DEEP SEA TO COAST CONNECTIVITY IN THE EASTERN GULF OF MEXICO: DEEP-C

Consortium Director: Eric Chassignet

ADMINISTRATION

1) CONTRACT ACTIVITY

Per the terms of the Master Research Agreement (MRA), all sub-agreement modifications were approved by Ocean Leadership prior to execution. During year 3, Deep-C:

- Requested and received approval from Ocean Leadership to reallocate $15,946 from the Florida State University Year 3 budget to the University of North Florida subcontract Year three budget in order to support funding for an additional graduate student and defray costs for laboratory procedures at UNF that were originally planned to take place at Florida State University (FSU).
- Requested and received approval from Ocean Leadership to change the PI on the USF/FIO sub-agreement from Jyotika Virmani to Nancy Thompson.
- Requested a time extension from Ocean Leadership to revise the contract expiration date from May 18, 2015 to December 31, 2015 to allow sufficient time for the completion of the original scope of work. Deep-C also requested permission to carry over funds remaining at the end of Year 3 into 2014. Both requests were approved.
- Requested and received approval from Ocean Leadership to reallocate $6,700 from Florida State University to Dauphin Island Sea Lab (DISL). This reallocation supported the fiscal responsibility for NGI interns from FSU to DISL. Also approved was a request to alter the number of NGI internships from a set number to a number that is based on the availability of positions, the suitability of mentors, and the relationship of projects to Deep-C's mission.
- Based on approval of the no cost extension by Ocean Leadership, staff initiated and completed extensions on nine of Deep-C's sub-agreements through a new end date of December 31, 2014. In consultation with Ocean Leadership, it was determined that the subcontract with Leidos could be extended until March 31, 2015, since plans call for all funds and all deliverables to have been provided by the subcontractor by that date.

2) RISKS AND IMPACTS

- None to report.

RESEARCH

1) GENERAL PROGRESS UPDATE

a. Accomplishments

Task 1: Geomorphology

By combining acoustic and image data, Deep-C scientists have been able to develop accurate geological descriptions to characterize habitat, quantify bathymetry, and determine the depth- and slope-dependent variability of the benthic environment. Ongoing collaboration between the Deep-C's geomorphology and modeling groups has provided insight on processes that may influence across-slope flow within channel systems flanking the northern margin of the De Soto Canyon and the reworking and transport of bottom material and water properties both upslope and downslope. Specific Year 3 accomplishments included:

- Completion of preliminary processing of piston core samples collected during earlier geomorphology cruises and collection of an additional set of piston cores from the canyons area during a 2014 cruise. Began planning for XRD and descriptive analysis of this material; this work is still in the early stages.
- Completion of a seafloor mapping cruise in June 2014. Data acquisition included interferometric sidescan sonar (USF), water sampling (VSU and FSU), and shipboard data acquisition systems (CTD, EK60, ADCP, MET) and 12 piston cores.
- Discovery of a species never before recorded in the Gulf of Mexico (Navilithus altivelum) was identified as well as niche parameters for specie assemblages observed. Navilithus altivelum is a rare deep photic species recorded only once in literature by Jeremy Young from samples he took off the coast of Java in the Indian Ocean. It was a surprise coming across it in our samples from a 2013 R/V Bellows cruise at stations P7 and C7. This was the first recorded observation of the Navilithus altivelum species in the Western hemisphere.
- Completion of a 25-day cruise on R/V Walton Smith to investigate the possible injury to mesophotic coral on the Pinnacle Reefs offshore Mississippi and Alabama. We determined that significant numbers of corals suffered injury at a few sites among the mesophotic reefs in the Mississippi Alabama hard grounds known as the Pinnacles. We undertook an analysis of existing sidescan data and other information to determine how widespread the habitat areas occupied by these corals may be in the region of the Gulf shelf.

- Researchers worked to integrate seafloor mapping datasets from shallow geomorphology 2012-2014 surveys. (USF).
- Sponsorship of an independent student, Chelsea Kuhs (Eckerd College) to work on processing and interpretation of sidescan data collected on the recent summer cruise (cruise ID WBII-1413). Researchers and students at USF continue to work on processing swath mapping data from shallow shelf geomorphology cruises.
- Completion of an investigation of channels in the De Soto region with benthic photo platforms and subbottom profilers during the Deep-C sponsored expeditions with Weatherbird II. In 2011, an expedition with the RV Okeanos Explorer

provided unprecedented bathymetric detail for the De Soto region. Among the features revealed were a series of deeply incised channels and we are able now to describe their basic characteristics. We also see clear evidence of substantial down-slope material transport through turbidity flows.

Task 2: Physical Transport

Experimental and fieldwork in physical transport focused on continued analysis of the datasets: floats, temperature, Sailbuoy, and current meters. Specific Year 3 accomplishments included:

- Continued development and bench testing a new multi-sensor, subsurface coastal drifter that provides effective ways to acquire oceanographic data at depths that remote sensing cannot penetrate. (FSU)
- Assembly of supporting data (Lagrangian drifters, satellite altimetry and imagery) for in-depth analysis of the moored observations. (FSU)
- Completion of work on the relative roles of the large scale circulation and wave induced Stokes drift on surface oil movement. (USF)
- Uncertainty quantification experiments on the Lagrangian Oil-Fate Code. The droplet sizes and the sub-grid scale parameters were perturbed and the ensuing impact on oil concentration propagated through the model.
- Deployment of iSpheres and homemade shallow drifters to investigate the difference in their behavior and the effect of Stokes drift at the very surface of the ocean.
- Investigation of the unexplained 15-day oscillations within the De Soto Canyon via wavelet transformation calculations, in collaboration with Joe Kuehl from the GISR consortium and Alexis Lugo Fernandez of BOEM.
- Initiation of quality assurance/control (QA/QC) measures and observational data obtained by Deep-C studies and other GoMRI consortia via moorings and floats were entered into the Leidos database. Integration of the various data sources in order to place moored observations in the context of wider eastern Gulf circulations. A video showing observed surface circulation was generated from satellite derived sea-surface height, surface and deep drifters, and velocities from moorings, in order to visualize the time and spatial evolution of eddies in the eastern Gulf. (FSU, Liedos)
- Continued data analysis integrating hydrography, drifter, satellite, and mooring data collected by Deep-C scientists. (Leidos, WHOI, and FSU)
- Completed uncertainty quantification studies focused on the near -plume dynamics and the far-field oil slick. The plume studies investigated the roles of entrainment parameters, oil distribution parameters, and gas bubble ratio on the plume model output; the results (1) showed that including model error is essential for building a good model surrogate and (2) identified the entrainment coefficient as the primary parameter leading to uncertainties in the trap height. The far-field old slick investigation focused on oil particle size distribution and the oceanic current on the surface oil concentration; uncertainty in oil particle distribution dominated the subsurface oil distribution while uncertainty in the oceanic current dominated the surface oil concentration.
- Completion of analyses of the hurricane Isaac ocean profiles and initiation of work on the air-sea fluxes based on ocean and atmospheric profilers and remotely sensed data from the aircraft during Isaac following the same approach that was used in hurricane Earl. (UM-RSMAS)

- Successful use of AXCPs repaired based upon Deep-C research during hurricane Edouard with high levels of success. Through detailed testing and working with the vendor, modifications were made to the airborne canister to improve the profilers' performance in the field. This testing also included a test flight where we physically pick-up the remains of the canister from a boat after deployment from research aircraft. Success rates increased by 30 to 35% from those deployed during the Deepwater Horizon flights between May and July 2010.
- Completed comparison of results from the Northern Gulf of Mexico model with salinity fields from the Sailbuoy (deployed March 2013). Model results were in agreement with Saibuoy data, demonstrating the potential to launch the instrument for rapid assessment of plume variability.

Task 3: Biogeochemical Effects
Through a series of ongoing field and laboratory experiments, Deep-C scientists have completed a number of detailed analyses and assessed the effect of key biogeochemical indicators. Specific Year 3 accomplishments included:

- Evaluation of data from the field work in December with chamber deployments in the sublittoral at Pensacola Beach and analysis of DIC, DOC and chlorophyll samples.
- Evaluation of gas chromatography data from beach samples measured over the last three years in order to quantify degradation rates of specific short chain compounds.
- Completion of Hg stable isotopic ratios in Tilefish muscle and liver was completed. Fish sampled close to the well head (47-68km) displayed significantly lower Hg species concentration in their tissues, and Hg isotopic composition indicated that different processes affected the Hg cycle and its accumulation and distribution in the fish tissues compared to fish caught >109km from the well head. Lower bioaccumulation rates of MMHg in muscle and both inorganic Hg and MMHg in the liver for fish living close to the well head indicated a possible modification of Hg bioavailability at the basis of the food chain or a different trophic level. In addition, it is possible that a lower feeding rate and reduced metabolic and physical conditions caused by the oil spill (Incardona et al, 2014, PNAS; Mager et al, 2014, ES&T) affected Hg metabolization and distribution in fish organs, as reflected by differences between liver and muscle at the different sampling stations along a well-head distance gradient. Findings indicated that the Deepwater Horizon spill clearly affected the Hg-cycle.
- Completion of a field experiment addressing oxygen consumption and carbon dioxide production in unsaturated beach sediment at Pensacola Beach. We started second laboratory column reactor experiment addressing oxygen consumption and carbon dioxide production in unsaturated Pensacola Beach sediment with oil contamination
- Characterization of oxygenated species in weathered Macondo oil (Energy & Fuels 2014, 28, 4043-4050).This analysis combined electrospray and atmospheric pressure photoionization FT-ICR mass spectrometry and time-of-flight mass spectrometry along with two-dimensional GCxGC analysis of anion-exchange chromatographic fractions to demonstrate the presence of O1-O8 ketones. Prior MS analysis showed only that oxygen-containing species were present, but not their functional form (e.g., alcohol/ketone/carboxylate/etc.). Detected and identified nickel and vanadyl

petroporphyrins in petroleum from oil seeps (Energy & Fuels 2014, 28, 2454-2464) — prior methods required chemical purification to detect porphyrins.

- Participation in a late summer research cruise. Sediment cores from this cruise were sub-sampled for radiocarbon, %carbon, 13C, metals, microbial community analysis, bulk density, grain-size and radionuclide analysis to determine sediment accumulation rates.
- Continued collection of oil spill patties along the northern coast of the Gulf of Mexico as part of a long-term monitoring program; processed more than 200 samples from historical archive of Gulf coast samples looking for weathering trends.
- Multiple field and lab beach oil degradation studies. Field studies determined sublittoral oxygen flux assessing the impact of deposits of oil snow, pelagic algae, and the combination of oil snow and algae on benthic respiration. Laboratory column reactor experiment addressed oxygen consumption and carbon dioxide production in sands, the role of moisture on oil degradation in beach sediments, the role of mechanical stress on tarball degradation in shallow shelf environments, and evaluated bioturbation and hydrocarbon release from tarballs under turbulence.
- Assessment of the light stable isotopes of carbon, nitrogen, sulfur, and mercury in the muscle and liver tissues of Greater Amberjacks (Seriola dumerili) Cutthroat eels (Synaphobranchus oregoni; CTE), King snake eels (Ophichthus rex; KSE) from oiled and non-oiled areas. Mercury isotope analysis of liver-muscle couples in these species revealed no consistent hepatic fractionation effect and revealed that the mercury source at depth (+1,000 meters) underwent a higher degree of photodegradation than the mercury source ingested by amberjacks and KSE on the shelf.
- Examination of the trophic structure and feeding ecology of hagfishes from the Gulf of Mexico collected quarterly from 2011-2014, using δ13C, δ15N and δ34S stable isotope analysis and molecular genetic analysis.
- Continuation of the laboratory column reactor experiment addressing oxygen consumption and carbon dioxide production in unsaturated Pensacola Beach sediment
- Continuation of the experiment on the role of mechanical stress on tarball degradation in shallow shelf environments and initiated measurements on tarball softness as key parameter for their degradation.
- Completion of analyses on 185 Kirby oil spill samples (collected during two sampling efforts), which occurred in Galveston, TX in March 2015 and finished lab work on the chemical composition of the oxidized compounds in oil samples. The unknown petroleum hydrocarbons were determined to be from creosote.

Task 4: Ecological Effects

The ecological component of Deep-C research focused on time series that define changes in community structure and function associated with the DwH blowout and its aftermath, while developing post-spill baselines of heretofore-unstudied environments and informing the food web model. Specific year 3 accomplishments included:

Community Profiles

- Community composition of two microbial groups – *Rhodococcus* and *Halomonas* – correlated with core depth and water column depth and revealed bacterial strains that can be used as indicators of hydrocarbon degradation and as models for understanding the ecophysiology of deepsea hydrocarbon metabolism.

- Preliminary results from three-year time series of deep-ocean sediment microbial and foraminiferal populations revealed that benthic communities structure along O^2 and redox gradients, likely controlled by carbon delivery. These data, coupled with studies of rates and controls of biodegradation, revealed: (1) that in surface waters, biodegradation is limited by N and P availability, with significant rates of CO^2 produced only in enriched treatments; and (2) that in deep sea sediments, degradation rates increased six-fold when enriched (a Deep-C and C-IMAGE collaboration)
- Documented 90+ species of coccolithophores, 123+ species of diatoms, and 29+ species of dinoflagellates, including new records in the Gulf of Mexico, a new species, and 4-6 new subspecies. 75% of the foram species captured were known to occur in the Gulf whereas 75% of the ciliate species represented new records.
- Analyses of depth profiles collected along WFS transects revealed dominance shifts from the diatom *Nanoneis cf. longta* (> 275,000 cells/l at 30 m) in September to the coccolithophorid *Emiliania huxleyi* in December. They also confirmed the presence of a distinct deep phytoplankton association (e.g., *Nanoneis cf. longta* >150,000 per liter at 46 m) at the shelf edge near the mouth of the De Soto Canyon, which may indicate the influence of local flow regimes in the region.
- Analysis of ~75 million rRNA gene sequences of benthic microorganisms in deep sea sediments revealed that community structure in replicate cores from a single multicore cast were similar within the top 1 cm, decreasing in similarity with depth. Community differences among different casts at the same sites are as great as those found among sites across the entire northern Gulf, suggesting that adequate representation of community diversity is only obtained by making multiple casts at each site, considering casts, rather than cores, as replicates.
- Completed the 10th GoMRI-funded research cruise documenting the effect of the oil spill on large deep-water (200-2,000 m) fish communities. Cruises resulted in sampling more than 4,000 fishes from 101 species, including 34 species of sharks and rays making this the largest survey of deep-sea elasmobranch fishes ever conducted in the Gulf of Mexico. These samples provide critical life history information and data on heavy metal contamination for a suite of significantly understudied species.

Biodegradation and Toxicity Studies

- Completed experiments revealing the presence of psychrotolerant and psychrophilic microbes in De Soto Canyon sediments capable of degrading MC252 crude oil at 4°C.
- Results from studies of specific hydrocarbons biodegradation rates in seawater and sediment samples from the northern Gulf revealed that biodegradation rates were nutrient limited, while temperature had less of an effect.
- Trials evaluating the toxicological effects of Macondo crude oil, Corexit® EC9500A, and dispersed oil (a mixture of the two) on the biodegradation potential of oil-degrading bacterial isolates, *Acinetobacter* and *Alcanivorax* (grown on either crude oil alone or dispersed oil) revealed that the presence of Corexit had no significant effect on biodegradation by *Acinetobacter*, but reduced the biodegradation potential of *Alcanivorax* by 20%. Conversely, acute toxicity tests conducted on the marine rotifer *Brachionus manjavacas* revealed that *Acinetobacter*-inoculated dispersed oil had significantly higher toxicity than uninoculated controls, whereas *Alcanivorax*-inoculated dispersed oil had slightly reduced toxicity compared to uninoculated controls. Overall, this suggests that if

Alcanivorax preferentially degrades Corexit over oil, it would explain the decreased toxicity and consequent reduction in oil-degradation potential.

- Examination of the spatial and temporal differences in PAH biomarkers of exposure(cytochrome P4501a1, the most reliable; glutathione-S-transferase (GST); biliary PAH metabolites) in fishes (N = 569 elasmobranchs, 294 teleosts - the first, long-term examination of biomarker trends in abundant teleosts) collected 12-42 months after the DwH blowout, including the more abundant sharks (gulper shark *Centrophorus granulosus*, shortspine dogfish *Squalus mitsukurii*) and bony fishes (tilefish *Lopholatilus chamaeleonticeps*, Gulf hake *Urophycis cirrata*, and Southern codling *U. floridana*). Our results reveal (1) that biomarker levels in specimens collected from oiled sites were significantly higher than those from specimens collected from non-oiled reference sites (e.g., in *S. mitsukurii* and *Urophycis spp* which occurred at both sites); (2) that *U. cirrata* biomarker levels declined with distance from the spill site (Macondo); (3) that biomarker levels (i.e., GST and biliary PAH metabolites) in the more abundant elasmobranch species increased 27-39 months after the oil spill, and then declined in later months while in the more abundant teleost species, biomarker levels were higher earlier in the sampling period (16 months after the oil spill), and declined thereafter: and (4) that PAH exposure was higher in animals closer to the wellhead than in those further away, while animals in close proximity exhibited increasing levels over time initially that indicated continued exposure.

Trophic Ecology and Models

- Results from studies into the effect of isotopically-light lipids and urea found in fish muscle of coastal and deepwater sharks and teleosts on stable isotope (δ13C and δ15N) and methylmercury analyses revealed: (1) that lipid removal from tissues prior to analysis was warranted and obligatory because its presence biased analytical results and therefore the determination of trophic level; and (2) that urea removal was unnecessary because it introduced no bias.
- Began incorporating trophic data into the Atlantis model with the completion of code development that automates the Atlantic model map conversion, and parameterization.
- Developed an rglobi R package with Jorritt Poelen (working the GOMEXSI team) and the Ropenscience network for the food web model and species interaction data. The rglobi package is now available via github (https://github.com/ropensci/rglobi).

Task 5: Earth System Model (ESM)

Modeling efforts focused on putting together the various elements of the Earth System Model. Specific year 3 accomplishments included:

- The Gulf of Mexico Forecasting System (GoM-FS), which incorporates a two-way coupling between the ocean and the atmosphere, was implemented and configured to perform forecasts once a day (extensible to four times a day) at 00 UTC. Results are integrated into the Deep-C Map Viewer tool. The forecast system is being transitioned to near-real-time.
- Hydrodynamic, atmosphere, and biochemistry modeling components were integrated into the COAMPS-COSINE Earth System Model. Simulations with this coupled system exhibit interesting bio-optical ocean response to air-sea interactions. Preliminary results are being investigated further to understand the complex bio-physical interactions as they

respond to air-sea coupling perturbations. These simulations also revealed that the COSINE bio-optical model is deficient in the vicinity of the Mississippi River and implementation of river nutrient fluxes are needed to produce more skillful results in this area.

- A toolbox of support routines was written for the Deep-C oil spill model. This toolbox consists of program that allows users to generate forcing from HYCOM/ROMS ocean models, the NOAA Global Forecast System and the Wave Watch models. These tools were made available along with the Deep-C oil model for general use and will also facilitate the coupling of the oil model to the Deep-C Earth System Model. We also made progress on using the Deep-C model and the method of polynomial chaos to propagate the input uncertainty in the droplet size distribution and quantify its impact on the oil-fate model forecast.
- New techniques were developed for comparing modeled river plumes to satellite optical data employing a modified Hausdorff distance metric. This metric is being used to evaluate multiple models, including the northern Gulf HYCOM, the NRL Gulf of Mexico HYCOM, and the DeSoto Canyon ROMS. This validation is being done in conjunction with studies of the three-dimensional Mississippi River plume structure using models and *in situ* observations in the Northern Gulf..
- The upwelling and downwelling across the continental slope in the De Soto Canyon region was characterized statistically and explained dynamically. This work analyzed data from a realistic multi-decadal numerical simulation of the Gulf of Mexico to show likelihood of upwelling/downwelling of different vertical and cross-shore extents, relationship of upwelling/downwelling to local wind variability, and relationship to offshore mesoscale circulation including local and remote impacts from the Loop Current and eddies. The results are synthesized into a master's thesis (T.-T. Nguyen) and have been submitted to a journal for review.

b. Obstacles

- A GRIIDC procedure was needed for registering datasets that will change dynamically (e.g., day to day). *Corrective measures:* The Deep-C data manager brought this issue up for discussion during the July 1 GRIIDC teleconference.
- Some CTD data for December 2013 samples on RV Bellows was determined to be unusable in the format uploaded to the Data Center. *Corrective actions:* The data center worked to determine if the original files were corrupted and came up with options to remedy the issue with the co-PI so the data can be accessed and used.

c. Collaborations

Networking and cooperation with organizations outside of Deep-C resulted in numerous collaborations that extended our reach, enhanced our efforts, and accelerated our progress. Deep-C scientists worked with **U.S. Geological Survey (USGS)** to conduct radiocarbon analysis of sediment trap samples and with both the USGS and **NOAA** to coordinate a 20-day cruise on R/V Walton Smith in order to investigate the condition of mesophotic coral reefs. Other collaborations with NOAA included efforts to: 1) serve the Gulf of Mexico Climatological products being constructed at NRL using model and satellite derived fields; 2) improve river mass transport and riverine flux formulations in ocean models; as well as 3) a joint effort investigating the frequency of injury possibly resulting from the DwH oil that reached the outer shelf hardbottom habitat offshore Mississippi and Alabama.

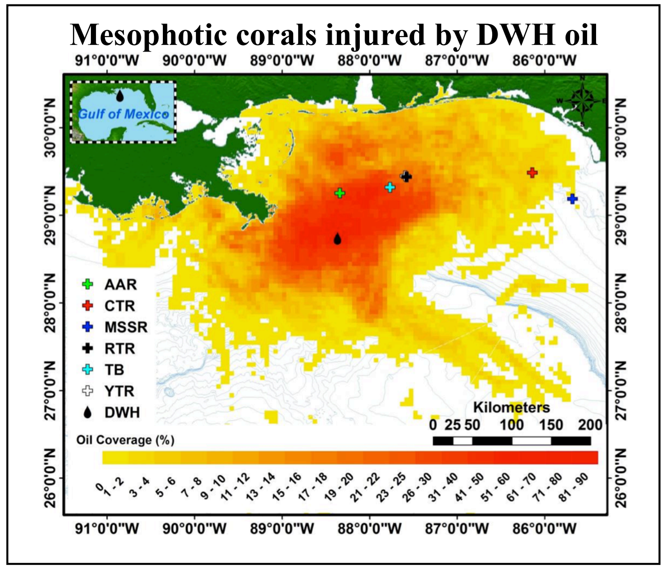
Additional collaborations included work with: **the Colorado Center for Astrodynamics Research, University of Colorado** to assess the uncertainty of Loop Current metrics using our multi-decadal simulation with the HYCOM model and altimeter observations; **Valdosta State University**, on the biomechanics and functional morphology of hagfishes; **Iowa State University** to leverage work on the Atlantis model to provide input to new economic models considering optimal management strategies for Gulf of Mexico Reef Fisheries (New Lenfest grant); the **USM Center for Excellence**, primarily in the use and processing of ocean color data relating to the Gulf of Mexico; and with **Scripps-University of Washington** on review of the 2013 SailBuoy experiment dataset. WHOI scientists, in particular, initiated several fruitful collaborations during year 3, including work with: P. Clement (**Auburn University**) to submit a small note to Marine Environmental Research on the status of the patties and comment on future work; and the **National Oil spill Response School, Texas A&M University, Corpus Christi)** to facilitate collection of additional oil samples from beaches impacted by the Kirby spill.

Outreach personnel worked closely with **Alma Bryant High School Coastal Studies Academy** (Signature Academy in the Mobile County School District) to provide an internship experience with the Deep-C ROV program at DISL. Other outreach-related collaborations initiated in year 3 included: the Boys and Girls Club,

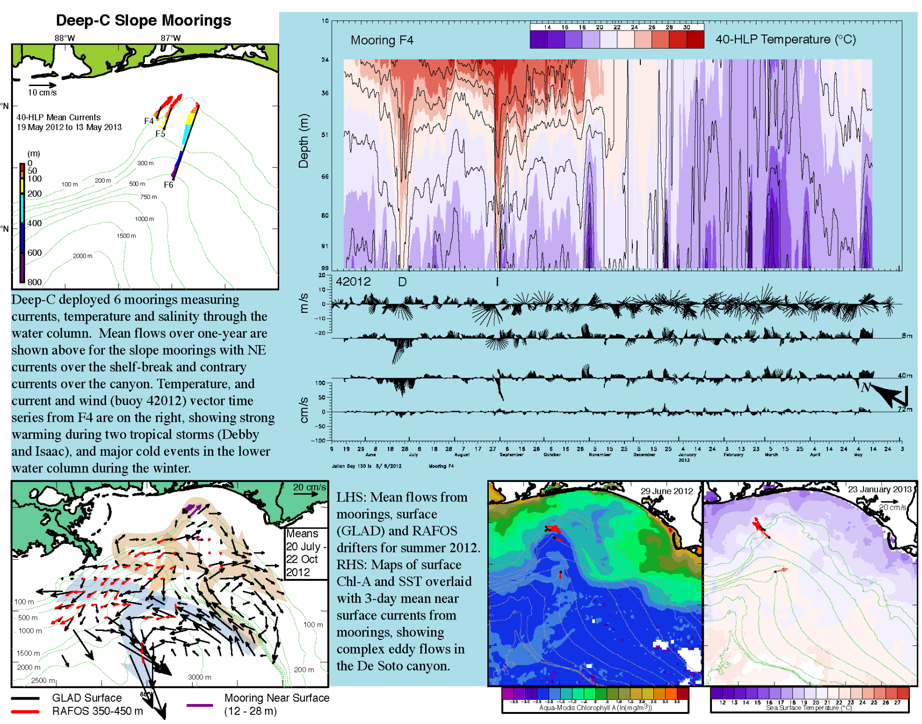
Collaborations with other GoMRI-funded consortia encouraged the development of innovative and groundbreaking strategies in our shared areas of interest and accelerated the pace of research, to mutual benefit (including GOMRI). Notable inter-consortia work during year 3 including collaboration with ECOGIG's Joe Montoya and Sarah Webber on a research paper about the Hercules Gas Well Blowout and GISR researcher Joseph Kuehl (Texas A&M/Baylor University) to identify potential areas for collaboration on which each consortium will work conjointly via the different and complementary datasets. Both Deep-C and GISR have mooring data, as well as SailBuoy data, drift cards trajectories and Stokes Drift calculations via NODC buoys. Another Deep-C/GISR collaboration was with S. DiMarco (GISR) to work on the hurricane Isaac data set.

RESULTS TO DATE AND SCIENTIFIC HIGHLIGHTS

Theme 1: Physical



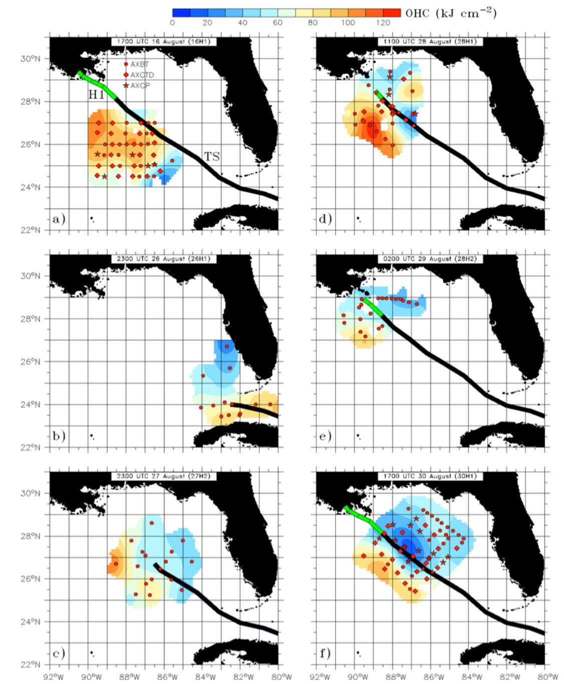
- A collaboration with the NOAA Ocean Exploration program targeted De Soto Canyon for a high-resolution bathymetric survey. Results were used to establish an array of sampling sites subsequently occupied by investigators in the Deep-C and C-IMAGE consortia.
- Impacts of the Deepwater Horizon oil to benthic communities were observed in the outer shelf regions. Two important implications were the following: 1) This oil reached the impacted area via the surface layers, not the mid-water plume. 2) Slow-growing corals will require a lengthy period of recovery.
- FSU developed a unique survey platform, MILET, for collecting geo-located images and subbottom profiles of the De Soto Canyon. Notably, an opportunistic MILET survey of a small mound at 2000m depth where the Ocean Explorer cruise had reported gas bubbles unexpectedly yielded discover of an asphalt seep, the first known report in the eastern Gulf. Generally, however, there was far less evidence of natural oil seeps in the Eastern Gulf.
- Deep-C deployed six moorings measuring currents, temperature and salinity through the water column. Observations reveal eddies and turbulent transport.



Deep-C deployed 6 moorings measuring currents, temperature and salinity through the water column. Mean flows over one-year are shown above for the slope moorings with NE currents over the shelf-break and contrary currents over the canyon. Temperature, and current and wind (buoy 42012) vector time series from F4 are on the right, showing strong warming during two tropical storms (Debby and Isaac), and major cold events in the lower water column during the winter.

LHS: Mean flows from moorings, surface (GLAD) and RAFOS drifters for summer 2012. RHS: Maps of surface Chl-A and SST overlaid with 3-day mean near surface currents from moorings, showing complex eddy flows in the De Soto canyon.

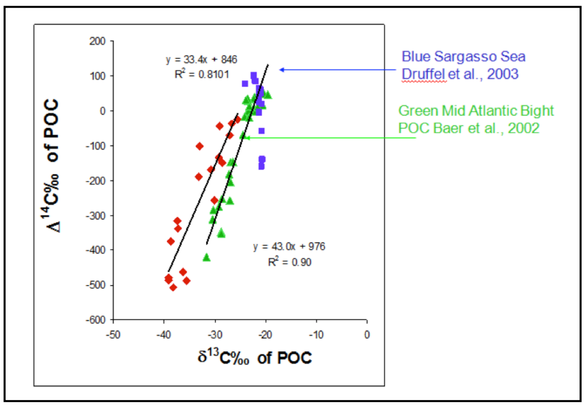
- Research revealed that upwelling response to tropical cyclones is significantly impacted by the geostrophic eddy field. In addition to translation speed, this response is a function of the curl of wind-accelerated geostrophic currents, rather than just a function of the curl of the wind stress. Results underscore the need for initializing coupled numerical models with realistic ocean states to correctly resolve the three-dimensional upwelling-downwelling responses and improve intensity forecasting. From a broader perspective, these results indicate that it is critical to reproduce realistic mesoscale eddy fields in ocean models (including correct initial conditions), for these models to better reproduce the vertical velocity response to wind forcing events. *Vertical velocities over the upper ocean play a key role in the transport and dispersion of nutrients, larvae, suspended mater and oil products throughout the water column.* Velocities attain maximum values during and in the wake of major wind-forcing events.



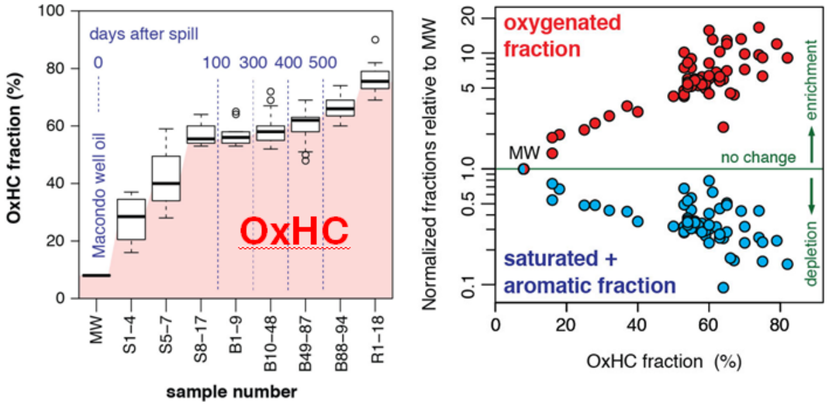
Observed mesoscale eddy field during the passage of Isaac. Red and blue shading is associated with anticyclonic and cyclonic ocean eddy features.

Theme 2: Chemical

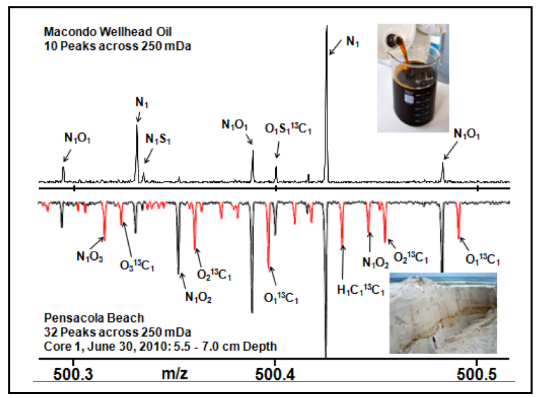
- Radiocarbon analysis indicates that a lower limit of 3-5% of the oil released by the DwH event was deposited on the seafloor. This finding accounts for a portion of the missing oil. Sediments may serves as long-term storage of hydrocarbons for unknown periods of time affecting the benthic fauna.
- Fossil carbon from the oil spill entered the food web. This appears to have happened primarily via methanotrophy. Further evidence for the impact of methanotrophy is evidenced via the uptake of methane in to particulate organic carbon. Isotopic signature of POC appears to be a good indicator of seepage impacts.



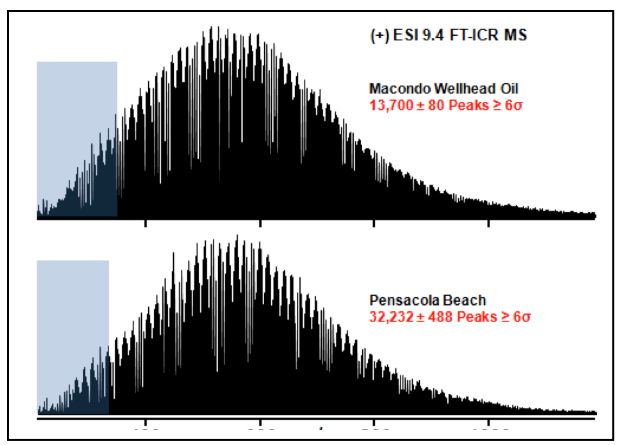
- A new pool of non-native, transformational products in the Macondo well oil was identified: oxygenated hydrocarbons (OxHC) and catalyzed numerous fields of study to investigate the OxHC. We observed a disappearance of Sat + Ar and concurrent relative increase of the more polar compounds, which we call OxHC. However we did not see any increase in compounds in GC-FID.



- We can now isolate the transformation products as a function of structure (aromatic vs. nonaromatic) and chemical functionality (ketone, alcohol, carboxylic acid…) The Macondo well oil (MWO) was quickly oxidized after entering the environment. This oxidation generated tens-of-thousands of ketone, alcohol, and carboxylic acid containing hydrocarbons. Thus, any impact study that employs the unweathered MWO will grossly underestimate the complexity (and chemistry) of the environmentally relevant MWO contaminant. Separation methods now allow for isolation and subsequent dosing of microcosms with structurally and chemically defined fractions to ascertain each variable's effect on toxicity. Thus, the most impactful transformation products can be specifically studied in great detail and without artifacts that might arise from uncontrolled (unknown) contaminant composition.



- FT-ICR MS can successfully target polar, high-boiling species in environmental samples and clearly shows that weathering generated nearly 20,000 new basic species that were not native to the parent MWO. Analysis of the same samples for acidic species reveals another 30,000 new species. This means that all of these new species are not GC-amenable. Thus, environmental transformation generates tens-of-thousands of new compounds that were previously unobservable at the molecular-level. To track these transformations and monitor their evolution, FT-ICR MS is required. Molecular-level information of the parent MWO, combined with molecular-level information of the transformation products facilitates the understanding of the weathering process and populates a transformation database with tens-of-thousands of new compounds that can be considered in regards to their environmental impact, effect on physical transport, and toxicity.



Theme 3: Environmental

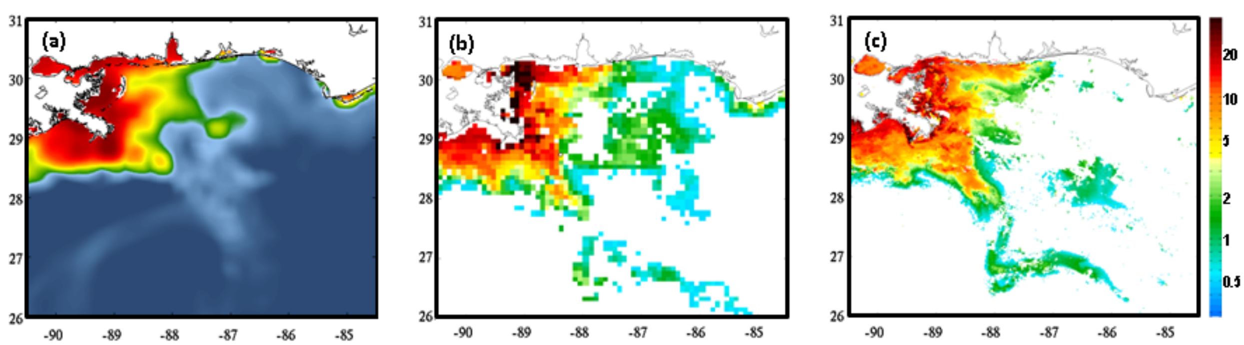
- A two-year time series following buried oil degradation showed that concentrations of aliphatic components decreased below 1 mg kg^{-1} after three months, aromatic components reached that level after about twice that time. After one year, most of the oil had disappeared. Temperature was a pivotal factor: During warm summer temperatures oil degraded three times faster than during colder winter months. Buried oil layers consumed four to five times more oxygen and produced up to six times more carbon dioxide than the unpolluted beach sand, revealing strong aerobic microbial decomposition activities. Modeling of the time series allows calculation of decomposition rates for specific oil components under in-situ conditions and predictions of the beach recovery period. The results can be used for designing responses in future beach oil contamination events.
- Studies showed that crude oil attaches readily to sand grains and thereby the transport of oil components into marine sands for the hydrophobic components is limited to a few centimeters sediment depth. Corexit detaches oil coating of sand grains and reduces adhesion of oil to sands, thereby enhancing mobility of oil components in submerged coastal sands. Through this mechanism, potentially harmful polycyclic aromatic hydrocarbons (PAHs) can penetrate tens of decimeters into the sediment and may reach groundwater level in shore environments. The mobility of the PAHs through the sand is controlled by the hydrophobicity of the PAHs.

- More than 4,000 fishes from 101 species (including 34 species of sharks and rays) resulted in 10,000+ biological samples distributed globally for analysis to over 18 different institutions. This is the largest survey of deep-sea elasmobranch fishes ever conducted in the Gulf of Mexico. These samples provide critical life history information and data on heavy metal contamination for a suite of significantly understudied species.
- We examined the spatial and temporal differences in PAH biomarker levels (cytochrome P4501a1, the most reliable; glutathione-S-transferase (GST); biliary PAH metabolites) in fishes (N = 569 elasmobranchs, 294 teleosts) collected 12-42 months after the Deepwater Horizon blowout, including the more abundant sharks (gulper shark *Centrophorus granulosus*, shortspine dogfish *Squalus mitsukurii*) and bony fishes (tilefish *Lopholatilus chamaeleonticeps*, Gulf hake *Urophycis cirrata*, and Southern codling *U. floridana*). Our results indicate: (1) that biomarker levels in specimens collected from oiled sites were significantly higher than those from specimens collected from non-oiled reference sites (e.g., in *S. mitsukurii* and *Urophycis spp* which occurred at both sites). (2) that *U. cirrata* biomarker levels declined with distance from the blowout site (Macondo); 3) that biomarker levels (i.e., GST and biliary PAH metabolites) in the more abundant elasmobranch species increased 27-39 months after the oil spill, and then declined in later months while in the more abundant teleost species, biomarker

The shortspine dogfish, *Squalus mitsukurii,* one of the more abundant shark species near the DwH blowout levels were higher earlier in the sampling period (16 months after the oil spill), and declined thereafter. Taken together, these trends support the hypothesis that differences in PAH exposure between oiled and non-oiled sites are at least partially related to the Deepwater Horizon oil spill. The question remaining is whether the exposure has had significant toxicological effects at the cell-, organ-, or organism-level.

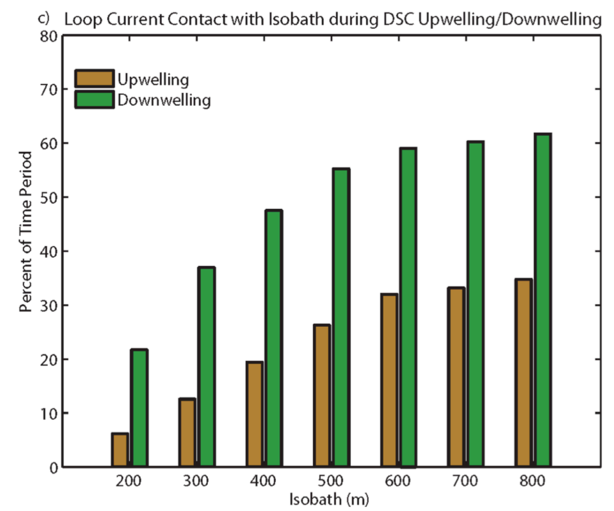
Theme 4: Technology

- Using the **West Florida Coastal Ocean Model (WFCOM)** developed by Deep-C we determined that the coastal ocean (defined as the continental shelf and estuaries) is driven by a combination of deep ocean and local forcing. This means that accurate coastal ocean circulation modeling requires the nesting of unstructured and structured grid models. We also learned that connectivity between shelf and estuary waters may require even higher resolution. For this we can nest an estuary specific model into WFCOM, such as the Tampa Bay, Sarasota Bay and the ICWW example shown to the right, including sub-regional enlargements. We can now model how contaminants such as spilled oil may flow within an estuary system. A daily, automated nowcast/forecast version of WFCOM is presently run at USF. Model results are available through the NOAA GNOME online oceanographic data server (GOODS).
- While based on existing infrastructure, the incorporation of the Wave models and the COSINE ecosystem model component into the coupled COAMPS ocean-atmosphere modeling system involved a long and overarching development and testing cycle. Once accomplished, model experiments revealed that air-sea coupled simulations generate much more realistic conditions as compared to satellite estimates (see figure). Further, sensitivity simulations conducted with the coupled ESM in the Mississippi Bight revealed three important points:
    - The inclusion of River Nutrient fluxes is critical, especially in the vicinity of the MS river (figure).
    - Data Assimilation in ecosystem models continues to be a challenge.
    - The ecosystem (biological blooms) responded much more energetically to Air-Sea coupled (vs. non air-sea coupled) simulations



Gulf of Mexico Ecosystem Chlorophyll (mg/m^3) 8-day composite (Aug 05-Aug 12, 2011) derived from the COAMPS model (a) and from the satellite observations (b and c). The figures are a close-up of the Mississippi Bight region to illustrate the model relative skill and the value of the 1Km satellite product (c) over the standard 9 Km product (b), in resolving the Mississippi River plume

- Polynomial Chaos and Gaussian Process methods are both useful in building faithful and efficient model surrogates that can be mined for robust statistical estimates, and to produce the probability density functions of model output, comparable to those obtained from Monte Carlo sampling but at substantially reduced computational cost. These methods have been incorporated into a newly developed Deep-C Oil Model (DCOM) that is being tested and integrated within the Earth System Modeling Components. These uncertainty estimation methods prove particularly important for simulation of the subsurface plume.
- Large-scale low-frequency downwelling events that can move isopycnals more than 100m vertically up or down the continental slope of the DeSoto Canyon Region are 2 to 4 times more likely to occur when the Loop Current impinges on the continental slope along the southern West Florida Shelf, than upwelling events, which are more likely in absence of impingement. Loop Current contact with the continental slope spawns a high pressure (SSH) anomaly that transits the continental slope toward the Mississippi Delta in the topographic Rossby wave direction. This high SSH suppresses isopycnals below, causing downwelling and/or hindering upwelling.



Percent of time period of upwelling (brown) or downwelling (green) across the DeSoto Canyon Slope during which the Loop Current was impinging on the West Florida Shelf slope at least several hundred kilometers to the south, illustrating a remote dynamic connection between the Loop Current in the southern Gulf of Mexico and the DeSoto Canyon.

- Analysis of historic observations and a high-resolution nested simulation of the DeSoto Canyon region show the occurrences of high-speed near-bottom currents during and following hurricane passages with speeds of 30-50 cm/s or higher at depths exceeding 1000m to 2000m or greater. Currents of this magnitude could be responsible for suspending and transporting material (oil) deposited on the sea floor, and can also be damaging to oil and gas infrastructure (risers and pipelines). Model simulations show the strongest currents are linked with steep topographic features, and persist for days to weeks as near-inertial oscillations.

OTHER PRODUCTS OR DELIVERABLES

d. Deep-C Data Management

- Deep-C Data Center Web Portal: http://deep-c.org/data
- The Deep-C Atlas - http://viewer.coaps.fsu.edu/DeepCProject/mapviewer
- Deep-C Data Center Tabular Interface - http://deep-c.org/data/tabular
- Deep-C Virtual Library - http://deep-c.org/library/

e. Models

- Models submitted to the Deep-C Data Center: http://deep-c.org/data/tabular/models

- Deep-C Oil Model: http://stargazer.coaps.fsu.edu/dcom/

f. Education & Outreach

- Deep-C website: www.deep-c.org
- Voices from the Field Blog: http://deepcconsortium.blogspot.com/
- Deep-C Facebook page: http://www.facebook.com/deep.c.consortium
- Deep-C Twitter account: https://twitter.com/DeepCConsortium
- Deep-C YouTube Channel: http://www.youtube.com/DeepCConsortium
- Deep-C Photo Gallery: https://picasaweb.google.com/112164058289504852022

2) TOTALS FOR THIS REPORT YEAR:

		Total for Report Year
a.	Cruises & Expeditions	15
b.	Workshops and meetings organized	11
c.	Peer-reviewed publications *(published + accepted)*	67
d.	Presentations and Posters	181
e.	Consortium participants	104
f.	Student and post-doctoral participants	105
g.	Outreach (products created and activities organized specifically for a public, educational, or stakeholder audience including: websites, videos, social networking pages and groups, brochures, tutorials, educational materials, educational activities, Congressional briefings, non-scientific meeting presentations, quotes, features, interviews, and articles*.	279

* *Many articles reappear online in various publications, so this number is certainly a low estimate for the exposure received.*

3) OTHER PRODUCTS OR DELIVERABLES

a. Updates to Conflict of Interest Statements – Attached are two revised Conflict of Interest (COI) forms (J. Nienow and C. Reddy). Based on previous years' instructions, we only require those who are PIs, co-PIs, or who have budgetary responsibilities to have an updated COI form on file. Also attached are forms for two Deep-C researchers (K. Speer and N. Wienders) that were not on the list provided, but for whom Deep-C does have a COI on file.

b. GoMRI Equipment Inventory/List of Requests to Make Additions to or Change Capital Equipment – ATTACHED