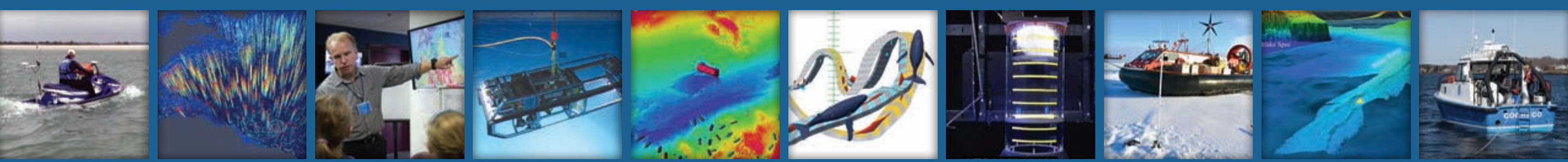
# UNH/NOAA Joint Hydrographic Center

## Performance and Progress Report

## Executive Summary



Project Title: Joint Hydrographic Center
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Flyers from the 2012 JHC/CCOM Seminar Series.

The NOAA-UNH Joint Hydrographic Center (JHC/CCOM) was founded thirteen years ago with the objective of developing tools and offering training that would help NOAA and others meet the challenges posed by the rapid transition from the sparse measurements of depth offered by traditional sounding techniques (lead lines and single-beam sonars) to the massive amounts of data collected by the new generation of multibeam echo sounders, and to promote the development of new ocean mapping technologies. Over the years, the focus of research at the Center has expanded, now encompassing a broad range of ocean mapping applications. Since its inception, the Center has been funded through Cooperative Agreements with NOAA. The most recent of these, the result of a national competition, funds the Center for the period of 1 July 2010 until December 2015. An initial goal of the Center was to find ways to process the massive amounts of data coming from multibeam and sidescan sonar systems at rates commensurate with data collection; that is, to make the data ready for chart production as rapidly as the data could be collected. Over the years, we have made great progress in attaining and now far surpassing this goal, and while we continue to focus our efforts on data processing in support of safe navigation, our attention has also turned to the opportunity provided by this huge flow of information to create a wide range of products that meet needs beyond safe navigation (e.g., marine habitat assessments, fisheries management, and national security). Our approach to extracting "value added" from data collected in support of safe navigation has become formalized with the enactment on the 30th of March, 2009 of the Ocean and Coastal Mapping Integration Act—and our establishment of an Integrated Ocean and Coastal Mapping (IOCM) Processing Center at UNH to support NOAA and others in delivering the required products of this new legislation. In 2010 the concept of IOCM was epitomized when we were able to quickly and successfully apply tools and techniques developed for hydrographic and fisheries applications to the Deepwater Horizon oil spill crisis.

In the relatively short period of time since our establishment, we have built a vibrant Center with over 90 employees and an international reputation as the place, "where the cutting edge of hydrography is now located" (Adam Kerr, Past Director of the International Hydrographic Organization in Hydro International). In the words of Pat Sanders, President of HYPACK Inc., a leading provider of hydrographic software to governments and the private sector:

> *"JHC/CCOM has been THE WORLD LEADER in developing new processing techniques for hydrographic data. JHC/CCOM has also shown that they can quickly push new developments out into the marketplace, making both government and private survey projects more efficient and cost effective."*

Since our inception, we have worked on the development of automated and statistically robust approaches to multibeam sonar data processing. These efforts came to fruition when our automated processing algorithm (CUBE) and our new database approach (The Navigation Surface) were, after careful verification and evaluation, accepted by NOAA, the Naval Oceanographic Office and other hydrographic agencies as part of their standard processing protocols. Today, almost every hydrographic software manufacturer has, or is, incorporating these approaches into their products. It is not an overstatement to say that these techniques are revolutionizing the way NOAA and others in the ocean mapping community do hydrography. These techniques can reduce data processing time by a factor of 30 to 70 and provide a quantification of uncertainty that has never before been achievable in hydrographic data. The result: "gained efficiency, reduced costs, improved data quality and consistency, and the ability to put products in the hands of our customers faster." (Capt. Roger Parsons, former NOAA IOCM Coordinator and Director of NOAA's Office of Coast Survey). We sadly note the death of Capt. Parsons in 2011—a tragic loss to the hydrographic and ocean mapping communities.

The acceptance of CUBE and the Navigation Surface represents a paradigm shift for the hydrographic community—from dealing with individual soundings (reasonable in a world of lead line and single-beam sonar measurements) to the acceptance of gridded depth estimates (with associated uncertainty values) as a starting point for hydrographic products. The research needed to support this paradigm shift has been a focus of the Center since its inception and to now see it being accepted is truly rewarding. It is also indicative of the role that the Center has played, and will continue to play, in establishing new directions in hydrography and ocean mapping.

Another long-term theme of our research efforts has been our desire to extract information beyond depth (bathymetry) from the mapping systems used by NOAA and others. We have made significant progress in developing a simple-to-use tool (GeoCoder) for generating a sidescan-sonar or backscatter "mosaic"—a critical first step in analyzing the seafloor character.

There has been tremendous interest in this software throughout NOAA and many of our industrial partners have now incorporated GeoCoder into their software products. Like CUBE's role in bathymetric processing, GeoCoder is becoming the standard approach to backscatter processing. An email from a member of the Biogeography Team of NOAA's Center for Coastal Monitoring and Assessment said:

> *"We are so pleased with GeoCoder! We jumped in with both feet and made some impressive mosaics. Thanks so much for all the support."*

Beyond GeoCoder, our efforts to support the IOCM concept of "map once, use many times" are also coming to fruition. In 2011, software developed by Center researchers was installed on several NOAA fisheries vessels equipped with Simrad ME70 fisheries multibeam echosounders. These sonars were originally designed for mapping pelagic fish schools but, using our software, the sonars are now being used for multiple seabed mapping purposes. For example, data collected on the *Oscar Dyson* during an acoustic-trawl survey for walleye pollock has been opportunistically processed for seabed characterization in support of essential fish habitat (EFH) and also in support of safety of navigation, including submission for charts and identification of a Danger to Navigation. In 2012, seafloor mapping data from the ME70 was used by fisheries scientists to identify optimal sites for fish-traps during a red snapper survey. Scientists on board ship said that the seafloor data provided by Center software was, "invaluable in helping accomplish our trapping objectives on this trip."

As technology evolves, the tools needed to process the data and the range of applications that the data can address will also change. We are beginning to explore the use of Autonomous Underwater Vehicles (AUVs) as platforms for hydrographic and other mapping surveys and are looking closely at the capabilities and limitations of Airborne Laser Bathymetry (lidar) in shallow-water coastal mapping applications. To further address the critical very shallow-water regimes we are also looking at the use of personal watercraft and aerial imagery as tools to measure bathymetry in that difficult zone between zero and ten meters water depth. The Center is also bringing many of the tools we have developed together to explore what the "Chart of the Future" may look like. In the last few years, a new generation of multibeam sonars has been developed (in part as a result of research done at the Center) with the capability of mapping targets in the water-column as well as the seafloor. We have been developing visualization tools that allow this water-column data to be viewed in 3D in real-time. Although the ability to map 3D targets in a wide swath around a survey vessel has obvious applications in terms of fisheries targets (and we are working with fisheries scientist to exploit these capabilities), it also allows careful identification of shallow hazards in the water-column and may obviate the need for wire sweeps or diver examinations to verify least depths in hydrographic surveys. These water-column mapping tools were a key component to our efforts to map submerged oil and gas seeps and monitor the integrity of the Macondo 252 wellhead as part of the national response effort to the Deepwater Horizon oil spill.

The value of our visualization, water-column mapping, and Chart of the Future capabilities have also been demonstrated by our work with Stellwagen National Marine Sanctuary aimed at facilitating an adaptive approach to reducing the risk of collisions between ships and endangered North American Right Whales in the sanctuary. We have developed 4D (space and time) visualization tools to monitor the underwater behavior of whales as well as to notify vessels of the presence of whales in the shipping lanes and to monitor and analyze vessel traffic patterns. Describing our interaction with the sanctuary, Craig MacDonald, superintendant said:

> *"… JHC/CCOM has been instrumental in creating novel tools to provide sound scientific understanding and information central to NOAA's ability to make informed spatial decisions that support ecosystem-based management in the sanctuary. As the National Marine Sanctuaries Act requires decisions to be made in an inclusive and transparent manner, the ability of JHC/CCOM to provide complex information in a form that can be readily understood by stakeholders (e.g., 3D swim paths of whales combined with multi-beam data on seafloor topography and sediment type) improves NOAA's ability to leverage stakeholder support for controversial decisions. In addition, our collaboration with CCOM has allowed us to monitor and evaluate the efficacy of our decisions, a key EBM requirement that is often neglected. These contributions have allowed NOAA and the sanctuary to occupy a lead position in CMSP and EBM, as identified by our Traffic Separation Scheme initiative being chosen as the single example illustrating the potential benefits of CMSP in the White House Council on Environmental Quality's Interim Framework for Effective Coastal and Marine Spatial Planning."*

Statements from senior NOAA managers and the actions of other hydrographic agencies and the industrial sector provide clear evidence that we are making a real contribution to NOAA and the international community. We will certainly not stop there. CUBE, The Navigation Surface, GeoCoder and The Chart of the Future offer frameworks upon which new innovations are being built and new efficiencies gained. Additionally, these achievements provide a starting point for the delivery of a range of hydrographic and non-hydrographic mapping products that set the scene for many future research efforts.

# Highlights from Our 2012 Program

Our efforts in 2012 represent the continued growth and refinement of successful ongoing research programs combined with the evolution of new programs developed within the seven research themes prescribed by the Cooperative Agreement (Sensors, Processing, Habitat and Water Column Mapping, IOCM, Visualization, Chart of the Future, and Law of the Sea). As our research progresses and evolves, the clear boundaries between these themes have become more diffuse. For example, from an initial focus on sonar sensors we have expanded our efforts to include lidar. Our data-processing efforts are evolving into habitat characterization, mid-water mapping and IOCM efforts. The data-fusion and visualization projects are also blending with our seafloor characterization, habitat and Chart of the Future efforts as we begin to define new sets of “non-traditional” products. This is a natural (and desirable) evolution that slowly changes the nature of the programs and the thrust of our efforts. While the boundaries between the themes are often diffuse and somewhat arbitrary, our Progress Report maintains the thematic divisions. The highlights outlined below offer only a glimpse at the Center's activities, but hopefully provide key examples of this year's efforts.

## Sensors

We continue to work closely with NOAA and the manufacturers of sonar and lidar systems to better understand and calibrate the behavior of the sensors used to make the hydrographic and other measurements used for ocean mapping. Many of these take advantage of our unique acoustic test tank facility, the largest of its kind in New England and now equipped with state-of-the-art test and calibration facilities. Among the highlights of this year’s efforts are the calibration of a Reson 7125 multibeam echo sounder (MBES) from the NOAA ship *Fairweather* and the return of that sonar to the fleet so that we can begin to inter-calibrate the many 7125s that NOAA uses and better understand the backscatter collected with these systems. Understanding that it will be impossible to bring all of NOAA's sonars into the calibration facility, we are developing a procedure for calibrating these sonars in the field.

The expertise of the Center with respect to MBES has been recognized through a number of requests for Center personnel to participate in field acceptance trials of newly installed sonars in the fleet. The Center has taken a lead in the establishment (through funding from the National Science Foundation) of a national Multibeam Advisory Committee (MAC) with the goal of ensuring that consistently high-quality multibeam data are collected across the U.S. Academic Research Fleet and other vessels. The experience gained from our MAC activities will be fed directly back into our support of NOAA mission related research and education. Part of this effort is the development and dissemination of best-practice documentation and quality assurance software that have already been introduced into the NOAA fleet.

Our concern about sensors extends to the instruments that collect the critical ancillary data needed for producing accurate bathymetric data. Unquestionably one of the greatest sources of uncertainty in our bathymetric data is our inability to capture the spatial and temporal changes of the sound speed structure of the water column (needed to convert the echosounder measurements to accurate depths). To address this issue NOAA has adopted "Moving Vessel Profilers" (MVPs) that allow closely-spaced sound speed profiles to be collected rapidly while the vessel is underway. One of the key questions facing those using these systems is the profiling interval needed for capturing the true variability of the water column.  Too few profiles can lead to poor data quality and too many can lead to degradation and possibly loss of the instrument. To address this problem, graduate student and NOAA Physical Scientist Matt Wilson and Center researcher Jonathan Beaudoin have developed the "CastTime" algorithm that determines the optimal spacing for MVP casts and automatically controls the profiler. CastTime was tested in the field on the NOAA Ship *Ferdinand R. Hassler* in September with excellent results leading to greatly reduced utilization of the system but the assurance of high quality data. The software will be installed on a small subset of NOAA field units during the 2013 field season with the goal of a fleet-wide deployment in 2014. This example epitomizes the role that the Center can play in support of NOAA. A NOAA student arrives at the Center with specific NOAA problem. She or he works with our faculty and staff to come up with a solution to the problem and returns to the fleet with a solution and implementation.

The efficiency of multibeam sonar mapping decreases as the water depths get shallower, yet the risks to navigation are typically magnified in the shoalest of waters. To address this issue, NOAA and others have looked to airborne lidar techniques as a possible means of providing rapid mapping in very shallow waters. Thus, in concert with our efforts to understand the behavior

Figure ES-1. The Coastal Bathymetry Survey System (CBASS).

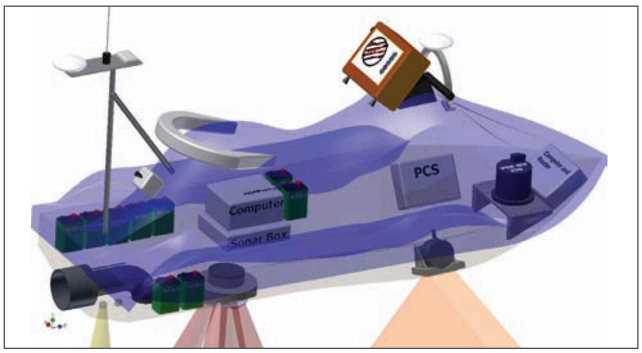


Figure ES-2. Scaled CAD drawing showing the location of the MBES (peach), SBES (yellow), ADCP (red) with acoustic beam patterns on the CBASS.

of sonar sensors, we are also undertaking a number of projects aimed at understanding the characteristics, behavior and limitations of lidar sensors. Shachak Pe'eri, working closely with NOAA's Chris Parish, has been developing a lidar simulator in the lab that will supplement theoretical studies to determine the behavior of the lidar pulse once it enters the water column. Among the issues being examined (both empirically and theoretically) are the impact of sea state on the resolution of the lidar pulse and the influence of substrate on the lidar return. This year, a new suite of in situ instruments (The Optical Collection Suite) has been developed that enable researchers to collect underwater imagery while measuring the spectral response, performing radiometric calibrations and quantifying the clarity of the water using simple and relatively inexpensive instruments that can be hand-deployed from a small vessel.

Many questions (resolution, target detection and limitations due to water clarity) remain about the ultimate viability of airborne lidar as a hydrographic tool. We are thus also exploring other means to make high-resolution bathymetric measurements in very shallow, rugged coastal areas. One of our approaches is the Coastal Bathymetry Survey System (CBASS), a highly maneuverable personal watercraft equipped with a very high-end motion sensor (POS-MV), kinematic GPS positioning, and a multibeam echosounder. This year, CBASS was deployed in New River Inlet, NC and produced bathymetric maps with 10-20 cm vertical resolution in water depths ranging from less than 1 m to 12 m (Figure ES-1).

Through collaboration with Prof. Art Trembanis at the University of Delaware, we are also exploring the viability of using Autonomous Underwater Vehicles (AUVs) as a platform for hydrographic measurements. This year, the Gavia AUV was equipped with a magnetometer module that allowed us to explore the positional drift of the AUV while surveying. To our very pleasant surprise, calibration surveys with the magnetometer revealed positional errors of 0.15 m in Easting and 0.88 m in Northing with standard deviations of 0.43 m and 0.54 m, respectively, for a typical 55 minute mission, much better than we had envisioned. The Gavia was also used to survey an artificial reef site off Delaware Bay a few days before and a few days after Hurricane Sandy in conjunction with a hull-mounted Reson 7125 (Figure ES-4). The results of these surveys will greatly enhance our understanding of the impact of the storm offshore as well as provide a direct comparison of data collected from a hull-mounted multibeam sonar with those collected by an AUV deployed phase-measuring bathymetric sonar.

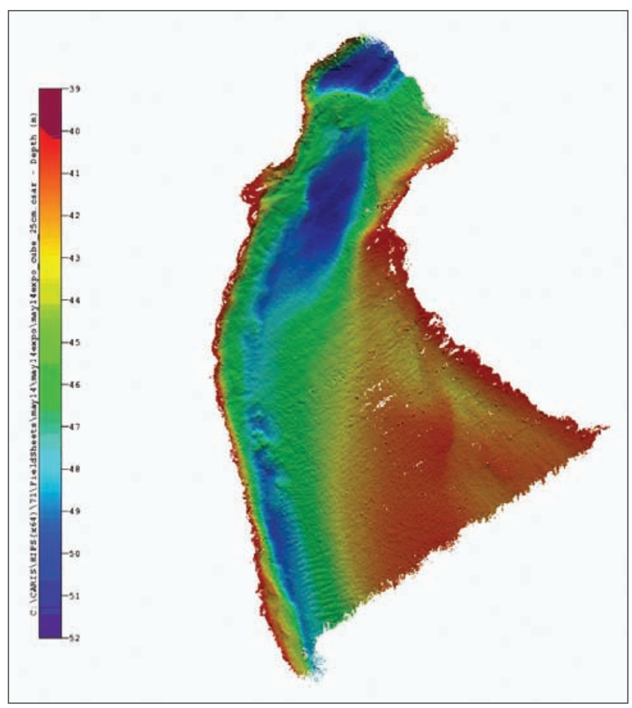

Figure ES-3. Bathymetry produced from CBASS (right). Color scale is meters relative to ellipsoid—depths were consistently measured in water less than 1 m deep.

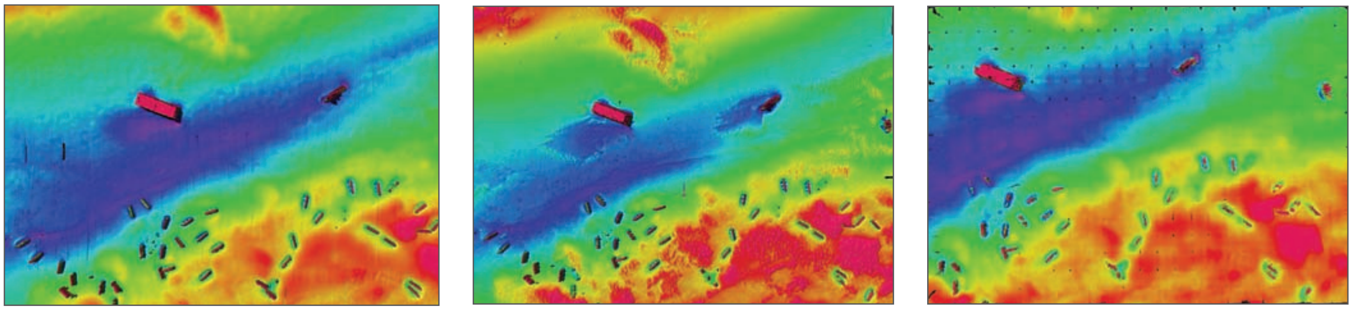

Figure ES-4. Seafloor surveys of “Redbird Reef” from before Hurricane Sandy (left) and after (middle) with the R/V *Sharp’s* Reson 7125. The large object is a barge, smaller objects are New York City subway cars. The horizontal extent of the seafloor shown is approximately 425 m with depths ranging from 27.8 to 30.1 m with the exception of the sunken barge and tug. Some subway cars may have moved as much as 10 m during the storm while others appear to have collapsed. Pre-hurricane bathymetry produced by Gavia AUV with GeoSwath phase measuring bathymetric sonar processed with Center-derived software (right).

## Processing

In concert with our efforts focused on understanding the behavior and limitations of the sensors we use, we are also developing a suite of processing tools aimed at improving the efficiency of producing the end products we desire, but just as importantly, aimed at quantifying (and reducing if possible) the uncertainty associated with the measurements we make. As CUBE becomes more and more accepted as the standard approach to processing hydrographic data, Brian Calder, developer of the algorithm, has continued to work with software vendors and NOAA to ensure appropriate implementation of the code.

This year’s efforts have focused on the CHRT (CUBE with Hierarchical Resolution Techniques) algorithm. CHRT is a software architecture for robust bathymetric data processing that takes the core estimator from the CUBE algorithm and embeds it in a system that allows for variable resolution of data representation that is data adaptive, meaning that the density of data collected is reflected in the resolution of the estimates of depth. As part of this year's effort, Calder has improved the accuracy of the resolution prediction, improved the stability and accuracy of the algorithm, implemented a parallelized version of the core algorithm, and is implementing a distributed (multi-computer) version for blade-server deployment.

Another exciting achievement in 2012 was Calder's work with the new multibeam sonar data collected by Andy Armstrong and Jim Gardner in support of our Law of the Sea efforts (see below) in the Mariana Trench region, applying robust statistical methods to determine the deepest depth in the world's oceans (10984±25m (95%) on 9 d.f.). Although developed for the specific purpose of finding the deepest depth in this data set, the technique may have important ramifications for several other hydrographic applications.

Our efforts to understand uncertainty and improve data-processing flow have also expanded to an alternative type of swath-mapping sonar—those that use multiple rows of offset arrays to determine depth through the measurement of phase differences. These sonars can offer wider swath coverage (and thus increase survey efficiency) but there are a number of outstanding questions about the quality of the bathymetric data they produce and the difficulties associated with processing. To address these issues, Val Schmidt and others have been developing new approaches to phase-measuring bathymetric sonar (PMBS) processing (“Most Probable Angle” algorithm) and with this, have been quantifying the uncertainty associated with these measurements.

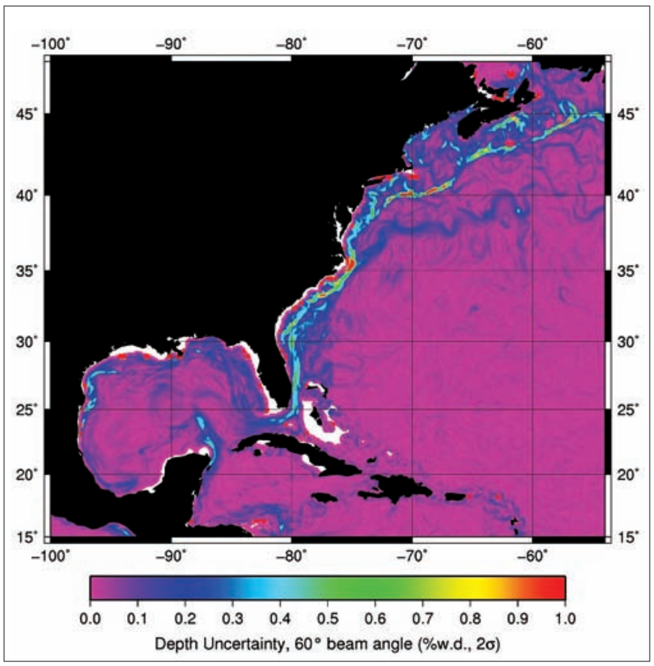


Figure ES-5. High-resolution SVP “Weather Map” of the Gulf Stream region, based on ray tracing analysis of NOAA’s Real-Time Ocean Forecast System nowcast for February 17th, 2012.

This year, Schmidt has combined his techniques with an approach developed by Center visiting scholar, Xavier Lurton, to determining uncertainty in PMBS and has used the combined tools to robustly process data collected with a PMBS system deployed on the Gavia AUV (see Figure ES-4).

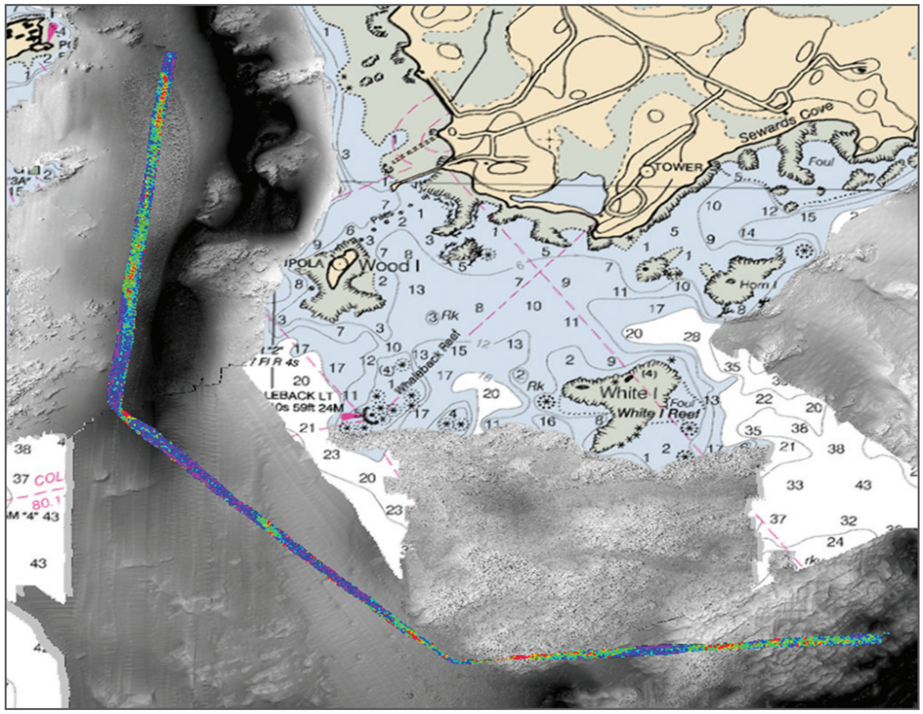

Figure ES-6. Backscatter repeatability measured with 10 passes of a standard line. The color represents the range within which 75% of the data fall over the 10 passes, with blue representing 2 dB or lower variation and red representing 5 dB variation or higher. High backscatter variability seem to be associated with shallow bedrock outcroppings (cause unknown but possibly related to macroalgae), moving bedforms such as sand waves, and boundaries between different types of seabed substrate.

As discussed earlier, it is becoming increasing apparent that the largest contributor to uncertainty in our collection of seafloor mapping data is our inability to fully capture the spatial and temporal variability of the speed of sound in the water masses in which we work. In addition to the CastTime approach to optimizing moving vessel profiler casts, Jonathan Beaudoin is also looking at the use of historical or model data to help in those areas where sufficient data does not exist and to streamline the process of entering sound speed data into our sonar systems. As part of these efforts, Beaudoin has developed an "SVP Editor" that allows for the rapid and automated input of sound speed profiles into MBES systems as well as interactive graphical data editing for removal of outliers and/or addition of points for vertical extrapolation.

The SVP Editor also offers the user the ability to run the software in "Server" mode whereby a synthetic sound speed profile is delivered to the echosounder based on oceanographic models such as the World Ocean Atlas (WOA) or the Real-Time Ocean Forecast System (RTOFS). The SVP Editor uses position information from the sonar to establish the date and position of the vessel which are then used to form a query for the oceanographic model of choice and to establish estimates of the temperature and salinity profiles for the desired location. A sound speed profile is constructed from these and then delivered to the MBES. This can be done continuously while in transit, enabling opportunistic underway mapping such that echo sounding data gathered in the absence of the directly observed sound speed data has at least a rudimentary refraction correction applied with no operator intervention required. In both use case scenarios, an important additional functionality of the SVP Editor is to provide the hydrographer with the ability to preview the effects of applying the new sound speed profile to data in real-time prior to delivery to the sounder in order to see the effect of the new profile. This allows for an important verification step in which the operator can correct or adjust the profile to minimize refraction residuals in real-time.

Carrying the approach of using oceanographic models in aid of seafloor mapping one step further, Beaudoin is working on developing tools to help better understand the "underwater weather" that can severely limit the achievable accuracies of echo sounding data, particularly with wide swath MBES. The result of this effort is something akin to a weather map for hydrographers; the basic idea is that oceanographic models of temperature and salinity can provide us with an estimate of where spatial variability in the water column can be problematic. With high-resolution models like RTOFS, it is now possible to compute forecasts with high spatial resolution and fidelity (Figure ES-5). The approach has proven invaluable for planning cruises and in avoiding times or areas of high oceanographic variability.

In concert with our efforts to improve the processing of bathymetric data, we are also focusing significant effort on trying to improve approaches to processing backscatter (amplitude) data that are collected simultaneously with the bathymetric data but was previously ignored by hydrographic agencies. These data are becoming more and more important as we recognize the potential for seafloor mapping to provide quantitative information about seafloor type that can be used for habitat studies, engineering evaluations and many other applications. Essential to this effort is to understand the uncertainty associated with the measurement of acoustic backscatter from the seafloor. The fundamental question is: when we see a difference in the backscatter displayed in a sonar mosaic, does this difference truly represent a change in seafloor characteristics or can it be the result of changes in instrument behavior or the ocean environment? The focus of our effort in addressing this difficult question is a new project we call the New Castle Backscatter Experiment (NEBEX). This project, which involves close collaboration with NOAA's Glen Rice and NOAA Graduate student Briana Welton, brings together several different existing lab efforts: Mashkoor Malik's Ph.D. thesis work; Carlo Lanzoni's work toward an absolute backscatter calibration for MBES; Sam Greenaway and Glen Rice's efforts toward field procedures for proper backscatter data collection; backscatter mosaicing (GeoCoder); backscatter inversion; and backscatter ground truth (e.g., optical imagery, bottom sampling, high accuracy positioning). Associated with this effort is our work calibrating individual sonars and addressing concerns raised by our NOAA partners about specific systems they are using in the field. Epitomizing this effort is the development by Glen Rice and Tom Weber (building on the work of Sam Greenaway) of a backscatter "saturation monitor," a software tool that helps field teams ensure they collect backscatter data that remains within calibration parameters. This tool has successfully been deployed in the fleet and is already improving the quality of data collected. This past year the NEWBEX project began a series of field experiments aimed at understanding the consistency (and sources of inconsistency) in backscatter data through the establishment of "reference surface" for data collection. The results of these experiments have already provided important insights into backscatter behavior (Figure ES-6).

## Habitat and Water Column Mapping

Our efforts to understand and calibrate the acoustic and optical sensors we use (Sensors theme) and to develop software to process the data they produce in an efficient manner while minimizing and quantifying the uncertainty associated with the measurements (Processing theme), are directed to producing products that not only support safe navigation but that can also provide information critical to fisheries management and other environmental and engineering problems. These efforts have focused on understanding and interpreting the backscatter (both from the seafloor and more recently with the advent of a new generation of multibeam sonars, in the water column) and generating tools to use this information to provide key information useful to marine managers. Our efforts in acoustic seafloor characterization have focused around the GeoCoder software package (designed to make fully

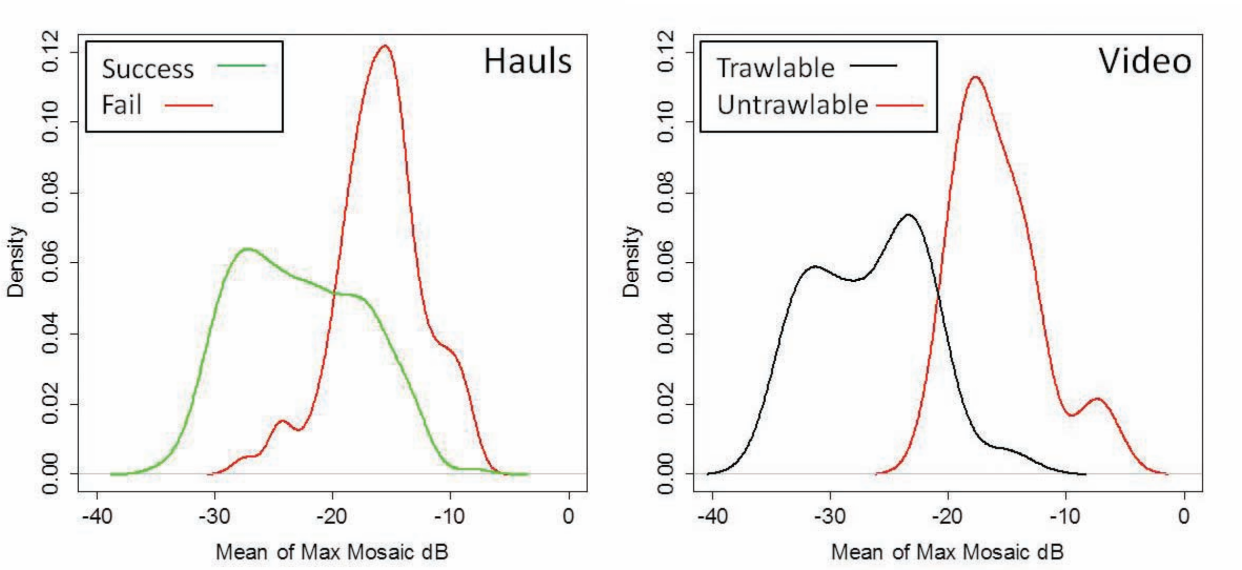


Figure ES-7. Histograms describing the distribution of seafloor backscatter strength (Ss) (mosaic values normalized to oblique incidence angles of 30-50°) at locations in the GOA previously sampled (1996-2011) by the AFSC bottom trawl survey and classified by performance as successful (success) or marginally successful and failed due to gear damage (fail) (left) and at camera stations characterized as trawlable or untrawlable based on video (right).

corrected backscatter mosaics and calculate a number of backscatter statistics) and a constrained ARA (Angular Response Analysis) inversion that is designed to analyze the angular response of the backscatter as an approach to remote seafloor characterization. While GeoCoder has been implemented by many of our Industrial Associates, many questions remain about the calibration of the sonars (e.g., the work described in the Sensor and Processing sections) and the inherent nature of the approaches used to segment and characterize seafloor properties. This year's efforts, led by Yuri Rzhanov, have focused on automating techniques for segmenting backscatter data into regions of common character and in sensitivity studies to better understand the relative importance of various components of the inversion model and the corrections being made. We have also begun to restructure the GeoCoder processing pipeline into software modules; these modules honor the algorithms implemented in the original GeoCoder framework but with clear boundaries being set between the various data-flow and processing stages so that researchers can investigate and potentially improve upon a single module without the overhead of maintaining the overall software framework or rebuilding (compiling) the entire application. Several "plug-in" modules have already been created that are enhancing the capabilities for specific sonars or applications.

As part of our IOCM activities (see IOCM theme), we are also exploring means of extracting multiple data sets from a single sonar survey/system. To this end, Jodie Pirtle and Tom Weber are collaborating with the NOAA Alaska Fisheries Science Center (AFSC) to map groundfish habitat in the Gulf of Alaska (GOA) using the Simrad ME70 multibeam echosounder (ME70) with the primary goal of distinguishing between trawlable and untrawlable areas of the seafloor. Last year, a clear relationship was demonstrated between the angular dependence of backscatter and the trawlability of the seafloor. This year, a simpler parameter, the maximum backscatter between 30-50°, was shown to be a good predictor of trawlability; a similar pattern was observed for trawlable and untrawlable camera stations (Figure ES-7).

This information will ultimately improve efforts to determine habitat-specific groundfish biomass and identify regions likely to contain deep-water coral and sponge communities that may be considered Habitat Areas of Particular Concern (HAPCs). This research supports NOAA's efforts to identify and describe Essential Fish Habitat (EFH) for harvested species, and to improve fisheries stock assessment methods for locations and seafloor types that are not easily accessible. And all this from a sonar that was not purchased to map the seafloor.

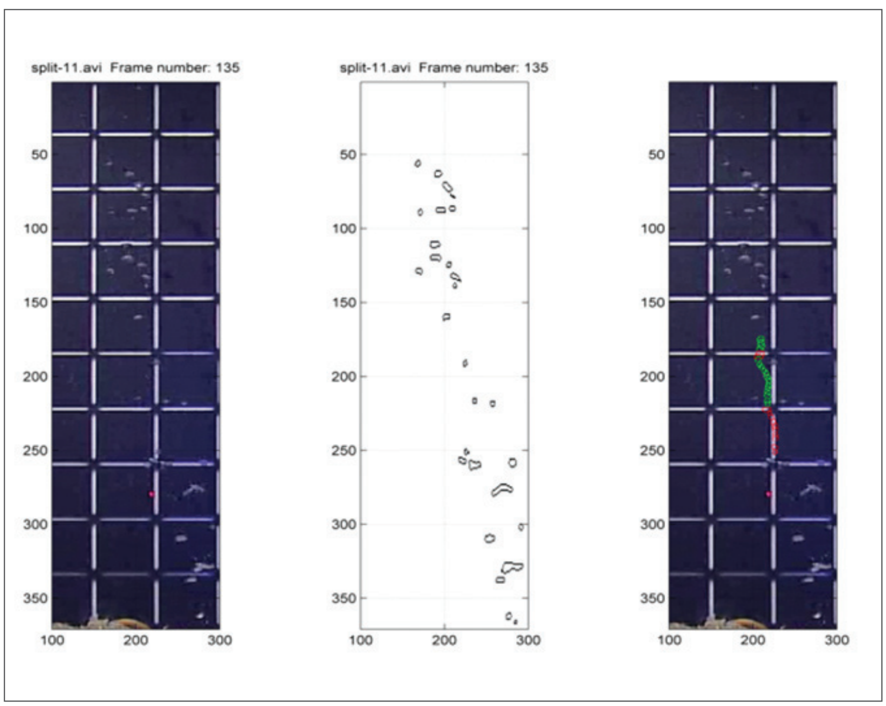


Figure ES-8. A calibrated grid for measurement of bubble size and rise rate (right).

Along with our work using acoustic data to attempt to extract critical habitat data we are also working on techniques to quantitatively analyze lidar, hyperspectral and optical imagery, including work with NOAA's biogeography group focused on mapping coral habitat in the U.S. Virgin Islands.

The efforts described above have focused on the seafloor. A new generation of multibeam sonars now has the ability to simultaneously map both the seafloor and the water column. Combining the ability to image the water column and the seafloor over wide swaths with high-resolution offers great opportunities for new applications and increased survey efficiencies. The Center has been very active in developing tools to capture, analyze and visualize water column

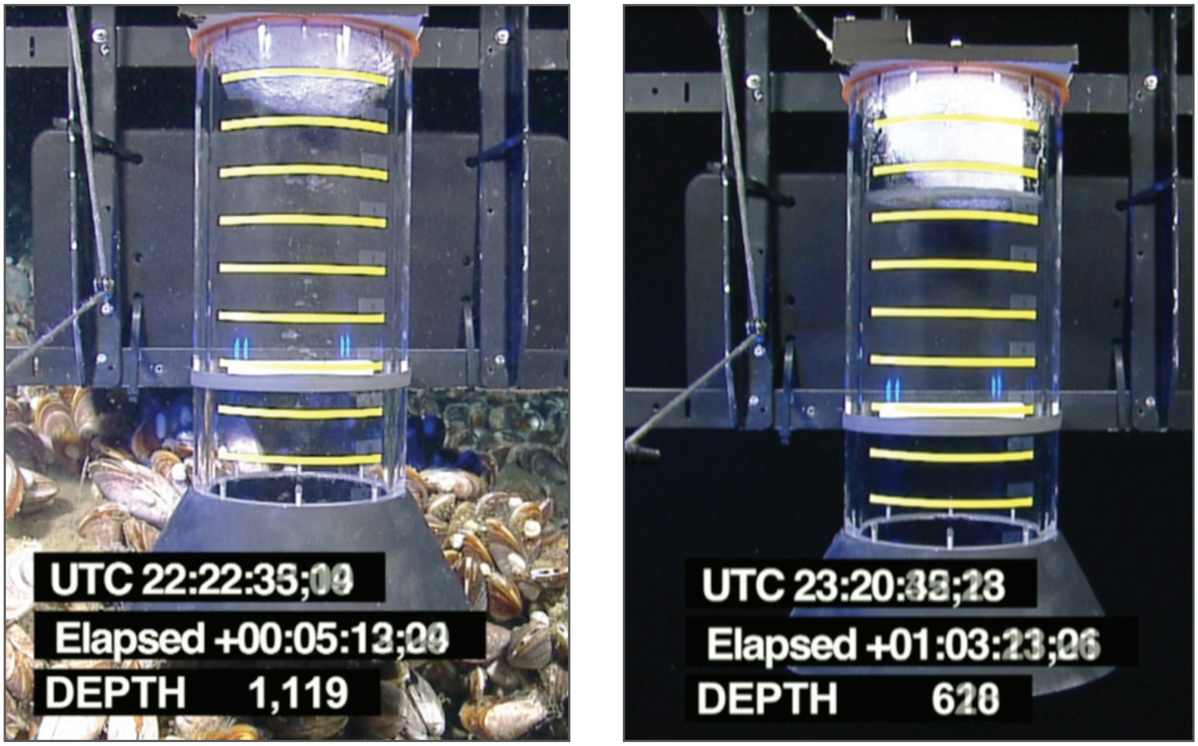


Figure ES-9. A methane capture device used to assess methane flux from a seep in the Gulf of Mexico. Note the hydrates forming in the top of the cylinder, which dissociate to form gas and water as the ROV rises to shallower depths and warmer waters.

data and these tools proved extremely valuable in our efforts to map the deep oil plume and monitor the integrity of the Macondo wellhead during the Deepwater Horizon (DWH) crisis (see the 2010 annual report for a full description of our activities related to Deepwater Horizon). Immediately following the Deepwater Horizon explosion and leak of the Macondo well head, we proposed the use of a 30 kHz multibeam sonar with water column capability (a Kongsberg Maritime EM302) as a potential tool for mapping deep oil and gas spills and monitoring the well head for leaks. At the time of the spill, such a system was not available and we used fisheries sonars instead.

In August and September of 2011, we finally had the opportunity to bring the EM302 multibeam echo sounder onboard the NOAA Ship *Okeanos Explorer* to the Gulf of Mexico in order to test the water column mapping capability for detecting and characterizing methane gas seeps. During this relatively short cruise (less than two weeks of active mapping) we mapped 17,477 km2 of the northern Gulf of Mexico making 573 seep observations. The results from this cruise demonstrate a new mid-water mapping technology for the *Okeanos Explorer*, and also suggest that wide-scale mapping of seeps in the deep Gulf of Mexico—an objective that is important for both scientific and industry management perspectives—is viable.

In 2012, we followed up these studies with another program on the *Okeanos Explorer* aimed again at making acoustic measurements but also using an ROV to estimate gas flux rates to compare to the acoustic data. For this effort, we took advantage of our telepresence capability and guided the science from shore including EM302 and EK60 seep mapping as well as the deployment from the Little Herc ROV of gas sampling apparatus and a calibrated bubble grid aimed at measuring bubble sizes and rise rate (Figures ES-8 and ES-9). These studies set the framework for using surface-ship acoustic backscatter mapping to determine methane flux rates over large areas of the Gulf of Mexico and elsewhere.

## IOCM—Integrated Ocean and Coastal Mapping

A critical component of the Center's 2010-2015 proposal was to establish an Integrated Ocean and Coastal Mapping Processing Center that would support NOAA's new focused efforts on Integrated Coastal and Ocean Mapping. This new Center brings to fruition years of effort to demonstrate to the hydrographic community that the data collected in support of safe navigation may have tremendous value for other purposes. It is the tangible expression of a mantra we have long-espoused "map once—use many times." The fundamental purpose of the new Center is to develop protocols for turning data collected for safety of navigation into products useful for fisheries habitat, environmental studies, archeological investigations and many other purposes and conversely, to establish ways to ensure that data collected for non-hydrographic purposes (e.g., fisheries) will be useful for charting.

Representing the Office of Coast Survey at the Center, LTJG Glen Rice has partnered with a number of Center members to design workflows for IOCM products and to provide a direct and knowledgeable interface with the NOAA fleet to ensure that we address high-priority issues and that the tools we develop are relevant for fleet use. In addition, Glen provides a direct link when specific operational difficulties arise in the field, allowing Center personnel to take part in designing an appropriate solution.

Epitomizing the IOCM concept have been our efforts on the NOAA fisheries vessel *Oscar Dyson*. In 2011 and 2012, while the *Dyson* was conducting routine acoustic trawl surveys, we were able to simultaneously extract bathymetry data (to date more than 452 square nautical miles of bathymetric data—along with uncertainty and calibrated backscatter derived from the ME70—have been submitted for charting), and produce habitat maps of trawlable and untrawlable seafloor. One of the most exciting aspects of this effort was discovery from the 2011 ME70 data of a previously uncharted shoal that led to a chart update and Danger to Navigation (DTON) warning. Thus, from a single fisheries sonar (ME-70) and a fisheries cruise dedicated to acoustic-trawl surveys, seafloor habitat data, bathymetric data for charting and a specific Danger to Navigation were all derived.

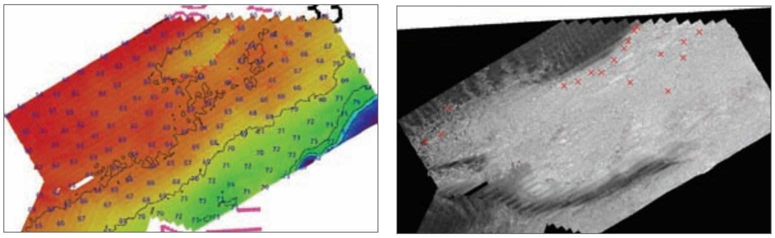

Figure ES-9. Bathymetry (left) and backscatter mosaic (right) used to determine areas of hard-bottom for optimal trap locations. Red Xs mark actual spots of trap drops.

This past year we had a similar example of the power of the IOCM approach when graduate student (and NOAA physical scientist) Matt Wilson, along with Jonathan Beaudoin and Glen Rice, installed Center-developed bottom mapping algorithms into the workflow of the NOAA Fisheries Vessel *Pisces*' Simrad ME70 producing both multibeam bathymetry and backscatter from this fisheries sonar in near real-time (Figure ES-9). Using these products, NOAA fisheries scientists were able to quickly and accurately identify areas of red snapper habitat suitable for setting their traps. In their words, these data were "invaluable in helping accomplish our trapping objectives on this trip."

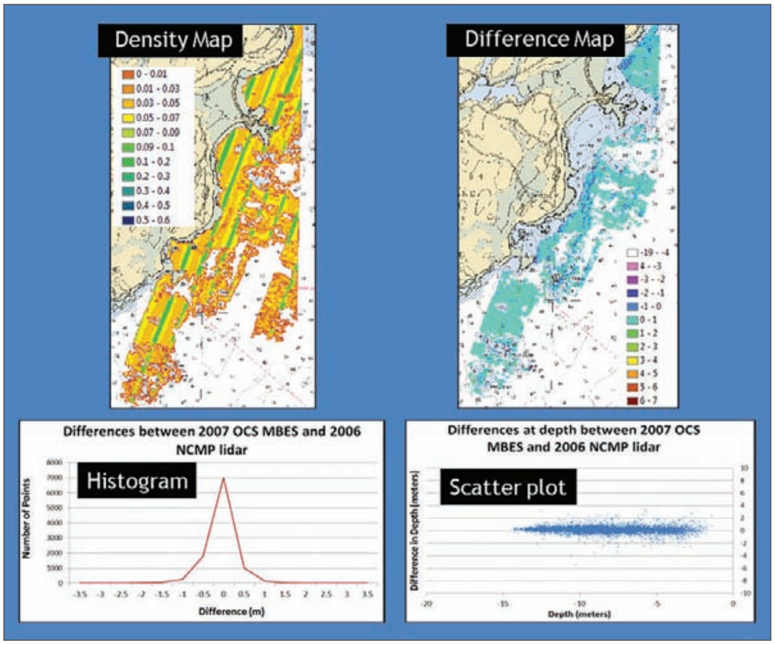


Figure ES-10. Statistical comparison of ACOE ALB data to NOAA MBES data from Kittery, ME. (Top left) Density map of laser measurement in laser measurements per square meter. (Top right) Difference map between ACOE lidar survey and NOAA OCS multibeam survey. (Bottom left) Histogram plot of the depth difference values between the NCMP and OCS datasets. (Bottom right) Scatter plot of the depth difference values between the ACOE and OCS datasets as a function of depth.

We are indeed mapping once and using many times. We are now formalizing the sounding extraction portion of the workflow with the goal of making this process standard aboard NOAA vessels with ME70s as part of the NOAA R2R program.

Our IOCM efforts have also extended to lidar data. Although many questions still remain about the viability of using Airborne Lidar Bathymetry (ALB) data for hydrographic purposes (see Sensor theme), there is no question that this approach provides the potential for the rapid collection of bathymetric data in very shallow water where traditional multibeam sonar surveys are least efficient. In an effort to better understand the applicability of third-party ALB data, the Center is working with NOAA to look at USACE and other outside ALB data sources and to compare the quality of the data collected by these systems as well as their standards and operations, to NOAA MBES data and to NOAA and international hydrographic survey standards (Figure ES-10).

## Visualization

We continue a very strong focus on the development of innovative approaches to data visualization and fusion and the application of these approaches to ocean mapping and other NOAA-related problems. Over the past few years, the visualization team under the supervision of Lab Director Colin Ware has produced a number of novel and innovative 3D and 4D visualization tools designed to address a range of ocean mapping applications. This year, Ware and Tom Butkiewicz have continued the development of a new interactive visualization environment for 3D/4D ocean data. The current focus is on multi-depth flow models, but the techniques are general enough to incorporate many other types of data. This project is unique in that it is an effort to bring together a number of different visualization/interaction technologies and techniques and combine them to support a cohesive visual analysis system that will empower users with the ability to explore and analyze complex time-dependent 3D ocean models. The system being developed employs a combination of stereoscopic rendering, to best reveal and illustrate 3D structures and patterns, and multi-touch interaction, to allow for natural and efficient navigation and manipulation within the 3D environment. Exploratory visual analysis is facilitated through the use of a highly-interactive toolset leverages the use of a smart particle system (a system that allows the particles to have independent properties).

Example of analyses that can be performed within the system include simulating pollutant releases by releasing particles configured with specialized behaviors such as vertical movements induced by density differences (modeling, e.g., oil spills or radioactive fluid leaks) and decay over time. Habitat mapping can be supported by modeling larval transport, etc. Survey mission planning for autonomous underwater vehicles can be enhanced by adding information on forecasted flow conditions. Imported or multi-touch plotted path-lines can be automatically evaluated against the surrounding flow patterns, resulting in energy efficiency scores along the proposed vehicle track.

In February 2012, Colin Ware visited Hendrik Tolman, the Branch Chief of Marine Modeling and Analysis NCEP in Camp Springs. The result is an agreement to collaborate on adapting the 3D environment so that it can display the global RTOFS model (a very high-resolution ocean flow model) and in this context show Argos float and glider data. A new analytical feature is the ability to evaluate the predictions within the Global RTOFS forecast model through comparison with collected observational data. This is accomplished by loading the newest profiles and positional data from Argo's global network of 3000 autonomous floats. Each Argo float drifts underwater for nine days, and

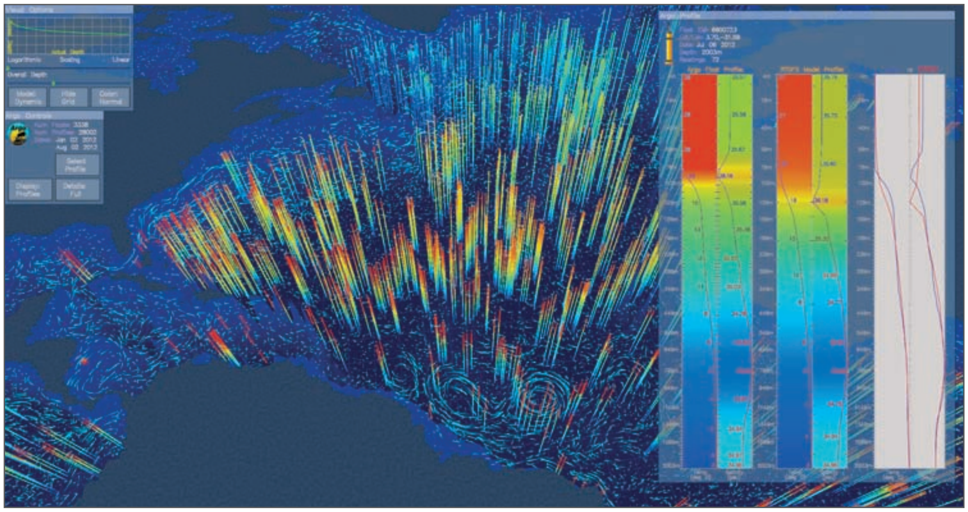

Figure ES-11. Profile explorer window showing the observed and predicted temperature and salinity profiles from an Argo float and the RTOFS model. The rightmost graph plots them against each other to highlight deviations.

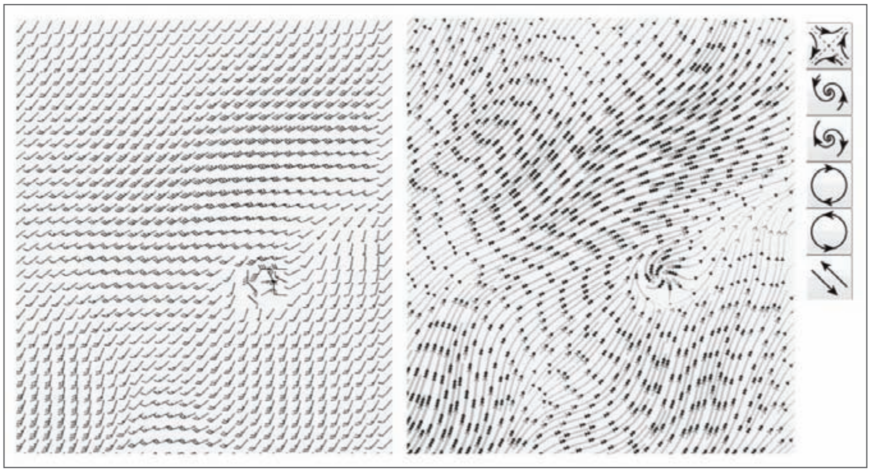

Figure ES-12. A wind pattern shown using the traditional method and using our new method (Pilar and Ware, in press). This is part of a study of pattern perception using different portrayal methods.

then ascends to the surface while collecting a temperature and salinity profile, which it transmits along with its current location before diving again. Analysts can select Argo profiles in the 3D view, which spawns profile explorer windows (Figure ES-11) that present the Argo profile data, along with corresponding profiles automatically extracted from the RTOFS model at the same location. By comparing the observed temperature and salinity values to those in the forecast model, simulation designers can gain critical insight regarding where and how their model succeeds or fails in its predictions. Furthermore, the accuracy of the model's flow forecasts can also be evaluated by comparing the float's observed positional data to predicted trajectories generated using the model's forecasted flow vectors. The Argo float analysis is just one example; we envision that this new visualization environment will become a powerful analytic tool for the exploration and evaluation of many types of complex 3- and 4D oceanographic data sets.

Adding to our visualization research, are efforts to establish new ways to display wind and wave patterns using newly developed wind "glyphs." Research into flow visualization has suggested that streamlines better represent flow patterns but these methods lack a key property—unlike the wind barb they do not accurately convey the wind speed. With the goal of improving the perception of wind patterns, and at least equaling the quantitative quality of wind barbs, graduate student David Pilar and Ware developed variations on the wind barb and designed a new quantitative glyph (Figure ES-12). Testing of the results has shown that the new design is superior to the classic, but also that the classic barb can be redesigned and substantially improved. They are currently investigating ways of using the new glyphs to show wave patterns from the WaveWatch III model and current patterns and will be integrating these innovations into NOAA's NowCoast Portal.

The visualization team also continues to develop tools to better understand the underwater behavior of humpback whales and the applications of this work in support of both basic science and policy decisions (humpback whales are an endangered species whose decline is attributed to ship collisions and fishing-gear entanglement). NOAA and Woods Hole Oceanographic Institution scientists have developed suction-cup-mounted tags that are attached to a whale that record depth, pitch, roll and sound for as long as the tag remains on the whale. Our visualization team has taken these data and created fully georeferenced 4D displays of the whale's diving and swimming behavior in the context of the bathymetry, other vessels and ambient sounds. Numerous papers on, and demonstrations of, this technology have been presented at both scientific and policy meetings. Ware has extended this work with the development of TrackPlot, an application designed to help visualize and analyze data from tagged marine mammals. It has evolved over the past eight years in close collaboration with marine mammal scientists and has become a significant research tool resulting in a number of journal papers detailing the kinematic behaviors of various species. Development of TrackPlot is ongoing and the user base of TrackPlot continues to expand. It has at least 14 users from different groups and it has been applied to 11 different species.

## Chart of the Future

Inherent in the Center's data-processing philosophy is our long-held belief that the "products" of hydrographic data processing can also serve a variety of applications and constituencies well beyond hydrography. Another long-held tenet of the Center is that the standard navigation charts produced by the world's hydrographic authorities do not do justice to the information content of high-resolution multibeam and sidescan-sonar data. We also believe that the mode of delivery of these products will inevitably be electronic—and thus the initiation of "The Chart of the Future" project. This effort draws upon our visualization team, our signal and image processors, our hydrographers, and our mariners. In doing so, it epitomizes the strength of our

Center—the ability to bring together talented people with a range of skills to focus on problems that are important to NOAA and the nation. The effort has had two paths—an "evolutionary" path that tries to work within existing electronic charting standards (which are very restrictive), and a "revolutionary" path that lifts the constraint of current standards and explores new approaches the may lead to the establishment of new standards. Within the evolutionary track we have worked with electronic chart manufacturers on approaches for including high-density hydrographic survey data and in particular, the concept of the "tide-aware" ENC that can vary the display with the state of the tide. The evolutionary track also includes our work to take advantage of the Automatic Identification System (AIS) carried by many vessels to transmit and receive data from the vessels. Our AIS efforts have led to the visualization of the behavior of the Cosco Busan after the San Francisco Bay spill incident, evidence for a fishing trawler violating Canadian fishing regulations and damaging Canada's Ocean Observatory (Neptune) equipment, and the creation of the vessel traffic layer in ERMA, the response application used by Unified Command during the Deepwater Horizon Spill. This application was a finalist for the Homeland Security Medal.

A very successful application of our AIS work has been its use in monitoring right whales in an LNG shipping route approaching Boston Harbor. Kurt Schwehr, in collaboration with EarthNC, has developed an iPad application that allows display on the iPad, iPhone, and other hand-held devices; we are now exploring using this model to transmit other information (e.g., tides) to vessels (Figure ES-13). In support of the growing need to support navigation in an ice-diminished Arctic, we have worked with Lysondros Tsoulos of the National Technical University of Athens to establish optimal map projections for Arctic navigation charts.

The revolutionary track for the Chart of the Future involves three-dimensional displays and much more interactivity. In the last few years, the focus of this effort has been the development of "GeoCoastPilot," a research software application built to explore techniques for simplifying access to the navigation information a mariner needs prior to entering or leaving a port. GeoCoastPilot is not intended to be used directly for navigation purposes, but instead is intended to demonstrate what is possible with current technology and to facilitate technology transfer. With such a digital product, the mariner could, in real-time on the vessel or before entering a harbor, explore through the click of a mouse any object identified in the text and see a pictorial representation (in 2D or 3D) of the object in geospatial context. Conversely, a click on a picture of an object will directly link to the full description of the object as well as other relevant information. GeoCoastPilot turns the NOAA Coast Pilot manual into an interactive document linked to a 3D map environment, that provides linkages between the written text, 2D and 3D views, web content and other primary sources such as charts, maps, and related federal regulations. This visualization technique helps the mariner become familiar with the relative location of critical navigation-related features within a port before ever going there.

This year's efforts were focused on further developing automated techniques for incorporating Local Notice to Mariners into the digital products and perhaps the GeoCoastPilot (Figure ES-14). The Local Notice to Mariner project has matured to the point where project lead, Briana Sullivan, has made several presentations to NOAA and USGC personnel involved in the creation and distribution of Local Notice to Mariners. These presentations have been well-received and further collaboration is being explored.


Figure ES-13: WhaleALERT iPad display as seen by a mariner approaching Boston Harbor. Credit: NOAA.

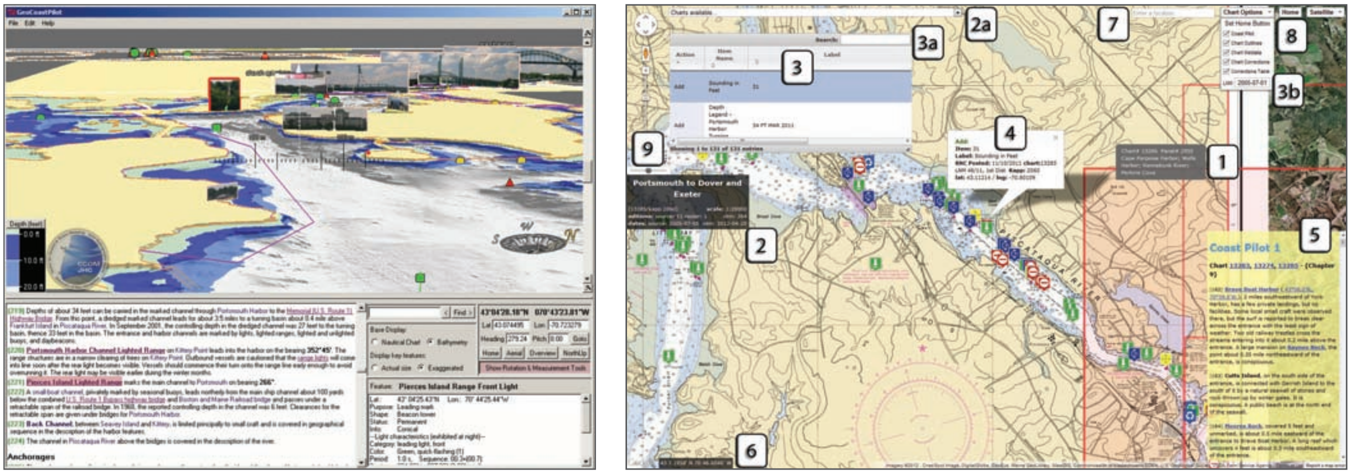

Figure ES-14. GeoCoastPilot (left) and Local Notice to Mariner Google Maps Mashup (right).

## Law of the Sea

Recognizing that implementing the United Nations Convention on the Law of the Sea (UNCLOS) could confer sovereign rights and management authority over large (and potentially resource-rich) areas of the seabed beyond our current 200 nautical mile limit, Congress (through NOAA) funded the Center to evaluate the content and completeness of the nation's bathymetric and geophysical data holdings in areas surrounding our Exclusive Economic Zone, or EEZ (**ccom.unh.edu/unclos**). Following up on the recommendations made in the UNH study, the Center has been funded, through NOAA, to collect new multibeam sonar data in support of a potential submission for an Extended Continental Shelf (ECS) under UNCLOS Article 76.

Since 2003, Center staff have participated in surveys in the Bering Sea, the Gulf of Alaska, the Atlantic margin, the ice-covered Arctic, the Gulf of Mexico, and the eastern, central and western Pacific Ocean, collecting 2,070,000 km2 of bathymetry and backscatter data that have provided an unprecedented high-resolution view of the seafloor. These data are revolutionizing our understanding of many geological processes on the margins and will result in significant additions to a potential U.S. ECS under UNCLOS, particularly in the Arctic.

In 2012, the Center organized and ran two Law of the Sea cruises—one in the Atlantic to continue mapping the location of the foot of the slope and the second in the high Arctic around the northern extension of the Chukchi Cap. The Atlantic margin survey work is a continuation of mapping started in 2004 and continued in 2005 and 2008 (see Progress Reports for those years or cruise reports at **ccom.unh.edu/theme/law-sea/cruise-reports**). These earlier cruises identified multiple possibilities for the location of the foot of the slope, a critical component for establishing an extended continental shelf, and additional mapping work was deemed necessary. A 30-day ECS cruise was planned using the NOAA Ship *Ronald Brown* but repeated generator failures led to a curtailed cruise of 17 days with Andy Armstrong, Brian Calder, and Shep Smith serving as co-chief scientists. The shortened cruise concentrated on the depositional lobe downstream of Hatteras Transverse Canyon and mapped 65,000 km$^2$ of seafloor with

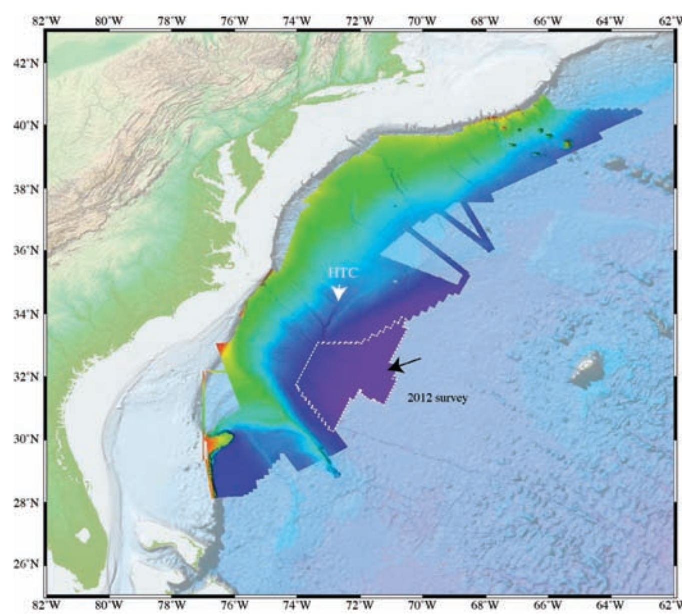


Figure ES-15. Location of the 2012 survey and Hatteras Transverse Canyon (HTC) and depositional lobe.

multibeam sonar bathymetry and backscatter (Figure ES-15). The data clearly show two large-scale mass failures (Cape Fear and Cape Lookout Slides) as well as the depositional lobe of Hatteras Transverse Canyon and will help define the foot of the slope in this region. Additional surveying will be required to the north.

The seaward termination of Blake Ridge had never been mapped before this cruise. Although the area where any relief from Blake Ridge disappears was not mapped, almost all of the eastern-most section of the ridge was mapped and shows a bifurcation of the ridge crest. The ridge extends as a single-crested feature for 450 km before the pronounced split (yellow arrow head in Figure ES-16). The bifurcation must be related to the interaction of the ridge sediments to the dynamics of the Western Boundary Current as it maneuvers around the bathymetric feature.

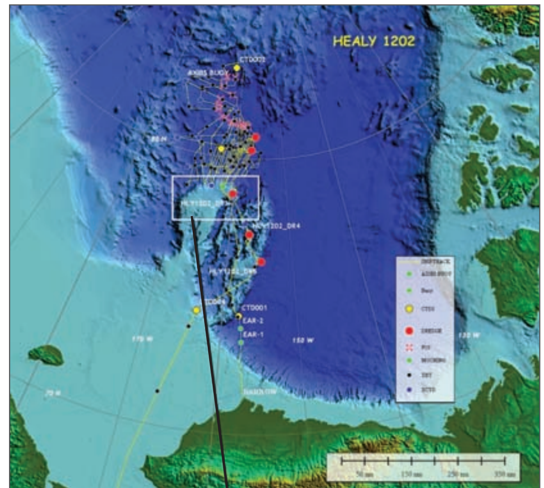


Figure ES-17. HEALY 1202 shiptrack, XBT, XCTD, CTD, buoy, and dredge locations.

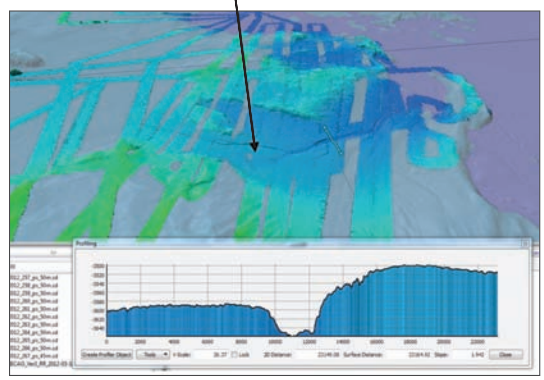

Figure ES-18. Submarine channel north of Chukchi Cap—overall length is approximately 160 km. Cross-section shown in figure is 23 km long.

This year's Arctic cruise (HEALY-1202) was the first ECS mapping program since 2008 that did not include participation of a Canadian icebreaker. The primary objective of this leg was to collect high-resolution multibeam sonar data in the region north of Chukchi Cap leading into Nautilus Basin in order to unambiguously locate the position of the "foot of the slope" as defined by Article 76 and to better understand the morphology of the northward extension of Chukchi Cap into Nautilus Basin. Secondary objectives included the collection of high-resolution chirp subbottom profiles to help in the determination of the location of the foot of the slope, the collection of dredge samples to better understand the geologic nature of Chukchi Cap and its northern extension, and the collection of underway gravity data. Ancillary projects were also carried out including oceanographic, wildlife and ice studies. Record breaking minimal ice conditions in 2012 allowed all scientific objectives to be met and much more seafloor was mapped than originally planned. Total track covered on HEALY 1202 was 11,965 km with 10,030 km of MBES collected in support of ECS purposes (Figure ES-17). These data were collected in average ice conditions of 6/10 ice cover and at an average speed of 7 knots in the ice, covering an area of approximately 68,600 km2 and adding approximately 25% to the U.S. Arctic MBES data holdings. Among the highlights of this cruise was the discovery of a spectacular submarine channel north of Chukchi Cap that drains from west to east over a distance of at least 160 km with an average gradient of about 0.18 degrees. The channel does not significantly meander but is complex with numerous small tributaries and several bifurcations. The maximum depth of the channel is approximately 80 m (Figure ES-18).

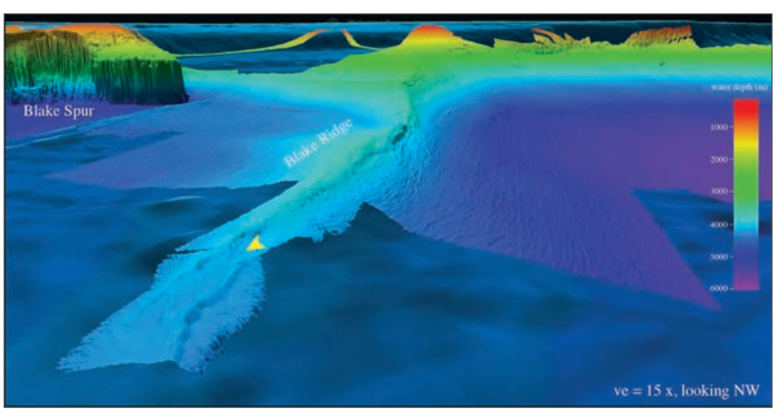


Figure ES-16. Perspective view of Blake Ridge showing a bifurcation in the ridge crest (yellow arrowhead).

Five dredge sites were occupied recovering a wide suite of rock types ranging from basalts to metamorphic rocks. At 78 degrees north, a sample of coral was recovered—most likely the farthest north a coral sample has ever been discovered. Analyses are currently underway on samples. Finally, as part of USGS studies of ocean acidification, four CTD stations, 625 discrete underway samples for pH, 614 discrete underway samples for alkalinity and 4000 continuous measurements of pH, $pCO_2$, and $TCO_2$ were taken.

## Outreach

In addition to our research efforts, we also recognize the interest that the public takes in the work we do and our responsibility to explain the importance of what we do to those who ultimately bear the cost our work. One of the primary methods of this communication is our website which underwent a substantial redesign and upgrade this year. Visits to the site (28,882) represent a 19% increase over last year with the visit duration increasing by 35%.

We also recognize the importance of engaging young people in our activities so as to ensure that we will have a steady stream of highly skilled workers in the field. To this end, we have also upgraded other aspects of our web presence including a Flickr photostream, Vimeo site, and Facebook. Our Flickr stream currently has 1,547 photos (with over 5500 views) and our videos have been viewed 1902 times. Our seminar series is widely advertized and webcast, allowing NOAA employees and our Industrial Associates around the world to listen to and participate in the seminars. Our seminars are also recorded and uploaded to Vimeo.

We have actively expanded our outreach activities and now have a dedicated outreach staffer (Tara Hicks-Johnson). Tara has hosted tours of the Center for hundreds of school children and community groups. Several large and specialized events were organized by the Center outreach team, including several SeaPerch ROV events and the annual UNH "Know the Coast" event. The SeaPerch ROV events have been coordinated with the Portsmouth Naval Shipyard (PNS). Students build ROVs and then bring them to the Center to test them in our deep tank (and also tour the Center and the Engineering facilities on campus). The interest in these ROVs was so great that PNS and the Center decided to hold our first competition between schools, the UNH SeaPerch Competition (Figure ES-19).

Further outreach is coordinated through Bob Ballard's E/V *Nautilus* and its "Educators At Sea" program. Here, we use the Telepresence Console to communicate with students across the country (many at Boys and Girls Clubs), researchers on the *Nautilus*, and visitors to the Mystic Aquarium's Nautilus Live Theater and the Nautilus Live website.

Center activities have been featured in many international, national, and local media outlets including *Science*, the BBC, *Sea Technology*, *The Telegraph* (U.K.), *Geographical Magazine*, *Science Now*, and *The Boston Globe*. Our work on the *Healy* was featured on National Geographic's Alien Deep series with more than 6 million viewers. The episode we were in won the Blue Ocean 2012 Film Festival Award for Best Exploration and Adventure Film.

The highlights presented here represent only a fraction of the activities of the Joint Hydrographic Center in 2012; more detailed discussions of these and other activities of the Center can found in the full progress report.

Figure ES-19. Middle school children building and testing small ROVs as part of the SeaPerch program (left) and learning about the activities of the Center at Know the Coast Day (center, right).

# NOAA/UNH Joint Hydrographic Center
# 2012 Research to Operations Initiatives

Since its inception, the NOAA/UNH Joint Hydrographic Center has taken pride in its efforts to turn the research projects undertaken by the Center into practical operational tools that serve NOAA and the nation. Examples of past successes are the CUBE and GEOCODER algorithms, both of which are now in widespread use by NOAA and other U.S. agencies, by hydrographic agencies worldwide, and by academics and the private sector. The concept of turning research into practical operational tools has now been formalized within NOAA under the label of "Research to Operations" (R2O), and in this report we briefly outline those aspects of our 2012 research endeavors that we believe qualify as successful examples of R2O.

A more detailed description of these research endeavors can be found in the JHC 2012 Annual Performance and Progress Report at: **http://www.ccom.unh.edu/reports**.

## Sensor Research Theme

- Using calibration technology and procedures developed at the Center, two Reson 7125 multibeam sonars from the NOAA fleet (*Fairweather*) have been calibrated at the Center and returned to the fleet. These calibration results will be applied to data collected with these systems at a Puget Sound backscatter reference surface, and then used to perform a relative calibration for other NOAA OCS systems that survey the same reference surface. In this way, the calibration performed at the Center can be propagated throughout the fleet without requiring a lengthy calibration procedure at the Center. The backscatter collected from the calibrated 7125 that has been returned to the *Fairweather* is also being used by NOAA Corps Officer Briana Welton to better understand commercial backscatter processing software as part of her studies at the Center.

- Under the supervision of Jonathan Beaudoin, and based on Beaudoin's research into sound speed uncertainty, NOAA Physical Scientist and graduate student Matt Wilson has developed the CastTime Algorithm that automatically optimizes the sampling interval of a Moving Vessel Profiler in reaction to changing oceanographic conditions. In conjunction with Rolls Royce, an interface has been developed that allows algorithms like CastTime to automatically trigger their moving vessel profiler. The software will be tested with a small subset of NOAA field units during 2013 with anticipation of fleet-wide deployment in 2014.

- Center-developed lidar ground-truthing tools (Optical Collection Suite (OCS)—developed by Shachak Pe'eri) have been used by NOAA scientists (Chris Parish and others) to ground truth lidar mapping in the Gulf of Maine, southwest Alaska and the U.S. Virgin Islands. These applications provide insight into the uncertainty of lidar measurements and the ability to use reflectance measurements for habitat studies (also relevant to the IOCM Research Theme).

## Processing Research Theme

- Brian Calder is developing a second generation of the CUBE algorithm—CUBE with Hierarchical Resolution Techniques (CHRT) that allows for variable resolution of data representation and is data adaptive, meaning that the density of data collected is reflected in the resolution of estimates of depth generated. Calder is working with Jack Riley at NOAA/HSTP on the testing of CHRT but also has implemented a co-development model that hasthe software vendors implementing CHRT assisting in the development of a test suite that defines what it means for an implementation to be called 'CHRT.' An implementation cannot be called 'CHRT' unless it passes the test suite; implementers will all share the same basic code base, and are expected to contribute to the development of the code. This process is expected to expedite implementation and assure the quality of the products delivered by the software vendors.

- Building on the thesis work of NOAA Corps Officer and graduate student Sam Greenaway and lessons learned from our calibration of Reson 7125 multibeam sonars, Glen Rice has built a "saturation monitor" that will help NOAA hydrographers ensure they collect backscatter data that remains within calibration parameters. At the beginning of the 2012 field season, the saturation monitor was distributed through Pydro (NOAA's Hydrographic Systems and Technology Program's data processing application) to NOAA field units. Documentation is now distributed with the application and is updated with improvements as they are made. Reson has expressed interest in implementing a similar approach in future systems, and Hypack and QPS have expressed interest in implementing this tool for their current applications.

- Jonathan Beaudoin has developed an SVP Server that provides pre-processing tools to help bridge the gap between sound speed/CTD profiling instrumentation and multibeam echosounder acquisition systems. The purpose of the software is to standardize and streamline the processing of oceanographic information that is collected in support of multibeam echosounder refraction corrections. This tool has been installed on NOAA Ships *Okeanos Explorer* and *Ronald Brown* (as well as numerous non-NOAA vessels)and used successfully during several expeditions.

## IOCM Research Theme

- In 2012, while the Center's IOCM deliverable was 100 $nm^2$ of processed data, the Center was able to deliver 352 $nm^2$ of processed data from the *Oscar Dyson*. As a result of lessons learned from this effort, Glen Rice has created a new set of Standard Operating Procedures now in use by the NOAA hydrographic field units and branches for the acquisition and processing of backscatter.

- ME70—Software and protocols developed by Tom Weber at the Center have been installed on the NOAA Ship *Oscar Dyson* that allows the ME70, a sonar originally designed for mapping pelagic fish schools to now routinely map the seafloor bathymetry and backscatter. Using the ME70, Jodie Pirtle and Tom Weber are collaborating with the NOAA Alaska Fisheries Science Center (AFSC) to map groundfish habitat in the Gulf of Alaska (GOA) and distinguishing between trawlable and untrawlable areas of the seafloor.

- On the NOAA Fisheries Vessel *Pisces*, Center-developed algorithms and workflows wer used to extract bathymetry and backscatter data from the ME70 that proved extremely useful to the NOAA teams conducting a Red Snapper stock assessment. Using products produced by the Center-defined workflow, NOAA fisheries scientists were able to quickly and accurately identify areas of Red Snapper habitat suitable for setting their traps. The development of follow up documentation for the rest of the FSV fleet is currently underway.

## Ocean Exploration Research

- Center involvement led to the development of direct methane flux measurement devices that were successfully deployed during an *Okeanos Explorer* expedition in the Gulf of Mexico while EM302 MBES and EK60 single beam sonar data were used as acoustic 'guides' for the ROV expeditions. Data collected during this cruise is greatly increasing our ability to interpret and analyze acoustic data collected during mid-water mapping expeditions in the same area. Work is currently underway to measure the flux of gas from a seep using both optical and acoustic methods. Work also continues to establish rigorous seep positioning algorithms using EK60 split beam echo sounders and to establish automated methods for detecting seeps in EM302 mid-water data.

## Visualization Research Theme

- An advanced flow visualization application, FlowVis2D, developed by Colin Ware, has become an operational part of the NOAA NowCoast Portal. This year, the ability to show wind data and wave data has been added, and transparent layers can now be written.

- Ware has also developed TrackPlot, an application designed to help visualize and analyze data from tagged marine mammal. It has evolved in close collaboration with marine mammal scientists and has become a significant research tool resulting in a number of journal papers detailing the kinematic behaviors of various species. The user base of TrackPlot continues to expand with at least 14 users from different groups including NOAA's Stellwagen Bank National Marine Sanctuary; it has now been applied to 11 different species.

## Electronic Chart of the Future Research Theme

- The Center continues to lead efforts to standardize formats for the distribution of full-density bathymetric data to be included in ENC's through the Open Navigation Surface Working Group. Brian Calder serves as the Chair of the Open Navigation Surface Working Group and as a member of its Architecture Review Board. The Open Navigation Surface Working Group released V1.5.1 on August 20, 2012. The standard-compliant version of BAG (IHO S-102) was recently adopted by the IHO as a new standard and is currently in use by NOAA, NAVO, the UKHO, and the Canadian Hydrographic Service in the St. Lawrence Seaway.

- The Center has been a key player in the Right Whale AIS Project aimed at providing Liquid Natural Gas (LNG) carriers and other mariners real-time input on the presence of right whales in their vicinity through a series of permanent, hydrophone equipped buoys, a right whale vocalization system, and the transmission of the confirmed presence of a right whale to the vessel via AIS. The Center's role has been the AIS transmission and interface with the electronic chart on board the vessel. This year an iPhone app—WhaleALERT—was developed to augment existing ship navigation tools informing mariners of the safest and most current information to reduce the risk of right whale collisions.


Flyers from the 2012 JHC/CCOM Seminar Series.

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