
A Gulf of Mexico event to coordinate glider and other ocean observing activities

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Acknowledgments

The events described within this report were sponsored by the Gulf of Mexico Research Initiative (GoMRI) funded RFP IV: Consortium for Oil Exposure Pathways in Coastal River-Dominated Ecosystems (CONCORDE). We are grateful to our partners in the AUV Jubilee development and planning, including the University of Southern Mississippi’s Department of Marine Science and the Gulf Coast Research Laboratory, the Gulf of Mexico Coastal Ocean Observing System, the U.S. Integrated Ocean Observing System, and Rutgers University. In addition we are appreciative of the enthusiasm shown by the AUV Jubilee participants, including Skidaway Institute of Oceanography, University of South Florida, MOTE Marine Laboratory, Texas A&M University, Oregon State University, NOAA, Roffer’s Ocean Fishing Forecasting Service, Inc., and the Florida Fish and Wildlife Research Institute. Finally, we’d like to thank the efforts of the Mississippi Enterprise for Technology and the Marine Industries Science and Technology cluster for getting the word out about the AUV Jubilee event.
1. Overview of Project and Participants

The AUV Jubilee was an inaugural event to coordinate glider and other in situ ocean data operations in the Gulf of Mexico for the month of July 2015. Our primary goal was to establish an open dialogue and collaboration with scientists across the Gulf, in order to acquire simultaneous ocean observations and leverage off of fellow participants to create a multifaceted and integrated data set. The AUV Jubilee was led by the University of Southern Mississippi’s Ocean Weather Laboratory (http://www.usm.edu/marine/research-owx), which hosted a series of webinars to display real-time satellite ocean color and several ocean circulation models (HYCOM/NCOM), as well as maps of product uncertainty to allow the participating scientists to adaptively sample features of interest (e.g., eddies, river filaments, fronts, etc.). This data fusion tool enabled the display of up-to-date locations of various glider and ship/aerial operations while they were deployed, and facilitated near real-time data exchanges in order to further assist in decision-making for adaptive sampling of ocean features. In addition to real-time operations, all participants were encouraged to submit data to the National Glider Data Assembly Center (NGDAC), so that the data could be available for assimilation into operational physical circulation models. The list of glider participants is shown below in Table 1. The scope of the AUV Jubilee also included an educational outreach component, in which a competitively selected group of highly qualified teachers were brought in for an intensive one week program that included curriculum development, hands on oceanographic experience, and participation in real-time glider operations.

Table 1: List of AUV Jubilee 2015 glider event participants

<table>
<thead>
<tr>
<th>Institution</th>
<th>Contact</th>
<th>Platform</th>
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<tbody>
<tr>
<td>University of Southern Mississippi/CONCORDE</td>
<td>Robert Arnone, Ryan Vandermeulen</td>
<td>Ocean Weather Laboratory</td>
</tr>
<tr>
<td>Rutgers University/CONCORDE</td>
<td>Travis Miles</td>
<td>Slocum</td>
</tr>
<tr>
<td>University of South Florida/MOTE Marine Lab</td>
<td>Chad Lembke</td>
<td>Slocum</td>
</tr>
<tr>
<td>Texas A&amp;M</td>
<td>Steve DiMarco</td>
<td>2 Slocums</td>
</tr>
<tr>
<td>Oregon State University/LADC-GEMM</td>
<td>David Mellinger</td>
<td>Seaglider</td>
</tr>
<tr>
<td>Skidaway Institute of Oceanography/University of Georgia/ECOGIG</td>
<td>Catherine Edwards</td>
<td>Slocum</td>
</tr>
<tr>
<td>Gulf of Mexico Coastal Ocean Observing System (GCOOS)</td>
<td>Matt Howard, Shin Kobara, Bob Currier, Barb Kirkpatrick, Landry Bernard</td>
<td>Data formatting, GANDALF, outreach</td>
</tr>
<tr>
<td>National Oceanic and Atmospheric Administration (NOAA)</td>
<td>James Churnside</td>
<td>Aerial LIDAR</td>
</tr>
<tr>
<td>Roffer’s Ocean Fishing Forecasting Service, Inc.</td>
<td>Mitch Roffer</td>
<td>Oceanographic Fishing Analysis</td>
</tr>
<tr>
<td>Florida Fish and Wildlife Research Institute</td>
<td>Susan Barbieri</td>
<td>Vemco Mobile Tranceivers</td>
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</tbody>
</table>
2. Ocean Weather Laboratory and “Adaptive Sampling”

The Ocean Weather Laboratory (OWX) is located at the University of Southern Mississippi’s Department of Marine Science on the John C. Stennis Space Center. The OWX is a real-time integrated and predictive center for ocean modeling, data integration, and ecological oceanography. The mission of OWX is to assemble and couple satellite remote sensing data with ocean models, in situ observations, and other remotely sensed products to fully characterize a 4-dimensional ocean. To facilitate meeting our objective, the OWX processes satellite ocean color data (MODIS, VIIRS) and several physical circulation models (NCOM, HYCOM) for the Gulf of Mexico on a daily basis. The integration of in situ, remotely sensed, and modeled data in real-time demonstrates the interaction of physics and biogeochemistry in complex ecosystems, and enables an increased understanding of inherent uncertainties. During the AUV Jubilee, the OWX hosted daily webinars to demonstrate data integration and promote the adaptive sampling of key oceanographic features to assist in glider piloting.

“Adaptive Sampling”
Comparisons of model data and in situ observations reveal areas of uncertainty, enabling targeted and efficient sampling regimes in real-time.

Unraveling the subsurface
Real-time data from gliders, ships, and LIDAR support remotely sensed data retrievals by telling the rest of the story. Beneath the surface, coupled physical and biological features are extremely dynamic.

Figure 1: Products from the Ocean Weather Laboratory, demonstrating adaptive sampling.

This comprehensive integration of data from several sources provides closure as well as highlighting ecological patterns that may otherwise go unnoticed in the Gulf of Mexico. With this system, we are able to examine the origin and date of river plumes, quantify biomass and physical volume transport, track the movement of bio-optical features, specifically characterize water masses, resolve spatial and temporal variance, and link the bio-physical coupling that ultimately drives ecosystem variability on global scales. For AUV Jubilee, we provided this data and collaborated with a diverse group of scientists in order to expand our collective capabilities and to provide real-time answers to rapidly evolving questions.
3. Glider Deployments and Science Plans

06/24/15: The Skidaway Institute of Oceanography / University of Georgia deployed 1 Slocum Glider northeast of GC600. The glider was equipped with pumped CTD, dissolved oxygen, CDOM/chlorophyll/turbidity, Vemco VMT, and Turner oil sensors. The glider survey, near GC-600, had its navigation optimized from models using the Glider Environmental Network Information System (GENIoS). This mission was part of the GoMRI funded consortium ECOGIG.

06/24/15: Oregon State University / NOAA, as part of the GoMRI funded consortium LADC-GEMM deployed 1 Seaglider equipped with a passive acoustic monitoring system (for marine mammal identification) near the Deepwater Horizon wellhead in the northern Gulf. In addition, and Autonomous Surface Vehicle (ASV) was deployed with a similar system and both data sets will be compared to data collected with a subsurface moored EARS hydrophone.

07/01/15: Texas A&M deployed 2 Slocum G2 gliders on the Texas Shelf. These gliders were equipped with CTD, dissolved oxygen (RINKO), and fluorescence (CDOM and chlorophyll) sensors. The purpose of the deployments was to study the near bottom oxygen concentrations and physical stratification associated with the Louisiana Deadzone near Galveston.

07/06/15: University of South Florida, in conjunction with MOTE Marine Laboratory deployed a Slocum glider along the Florida Shelf, near Tampa Bay. The glider was equipped with CTD, Chlorophyll, CDOM, backscattering, dissolved oxygen, Vemco VMT, and radiance/irradiance sensors. This 10-day mission served as a continuation of a series of water quality surveys.

07/07/15: Rutgers University launched a Slocum glider from the USM mooring (NDBC Station 42067) in the Mississippi Bight. The purpose was to explore the impact and structure of river filaments in coastal waters, in order to define preferred transport pathways in the Bight. However, given the large density gradient present (over 8 sigma), the glider (ballasted for ~4 sigma range) was not able to effectively fly, and was recovered the next day. Another deployment is scheduled for October 2015, and the glider will be equipped with thrusters and an enhanced pump to compensate for the large density gradient.

07/08/15: Concurrent with the USF/MOTE glider deployment time frame, there was coordination with NOAA to conduct aerial LIDAR surveys. These surveys derive profiles of optical backscatter in order to measure plankton layers off of the West Florida Shelf. Overflights periodically coincided with USF glider tracks, and a separate ship support cruise for optical measurements was performed out of USF for LIDAR validation.

Supporting Services: Several other services were made available to glider participants. Florida Fish and Wildlife Research Institute provided passive acoustic arrays free of charge to AUV Jubilee participants, in order to detect acoustically-tagged animals. In addition, Roffer’s Ocean Fishing Forecasting Service, Inc. provided periodic oceanographic fishing analysis, in support of the VMTs and individual glider missions. Finally, the Gulf of Mexico Coastal Ocean Observing System hosted several data streams from deployed gliders and made real-time locations and data visualization available through the Gulf AUV Network and Data Archive Long-term storage Facility (GANDALF) website (http://gcoos2.tamu.edu/gandalf).
4. Submitting to the National Glider Data Assembly Center

All participants were encouraged, if possible, to submit their data to the National Glider Data Assembly Center (NGDAC), which is part of the U.S. Integrated Ocean Observing System (IOOS). By submitting to the NGDAC, real-time glider data can be distributed to the Global Telecommunications System (GTS) for use in regional and global scale ocean forecasting models. Data is made available for public access via ERDDAP and/or THREDDS end-points, and is subsequently channeled to the GTS through the NOAA National Data Buoy Center (NDBC). The data in the NGDAC contains individual profiles, as well as trajectory and deployment data. The figure below outlines the data flow schematic for AUV Jubilee 2015.

In order to submit data to the NGDAC, specific metadata are required, which differ slightly from the NOAA National Oceanographic Data Center (NODC) format. The regional GCOOS group was extremely instrumental in re-formatting raw glider data files into the proper IOOS NetCDF format for AUV Jubilee. This re-formatting made data available for submission directly to the NGDAC. During this exercise, three glider missions were submitted to the NGDAC in real-time. Concerns over release of glider data to the public and/or data “embargos” prevented some participants from submitting.
5. AUV Jubilee Webinars, July 13-17

A series of daily webinars were held from July 13-17 (Figure 3). These meetings were hosted by the Ocean Weather Laboratory, which showcased daily products derived from physical circulation models and satellite ocean color, in addition to displaying updated locations of gliders. During these calls, glider pilots and other participants discussed regional oceanography (i.e., location of river filaments, eddies, high/low chlorophyll regions, surface currents), mission challenges/successes, future waypoints, data collected (via GCOOS-generated kmzs with profile data visualized in real time), and comparisons of *in situ* subsurface features with the surface expression as shown by VIIRS ocean color or model output. Participating glider pilots were given the opportunity to give an in-depth description of their individual missions and the ocean technology being used. In addition to round-table discussions, several teachers associated with CONCORDE outreach listened in to the calls and engaged gulf scientists with questions about their respective missions and glider science in general.

During the July 2015 period, the physical and biological properties in the Gulf of Mexico were extremely dynamic. A summary of glider locations for AUV Jubilee 2015 as well as the regional oceanography is shown on the next page, in Figure 4. A large freshwater plume from the Mississippi River extended into the open Gulf of Mexico, as shown by the satellite chlorophyll, which highlights complex circulation features. This feature prompted the NOAA LIDAR survey to sample the edge of the plume structure (Figure 4; red lines). The loop current broke off into a large anti-cyclonic ring in the mid-Gulf, contributing to the movement of river water along the Florida Shelf. Recent rain events led to a large chlorophyll expression off of the Texas Shelf, which was sampled by the TAMU group. The synoptic ocean perspective provided by ocean color and model products prompted the discussion of optimized flying for glider participants.

![AUV Jubilee daily webinar](image3.png)

*Figure 3: AUV Jubilee daily webinar held in the Ocean Weather Laboratory at the University of Southern Mississippi. The Ocean Weather Laboratory, in conjunction with GCOOS, provided the visualization and real-time updates of satellite ocean color, physical circulation models, glider locations, and glider data.*
Figure 4: Google Earth image with VIIRS-derived chlorophyll-a overlaid with HYCOM surface currents and salinity contours for July 11, 2015. The boxes highlight the paths for glider and LIDAR surveys conducted during AUV Jubilee. Daily updates of oceanographic features and real-time glider locations were provided to AUV Jubilee participants to facilitate discussions of localized oceanography and adaptive sampling.
6. Educational Outreach for AUV Jubilee

During the AUV Jubilee, a concurrent science teacher professional development workshop took place. Ten teachers from southeastern states including Virginia, Tennessee, Louisiana, Alabama, and Mississippi, were competitively selected to participate in this workshop. The teachers came from coastal and landlocked communities, and represented a mix of schools and student populations—public and private, wealthy and poor. The one week intensive course included lectures from Gulf of Mexico scientists, tours of federal oceanographic agencies, a glider deployment exercise, a research vessel cruise that covered various data collection and processing techniques, lab experiments, and regular involvement in the AUV Jubilee webinar calls. Participating teachers subsequently developed educational modules based on what they learned about the research they encountered.

The outreach program was organized through USM’s Marine Education Center (MEC; http://www.usm.edu/gcrl/mec). In order to facilitate a technology-rich educational experience, the teachers worked alongside 28 CONCORDE scientists including senior investigators, post-doctoral researchers, graduate students, and technicians. Presentations and land-based demonstrations gave teachers the background for a twelve-hour research cruise aboard the R/V Point Sur in the Gulf of Mexico to deploy a glider and use a depth-specific sampler to collect ichthyoplankton. During the cruise, the teachers processed plankton samples and launched the CTD, however, the glider deployment was postponed due to a steep vertical density gradient that was outside of the ballast range for the glider. This exercise resonated with teachers in demonstrating how adaptive sampling might help avoid the loss of expensive instruments. The teachers also gained a practical understanding of the vertical structure of the water column by analyzing CTD and plankton data collected at different depths.

The teacher experience was further enriched by the AUV webinar briefings, in which they observed operational decision making taking place in real-time. During these calls, researchers from various institutions addressed basic teacher questions about nearshore processes and current conditions in the Gulf as well as details of specific technologies and ongoing research projects. These collective lessons were integrated into classroom materials that the teachers began to develop, which included topics such as: 1) Gulf of Mexico processes, 2) buoyancy, and 3) ichthyoplankton behaviors and interactions with oil. After pilot implementation and revision, the developed materials will be posted to the CONCORDE website (http://www.con-corde.org).
7. Summary

The 2015 Autonomous Underwater Vehicle Jubilee was a coordinated field demonstration of ocean observing technologies, focused in the Gulf of Mexico. This cooperative effort to join disparate individual ocean research efforts facilitated an opportunity for mutually beneficial collaborations with various academic, industry, private, and government partners across the Gulf of Mexico, in addition to supporting the increased characterization of ocean processes. The provision of glider support products, including real-time ocean circulation models and satellite ocean color data, enabled the optimization of glider flights, and showcased how multiple technologies can be used to optimize adaptive sampling of ocean processes. The integration of real-time observations with AUV data helped validate satellite observations and created an enhanced ocean monitoring capability. Select gliders were also able to submit data to the NGDAC, thereby enhancing the capabilities of physical circulation models by making real-time data available for assimilation. In addition, an associated outreach component enabled classroom teachers from across the region to participate in interactive operational oceanography and create educational materials so other educators can also teach their students practical aspects of Science, Technology, Engineering, and Math (STEM).

8. Lessons Learned from AUV Jubilee 2015

Based on this exercise, there are several important considerations for future collaborative events involving data integration from multiple sources:

1) This event would have benefited from establishing clear criteria for what participation entails early in the planning stage, including setting a standard objective for what and how data will be shared. Given that the webinars were open to the public and possible media outlets, several glider participants were not comfortable with releasing real-time updates of glider locations or visual interpretations of data. Addressing these concerns requires a strict delineation of the extent and type of public data release (e.g., visual or geographic data only), in order to encourage inter-participant collaboration while simultaneously exercising sensitivity to data “embargos” that enable a window of opportunity for publishing results.

2) Participation in webinars and planning meetings was not always maximal, therefore it would be useful to provide enhanced incentives for participants to collaborate and contribute to the team. This may include providing activities that involve all participants, and/or establishing accountability for specific deliverables that contribute to a cooperative planning effort.

3) The exercise demonstrated that monitoring daily ocean conditions in the Gulf of Mexico can provide a critical asset for ocean sampling. For example, the success of a glider deployment in coastal areas, especially in river dominated regions, requires the correct adjustment of glider buoyancy. Determining the accurate locations of river plumes is essential for successful glider operations, and requires executing an ensemble approach that merges satellites with several models to define river plume locations.
CONCORDE, the CONsortium for oil spill exposure pathways in COastal River-Dominated Ecosystems, is a multi-university research team looking to expressly address how complex fine-scale structure and processes in coastal waters dominated by pulsed-river plumes control the exposure, impacts, and ecosystem recovery from offshore spills like the Deepwater Horizon release of 2010. CONCORDE is fully funded by a generous grant from the Gulf of Mexico Research Initiative (GoMRI).

The mission of CONCORDE is to fill critical knowledge gaps concerning the movement of oil, dispersed oil and dispersant in the complex, dynamic and highly productive coastal waters of the northern Gulf of Mexico. The integration and synthesis of CONCORDE research will advance the understanding of how coastal marine ecosystems respond to, and recover from, large-magnitude oiling events. In addition to scientific impacts, CONCORDE incorporates a well-rounded education and outreach element to build public trust in science. CONCORDE will help educators and key stakeholders understand the scientific process and how it relates to decision-making during crises such as oil spills.