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Cost-effective Monitoring and Vanguard Technologies for Ocean Management

AUVs — self-powered, untethered, subsea platforms equipped with a wide variety of payloads — are emerging tools for oceanography. Subsea gliders are a class of AUVs designed to conduct jigsaw water column sensor profiles over long distances for example, the recent transatlantic expedition led by Teledyne-Webb and scientists from Rutgers University using RU’s Slocum Glider (Sea Technology, Feb. 2010). AUVs and gliders played a prominent role in the 2010 post-spill assessment following the Macondo well site accident in the Gulf of Mexico, mapping oil and providing input to regional current models (Figure 1). At a post-spill meeting sponsored by the Council for Ocean Leadership (COL, 2010), experts recommended use of AUV and glider sampling “to quantify concentrations of dispersed oil and identify microbes to ascertain impacts on respiration.” The Joint Analysis Group’s June post-spill report (JAG, 2010) highlighted the importance of fluorometric data on the likely presence of sub-surface oil and its location in the water column. The Gulf glider fleet completed over 34,000 profiles with fluorometric and CTD sensors.

The NOAA Next Generation Strategic Plan calls for deployment of “Autonomous Underwater Vehicles (AUVs) and Unmanned Aircraft Systems (UASs) to explore hard-to-observe regions such as deep oceans and the Arctic.” NOAA’s Office of Ocean Exploration also has a Strategic Plan now in final review that states, “OER strives to be a NOAA and national focal point for the design, development, deployment, testing, and evaluation of new marine technologies and tools, including instrument systems, sensors, and platforms [including AUVs].”

Manley (2006) described many AUV applications relevant to NOAA’s mission, offering practical reasons for transition beyond exploring hard-to-reach frontiers. Most important is the role AUVs will play in complementing and replacing traditional oceanographic methods, based, for example, on cost-per-observation, density of observations, and ability to respond quickly to events. Transition will be accomplished at different time and space scales, including single-vehicle deployments, event-based swarms (similar to the Gulf response), and regional networks of coordinated platforms.



Figure 1 *Glider paths achieved between May and July 2010 in response to the DWH spill event*

These are high-profile examples of glider applications. The question is what role will gliders play in federal agencies’ mission responsibilities? Acceptance by these agencies, not just the Navy, will be essential to the transition of emerging technologies to operational status and successful enterprises.

AUV strategic plans

The first step in this transition is recognition of AUV technologies’ integral role in strategic plans. The Navy has an AUV Implementation Plan since 2004, which has sparked development of many of today’s unmanned platforms. The National Oceanic and Atmospheric Administration (NOAA) is not far behind.

UNCW Glider

With funding from NOAA via its National Institute for Undersea Science and Technology, the University of North Carolina at Wilmington (UNCW) purchased and operates a 100m Webb-Slocum glider, Pelagia (Figure 2).

Payloads include:

- Conductivity/temperature: SeaBird SBE41CP conductivity/temperature sensor
- Fluorometer: WET Labs 3-channel ECO Puck Chlorophyll-*a*
- Colored dissolved organic matter (CDOM) 600nm optical backscatter
- Beam Attenuation: WET Labs BAM sensor for beam attenuation coefficient *c*
- Dissolved oxygen: Aanderaa Optode 3835 0 to 120% saturation sensor

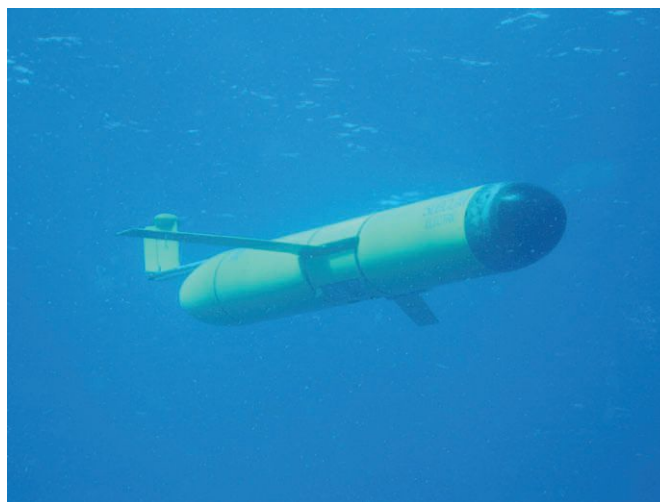


Figure 2 *UNCW’s Webb-Slocum glider, Pelagia*

Purchased in 2005 for \$100,000, including the Eco-Puck fluorometer, operational costs include:

- Current day rate for use of UNCW glider is \$1,200 per day for a 10-day mission;
- Estimated cost for a small boat to deploy and recover within 5nm of shore is \$3,000;
- Estimated shipping and support personnel travel to a location off the southeast U.S. is \$5,000; and
- Total cost for a 10-day mission would be \$20,000; based on a 6-second sampling rate, this results in a cost-per-observation record (all of above measurements; 144,000 records) of \$7.20.

Emulating this sampling program using a support vessel and towed (to-yo) sensor package, would require the following:

- Support vessel, estimated to be \$3,000 per day (very conservative and uncomfortable if out for 10 days)
- Towed vehicle costs similar to glider day rate (\$1,000/day);
- Other support costs also similar (\$8,000 per mission); and
- Total for 10-day mission of \$48,000, or almost 2.5 times the glider cost-per-observation record. This does not include the likelihood of weather days, which are not an issue for glider operations (Pelagia has sailed in a tropical storm).

Pelagia Applications

In 2004, hypoxic water mass formation in Long Bay, SC, resulted in a “flounder jubilee” off Myrtle Beach, driven to the shore piers by the low oxygen conditions (SCSG, 2011). Similar events occurred in the summer of 2009. The conditions that led to these hypoxic events were a combination of factors, including strong water column stratification and inputs of nutrients from offshore and land-based sources. In the summers of 2004 and 2009, strong southwesterly winds pushed cold, deep water from far offshore toward the Long Bay beachfront in a process called upwelling. These southwesterly winds and resulting upwelling were persistent, constraining a mass of colder water in the nearshore zone just seaward of the surf zone. Pelagia was part of a 2008 sampling program funded primarily by the South Carolina Sea Grant Consortium to document shelf transport and helped define water column properties and contribution of Gulf Stream intrusions to potential delivery of upwelled nutrients to the coast (Figure 3).

Mesoscale eddies and fronts associated with the Florida Current are critical to the presence and survival of the coral reef ecosystem off the Florida Keys. Fiechter (2007) employed a modeling and in situ sampling program to characterize particle, nutrient, and larval dispersion on the East Florida Shelf. As stated, “Acquiring high-resolution *in situ* observations is critical to the understanding of larval transport mechanisms in shallow-water near coral reefs.” High-resolution *in situ* measurements using acoustic Doppler current profilers, surface drifters, and the Pelagia glider were used to characterize the physical environment in the vicinity of the reef tract, and provide a basis for model-data comparison.

Regional Networks - Southeast US Glider Network

Rudnick et al. (2004) reported on AUV activities in Monterey Bay as part of the Autonomous Ocean Sampling Network (AOSN), described as “observing platforms linked by real-time communication to form an array that could adapt its strategy according to observations made.” As they further observed, “A wide range of sensors has already been deployed on gliders, with many under current development, and an even wider range of future possibilities. Glider networks appear to be one of the best approaches to achieving subsurface spatial resolution necessary for ocean research.”

Seim et al. (1999) provided a comprehensive plan for a regional ocean observing system off the southeast U.S. capable of observing, simulating, and predicting ocean processes that are three-dimensional, time-dependent, and occur on many space-time scales, using a “multi-platform, multi-variable” observational approach integrated with models. As proposed, the system would include a combination of profiling floats, moored profilers, AUVs, and gliders to obtain regular (i.e., routine, standardized, and sustained) mapping of the vertical and horizontal T/S structure and other variables with the addition of appropriate sensors. Over a decade later, their vision may be launched in 2011 with funding from the NOAA Integrated Ocean Observing System to the Southeast Coastal Ocean Observing Regional Association (SECOORA).

Led by SECOORA, the proposal for “Coordinated Monitoring, Prediction and Assessment to Support Decision Makers Needs for Coastal and Ocean Data and Tools” (SECOORA, 2011) will integrate and augment existing SECOORA regional observational, modeling, data management, and education assets to help the following accomplish:

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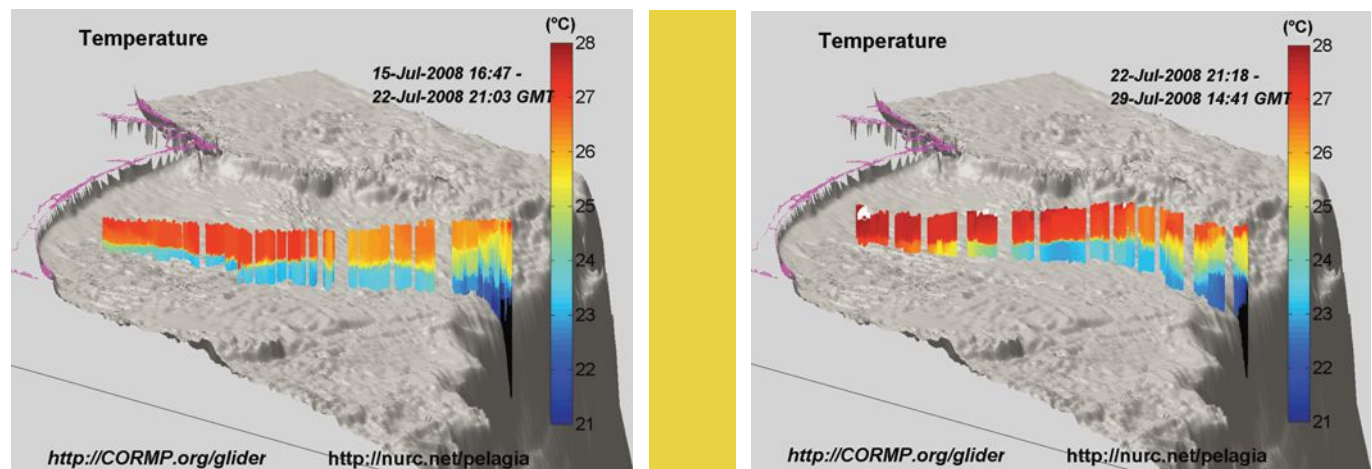


Figure 3 Glider track from 15 to 22 July 2008 in Long Bay, SC; temperature data (left-out and right-back) show water column stratification that existed throughout mission, but weakens in last couple of days nearshore during passage of Tropical Storm Cristobal

- Protect people and communities through quantitative improvements in the forecast of potentially destructive winds, waves, and storm surges;
- Improve coastal and marine use decision-making through enhanced and more comprehensive characterization of the coastal and marine environment;
- Improve public safety through more timely and site-specific health advisories, storm surge, and rip current warnings;
- Support safer and more efficient marine operations and emergency response through enhanced coastal and marine situational awareness;
- Provide positive economic impact through facilitation of more informed decision-making regarding commercial and recreational fisheries, and shoreline and climate change impacts.

C. Edwards, Skidaway Institute for Oceanography, led development of the initial glider sampling plan to be implemented in years 2 to 5 contingent upon funding and in collaboration with operational, modeling, and fisheries management partners (Figure 4). Survey areas coincide with important fisheries habitats, areas of ongoing stakeholder work, historical data, and other operational SECOORA assets (e.g., HFR, moorings). The plan also is timed with spawning seasons of key fisheries and to overlap with



Figure 4 SECOORA Glider Observatory study areas

modeling domains to support verification. Observations will support product development, such as the stock assessment work, and be used to improve, validate, and constrain regional circulation and ecosystem models. Regional and subregional circulation models also will be used to optimize vehicle control and mission strategy, taking advantage of control theory and model predictions of currents and frontal positions to guide glider sampling.

Looking Glass

Looking back on the 2010 Gulf oil spill disaster, critical lessons enlighten the way ahead to improving prevention and response preparedness. Recommendations from the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, report to the President in January 2011, "Deep Water: The Gulf Oil Disaster and the Future of Offshore Drilling," specifically call for the National Response Team to develop and maintain expertise within the federal government to obtain accurate estimates of flow rate or spill volume early in a source-control effort. As Klemas (2010) observed, "to limit the damage by a spill and facilitate cleanup efforts, emergency managers need information on spill location; size and extent; direction and speed of oil movement; and wind, current, and wave information for predicting oil drift and dispersion. The main operational data requirements are fast turn-around time and frequent imaging to monitor the dynamics of the spill." These are requirements for many of the nation's marine environmental challenges and gliders are a vanguard technology in this battle.

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