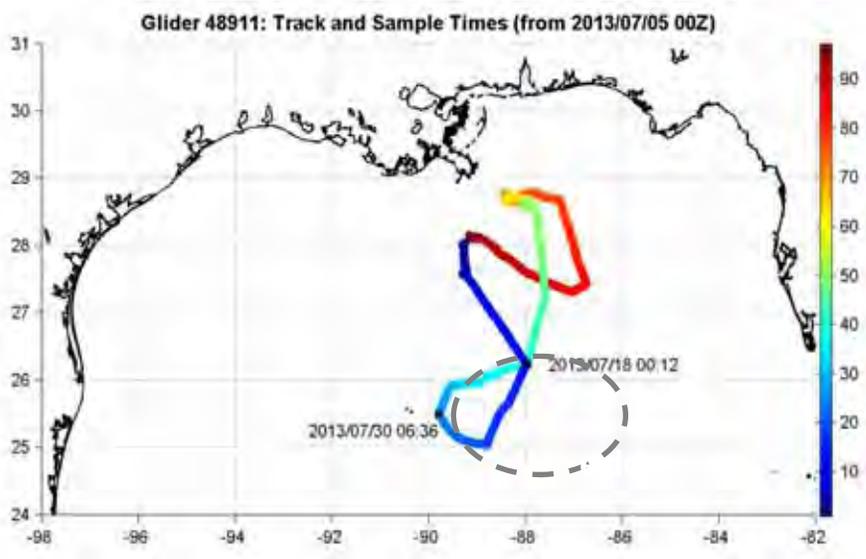
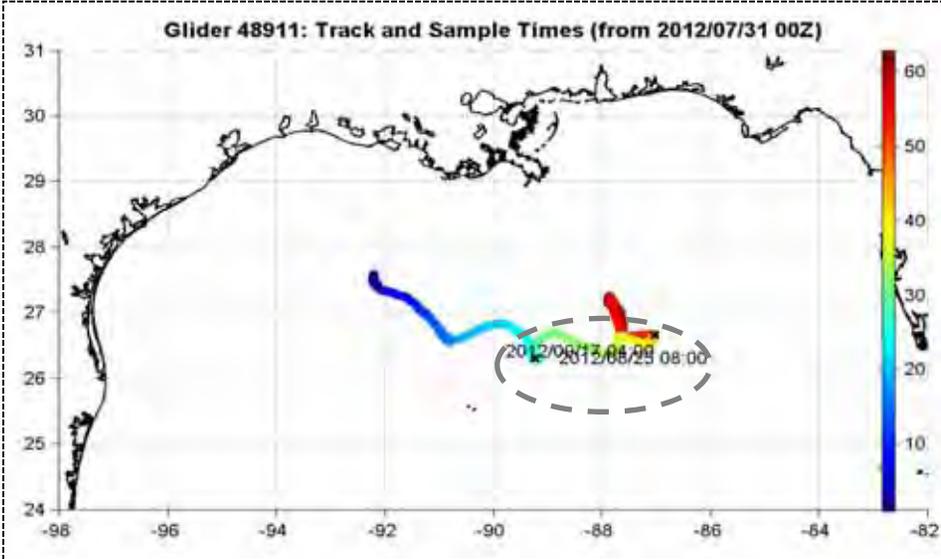
Hurricane RITA: Sea Surface Temperature and Current forecast for 09/24/05 18Z



Hurricane RITA: 75m depth Temperature and Current forecast for 09/24/05 18Z



NOAA Gliders GOM 2012 and 2013 temperature courtesy NOAA



Capable Ship for the GOM



Integrated Ocean Observing System for the GOM (Smart Gulf)

