Gliders in the Gulf of Mexico

Building towards an operational and integrated observing system in the Gulf of Mexico

R.L. Perry, A.E. Jochens, M.K. Howard
Gulf of Mexico Coastal Ocean Observing System
3146 TAMU
College Station, TX 77843-3146
rlperry@geos.tamu.edu

***Abstract*—The Gulf of Mexico Coastal Ocean Observing System (GCOOS) is being built as a sustained, end-to-end integrated and operational System of Systems designed to provide data and products to diverse stakeholders. The Gulf of Mexico Coastal Ocean Observing System Regional Association (GCOOS-RA) is bringing together academic groups, governmental agencies, non-governmental organizations, and the private sector to plan and implement the GCOOS Build-Out Plan. The development of a GCOOS Gulf Glider Plan started in 2010, and was incorporated into the Gulf Build-Out Plan, which was released in 2011. A GCOOS Gulf Glider Task Team (GGTT) was established in 2012 by GCOOS-RA. The GGTT was constituted in April 2013 and charged to engage Gulf gliders stakeholders and to revise and further develop conceptual plans for Gulf glider operations in the GCOOS Build-out Plan.**

This paper will discus the progress of the GGTT, pilot projects involving gliders, and glider operations supported by the GCOOS-RA and its partners. Plans for future pilot projects and activities building toward a phased implementation of the glider network, its associated infrastructure, and product development to address the needs of Gulf stakeholders will be presented. GGTT activities, particularly as related to revisions to the GCOOS Build-Out Plan in light of recent events and expected future monitoring of Gulf ecological and economic resources, will be summarized.

Keywords—U.S. Integrated Ocean Observing System, Gulf of Mexico Coastal Ocean Observing System, Gulf of Mexico, AUVs, gliders, ocean observing systems

I. INTRODUCTION

The U.S. Integrated Ocean Observing System (U.S. IOOS) is an end-to-end integrated and operational System of Systems designed to provide data and products to national stakeholders and is the U.S. contribution to the Global Ocean Observing System. The Gulf of Mexico Coastal Ocean Observing System Regional Association (GCOOS-RA) is 1 of the 11 regional components within U.S. IOOS. Its boundaries include the U.S Gulf of Mexico (Gulf) from the boundaries of the U.S. Exclusive Economic Zone into the estuaries, bays, and head of tidal influence in the five Gulf States (Texas, Louisiana, Alabama, Mississippi, and western Florida). GCOOS-RA is a user-driven system tasked with providing information to improve decision-making capabilities that is used to empower Gulf people, communities, and businesses to improve their lives, work, and recreational activities along the Gulf Coast [1].

The Gulf of Mexico Ocean Observing System (GCOOS) is the sustained system of networked sensors, computers, and software that provides Gulf stakeholders with integrated near real-time and historical coastal and ocean data from distributed observing systems. To date, the GCOOS-RA does not operate any observing assets, but works to integrate data from systems owned and operated by federal and non-federal (regional, state, local, academic, and private) entities. The GCOOS-RA is working to expand the GCOOS to address data gaps in the Gulf identified by stakeholders and to address coastal hazards, economic and ecological resources, and events such as the 2010 Deepwater Horizon oil spill.

GCOOS-RA held a series of stakeholder workshops over the last decade to identify users needs and requirements for Gulf data, information, and products. These needs and requirements were consolidated and prioritized to guide the GCOOS-RA Board of Directors and regional subject matter experts in the development of the GCOOS-RA Build-Out Plan (BOP;http://gcoos.org/BuildOut/GCOOS_BuildoutPlan_V1.pdf). One of the priority elements of the BOP was the establishment of an autonomous underwater vehicle (AUV) network in the Gulf of Mexico for monitoring waters prone to hazards, such as hypoxia and harmful algal blooms, and to measure and resolve in real-time key physical, chemical, and biological phenomena [2]. The major type of AUV considered in the BOP is the autonomous glider. To move forward with the glider applications presented in the BOP, the GCOOS-RA established the Gulf Glider Task Team (GGTT) and tasked them to address the future of glider operations in building the integrated ocean observing system in the Gulf.

II. GLIDERS IN THE GCOOS BOP

For the past decade, the GCOOS-RA has worked to identify the needs of stakeholders for information, data, and products from the Gulf, together with Gulf resources, and ecosystems [3]. From this effort, 17 key elements were identified with AUVs, including gliders, being one. The BOP considers two different cases—base and full—on how to built-out the Gulf observing system given current and future funding scenarios and future advances in oceanographic technology.

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Considering the funding and resources estimated to be available, each case addresses a hierarchy of ocean observing needs based on the 17 key elements, the gaps in the federal system of measurements, and the needs of the various user groups, including the public. The 'base case' is designed to fill the most important gaps in the existing observing system at a relatively modest cost (Fig. 1) [3]. The base case plan prioritizes observations on the shelf, slope, and deep water portions of the Gulf by including observing stations needed to fill major gaps in the federal system of measurements.

To develop the "full case" and to populate the "base case", the GCOOS BOP addresses the build-out in a series of three phases. Phase I is the current phase, and the goal is to engage, maintain, and integrate existing observing resources (For a list of resources, please visit the GCOOS Data Portal at http://data.gcoos.org). Phase II includes the addition of new observation sites to supplement the existing systems to complete the base case. The final phase, Phase III, is to complete the installation of the full set of observing stations and resources for the GCOOS to provide a comprehensive ocean observing system for the Gulf that will meet diverse needs of many different stakeholders and users, much as the current atmospheric observing system meets the needs of many.

AUV operations are identified in each case and phase of the GCOOS BOP. There are two parts to the GCOOS base AUV plan:

1) Continuous operations in a conveyor belt pattern to be run along the entire US Gulf (orange and yellow lines in Fig. 1) and,
2) Deep water monitoring pattern to provide continuous sampling in the deep water and Loop Current region to support modeling and other interests.

The glider plan includes not only general monitoring of Gulf conditions, but also has a focus on Harmful Algal Blooms (HABs) and hypoxia.

Plan components include the series of predetermined glider tracks, field operation centers, advances to glider payload instrumentation suites, and collaboration among Gulf stakeholders to assure key Gulf priority areas, such as the HABs and hypoxic areas, are monitored. Phase I goals for operations include maintaining existing glider operations in the Gulf and adding new payloads on existing platforms [3]. Phases II and III identify the additional use of AUVs for water property monitoring in nearshore environments such as estuaries and bays.

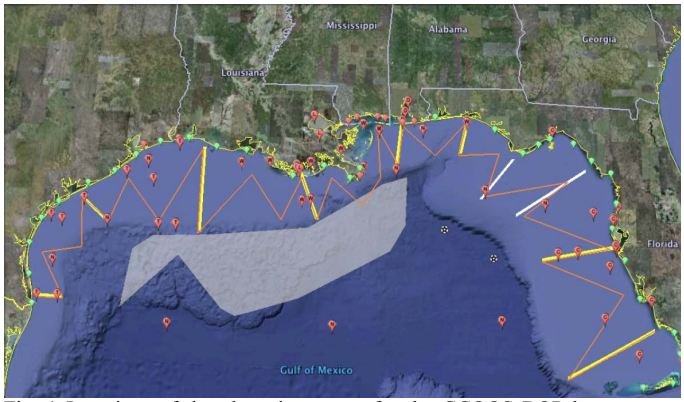

Fig. 1 Locations of the observing assets for the GCOOS BOP base case. The orange lines are schematic AUV tracks and yellow lines are continuous AUV tracks for routine shelf monitoring.

III. The GCOOS Glider Task Team (GGTT)

The GCOOS-RA established the GCOOS Gulf Glider Task Team (GGTT) in April 2013 to: engage stakeholders using gliders in the Gulf, to improve the glider component of the GCOOS BOP and develop the implementation plans for Gulf glider operations that are consistent with the BOP. The GGTT is comprised of twelve members from academic, government, and industry Gulf stakeholders. The main focus of the GGTT is to provide recommendations to the GCOOS-RA Board of Directors on the development of details for gliders in the Gulf. Charges for the GGTT include development of (1) a plan for the Gulf glider infrastructure, tentatively with an operations center and two or more shared field maintenance locations, (2) a phased implementation plan for glider operations that uses an integrated approach to resources and personnel, and (3) protocols for data sharing and visualizations of glider data to meet the needs of the Gulf stakeholder community. Additional tasks of the GGTT include providing a forum for scientists, manufacturers, and others interested in developing a network of operational gliders for the Gulf, participating in the development of a national glider plan and related federal IOOS efforts for gliders, and coordinating the Gulf glider network with that of the adjacent Southeast Coastal Ocean Observing Regional Association (SECOORA).

Having just been established, the GGTT has a short-term priority to identify glider operators in the Gulf and to bring those operators together to identify the current and future needs and plans of the glider community. The GGTT has met and is in the planning stages for organizing a Gulf glider workshop to bring the glider operators together to identify ways for the diverse entities to cooperate and collaborate to meet the needs of the Gulf community.

The workshop is planned for late 2013 or early 2014. The GGTT currently is considering goals and outcomes for the workshop that may include development of:

- A understanding of current and planned glider activities in the Gulf of Mexico by the myriad of groups operating gliders or developing operations for gliders in the Gulf;
- A list of potential studies that could be served by glider data;
- A plan for promoting collaboration, coordination, and resources among the Gulf glider community;
- An understanding in the Gulf glider community of the national (U.S. IOOS) and regional (GCOOS-RA) glider system plans and the needs those

plans address, as well as provision for input to the GCOOS Build-Out plan;

- A list of potential future funding opportunities.

IV. GCOOS-RA Gulf Glider Pilot Projects

In addition to the GGTT efforts, the GCOOS-RA is currently progressing toward the phased implementation program for AUV operations in the Gulf. Forward movement includes the support of pilot project glider missions and the development of glider data streaming and visualization through the GCOOS website (http://gcoos.org/products/index.php/gliders/

A. Deepwater Horizon Oil Spill (2010)

GCOOS-RA glider data support started with GCOOS contributions and participation in the response to the 2010 Deepwater Horizon Oil Spill. GCOOS-RA staff converted glider data from the Environmental Response Management Application (ERMA) Deepwater Gulf Response website into new ERMA data visualization layers for the National Oceanographic and Atmospheric Administration (NOAA) response team [2]. The layers became part of the GCOOS-RA oil spill resources (http://gcoos.org/products/index.php/oil-spill/). GCOOS-RA partners also participated with other IOOS RAs in an effort organized by U.S. IOOS partners to identify the presence and extent of a subsurface oil plume from the spill using gliders, a first spill response effort that employed gliders (Fig. 2). Participating regional associations were: GCOOS-RA through Mote Marine Laboratory, SECOORA, Mid-Atlantic Regional Coastal Ocean Observing System, and Southern California Coastal Ocean Observing System.

B. Harmful Algal Bloom Integrated Observing System: University of South Florida and Mote Marine Laboratory

Starting in 2010, in cooperation with the U.S. Gulf states through the Gulf of Mexico Alliance (GOMA), the GCOOS-RA held a series of workshops to design a Harmful Algal Bloom Integrated Observing System (HABIOS). Automated systems, such as gliders, can help to detect HAB events by continually monitoring for selected HAB species [2]. In 2012, the GCOOS-RA supported a pilot project conducted by GCOOS partners at the University of South Florida (USF) College of Marine Sciences and Mote Marine Laboratory. The project consisted of a coordinated tandem glider mission to better understand *Karenia brevis* blooms (the Florida "red tide") in southwest Florida. The project included collaboration between the GCOOS Data Portal group for data ingest and visualization, the USF Ocean Circulation Group for numerical model forecasts and the USF Optical Oceanography Lab for integration with satellite data. In October 2012, the GCOOS-RA participated in education and outreach activities for a science festival in St. Petersburg, FL, by highlighting this glider mission and harmful algal bloom monitoring in Florida.

C. Ocean Acidification: The University of Southern Mississippi and Liquid Robotics, Inc.

In late 2012 and early 2013, the GCOOS-RA provided data support and funding to enhance a NOAA-supported surface glider effort by The University of Southern Mississippi and Liquid Robotics, Inc. to study ocean acidification offshore Mississippi. (http://gcoos.org/?p=3638). A Liquid Robotics, Inc., Wave Glider was equipped with sensors to measure carbon dioxide, pH, dissolved oxygen, salinity and water temperature, to better understand ocean acidity relative to carbon dioxide fluxes between the atmosphere and ocean. The GCOOS-RA support enabled the addition of barometric pressure, air temperature, wind speed and direction, and water speed to the suite of data collected. During these missions, GCOOS-RA worked with the USM and Liquid Robotics, Inc., to stream the data in real-time through the GCOOS Data Portal and develop an ESRI GIS-based trajectory and data display viewer to share data with the Gulf community (Fig. 3).

D. Ongoing GCOOS Contributions

The ESRI GIS-based trajectory and data displayer viewer product continues to be used as a data sharing tool for additional academic glider operations in the Gulf, including glider operational tests conducted by the Department of Oceanography at Texas A&M University (TAMU) and the Geochemical Environmental Research Group (GERG) for environmental monitoring in the western Gulf and Flower Garden Banks. TAMU-GERG glider operation tests and missions conducted in mid-2013 also were supported by the GCOOS-RA through data and products support similar to those of the HABIOS and USM-Liquid Robotics glider pilot projects.

In addition to data streaming and visualization support, the GCOOS-RA also highlighted additional glider missions and operators in the Gulf, including those of industry partners, through a series of bi-monthly and webpage stories (e.g., http://gcoos.org/?page_id=4468) to increase exposure and awareness of such activities in the Gulf community.

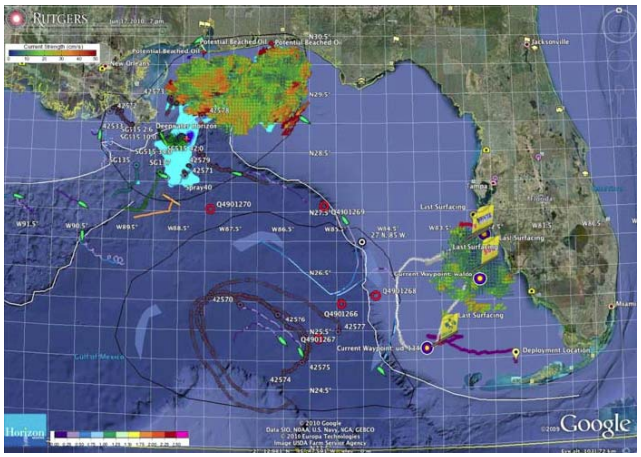

Fig. 2 U.S. IOOS glider fleet identifying the subsurface oil plume after the Deepwater Horizon Oil Spill (Image courtesy of Rutgers University) (www.ioos.gov/library/deepwater_horizon_051911.pdf). The last waypoint locations of each glider are indicated with "bullseyes." The glider named Waldo deployed off Southwest Florida was the contribution of GCOOS partner Mote Marine Laboratory.

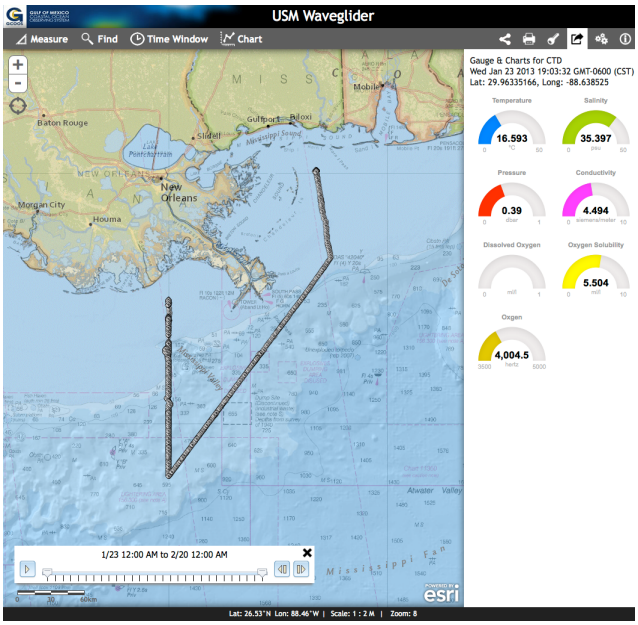

Fig. 3 GCOOS glider data product developed for the University of Southern Mississippi and Liquid Robotics, Inc. Wave Glider. The glider product is an ESRI-based trajectory and data display viewer that GCOOS is using to integrate for glider operations in the Gulf of Mexico.

V. CONCLUSIONS

Recent events in the Gulf, such as the Deepwater Horizon oil spill, harmful algal blooms, and hypoxia, demonstrate the need for a Gulf integrated ocean observing network. The 10-year GCOOS Build-Out Plan calls for an array of marine buoys, shore stations, and AUVs to meet the needs of the many stakeholder groups of the Gulf. The GCOOS-RA is moving forward to address the need for a continuous glider observational network in the Gulf. Efforts by the GCOOS Gulf Glider Task Team will lead to incorporation of an operational glider network into the GCOOS that will improve current and future monitoring of ecological and economic resources in the Gulf of Mexico.

The GCOOS-RA will continue to broaden collaborations to advance the establishment of a comprehensive and continuous Gulf glider network. It also will continue to work with the U.S. IOOS community on the development of a National Glider Network Plan to investigate the application of gliders in national waters. Furthermore, the GCOOS-RA will continue working with glider operators and Gulf stakeholders to develop glider data visualization tools and products. Better tools and products will enhance the monitoring of Gulf hazards and conditions and improve decision-making capabilities to empower Gulf people, communities, and businesses to improve their lives, work, and recreational activities along the Gulf Coast.

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