New Frontiers in Ocean Exploration

The E/V Nautilus, NOAA Ship Okeanos Explorer, and R/V Falkor 2018 Field Season

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The R/V Falkor team dove on “Rosebud,” a whale fall that was placed by researchers off San Diego, California, in La Jolla Canyon. Researchers noted changes in composition and life forms around the location in a beautiful, exciting dive investigating ecosystems unique to whale falls. *Image credit: SOI*
After three contiguous field seasons of remote expeditions in the Pacific Ocean, NOAA Ship *Okeanos Explorer* transited the Panama Canal in fall of 2017 to commence new exploration efforts in the Gulf of Mexico and the Atlantic Ocean. In 2017–2018, the ship boldly continued its tenth year of ocean mapping field operations in support of exploring and characterizing the US Exclusive Economic Zone and the world ocean, mapping almost 300,000 km$^2$ of seafloor (an area larger than the state of Arizona), while transiting a linear ship track distance of 53,374 km. That distance represents the equivalent of circumnavigating Earth at the equator 1.3 times. Six of the 12 expeditions summarized in this supplement to *Oceanography* were fully dedicated to 24-hour per day mapping exploration. For the remaining six combined ROV/mapping cruises, mapping operations typically comprised over 50% of the at-sea mission time.

**IMPROVEMENTS IN OCEAN MAPPING**

Each field season of exploratory ocean mapping work brings new opportunities to upgrade equipment, software, procedures, and collaborations to improve methodologies aboard *Okeanos Explorer*. Over the past year, the mapping team implemented Sound Speed Manager, an open-source, user-friendly application for importing, editing, and exporting sound speed profile data, a fundamental requirement for obtaining high-quality multibeam sonar data (Masetti et al., 2017a; Figure 1). This application enables mappers to utilize historical salinity and temperature data from the World Ocean Atlas to improve sound speed profiles and generate synthetic profiles when physical sampling is not possible. The software also provides an easy interface for editing and comparing oceanographic profiles of the water column and exporting GIS files or tables of all casts completed during a cruise—all of which streamlines record keeping. The application is often used in combination with SmartMap, a web GIS that helps

**TEN YEARS OF OCEAN EXPLORATION MAPPING ACHIEVEMENTS**

From 2008 to 2018, NOAA’s Office of Ocean Exploration and Research—utilizing “America’s Ship for Ocean Exploration,” *Okeanos Explorer*—has mapped a cumulative 1.79 million km$^2$ of seafloor with the ship’s multibeam sonar. If projected over the contiguous United States, this area would cover about 23% of the land area of the country (blue area in figure). A majority of this work has been completed within the US Exclusive Economic Zone—host to America’s hidden and still largely uncharacterized deep-sea habitats. If projected over the contiguous United States, this area would cover about 23% of the land area of the country (blue area in figure). A majority of this work has been completed within the US Exclusive Economic Zone—host to America’s hidden and still largely uncharacterized deep-sea habitats.
Mapping priorities for the year were driven strongly by OER’s commitment to strategic marine mapping and research collaborations with a diversity of national and international partners. For each of these initiatives, maps of the unknown ocean serve as baselines upon which further characterization work can be done. In addition to the primary driver of the ASPIRE campaign (see pages 74–75), mapping work completed during the last field season directly supported the following efforts.

Southeast Deep Coral Initiative
OER continues to be a key collaborator on the Southeast Deep Coral Initiative (https://oceanexplorer.noaa.gov/explorations/17sedi/background/sedi.html) led by NOAA’s National Centers for Coastal Ocean Science. This effort is collecting new scientific information about the distribution, abundance, and diversity of deep-sea coral ecosystems within the Caribbean, Gulf of Mexico, and South Atlantic Bight. Mapping work and ROV exploration completed by Okeanos Explorer in this region has been fundamental to providing baseline information on the location of corals and the environmental conditions that support coral habitats (Figure 2). This information is being directly used to improve habitat prediction models for deep-sea corals and inform ocean management decisions.

Figure 2. Linear ridge features discovered offshore due east of Savannah, Georgia, at about 800 m depth. During the 2018 Windows to the Deep expedition, ROVs explored one of these features (dubbed “Richardson Ridge”) that was found to be densely covered in *Lophelia pertusa* deep-sea corals. The dive track on the ridge feature is shown in yellow (4x vertical exaggeration).
DEEP SEARCH
OER is providing both financial support for, and allocation of *Okeanos Explorer* sea days to, the DEEP SEARCH project (see pages 104–105). Two *Okeanos Explorer* cruises were dedicated to mapping and ROV exploration within DEEP SEARCH priority areas off the southeast US coast.

**Atlantic Seabed Mapping International Working Group**
The Atlantic Seabed Mapping International Working Group (ASMIWG) emerged as an implementation group for the Atlantic Ocean Research Alliance formed between Canada, the European Union, and the United States, which resulted from the Galway Statement on Atlantic Ocean Cooperation signed in May 2013. ASMIWG is leveraging resources to collaboratively map the North Atlantic Ocean and has identified high-priority areas to pursue ship-based mapping surveys. *Okeanos Explorer* completed the first focused survey of one of these priority areas (see pages 88–89), and OER is planning extensive exploration work in the North Atlantic for 2019.

**Seabed 2030**
Seabed 2030 is an initiative led by the Nippon Foundation and the General Bathymetric Chart of the Oceans (GEBCO), with the goal of producing a publicly accessible definitive map of the world ocean by 2030 (https://seabed2030.gebco.net/). With the vast majority of the world’s deep ocean remaining unmapped by modern surveying methods, all *Okeanos Explorer* mapping data are substantially contributing to this global effort.

**NASA’s Visible Infrared Imaging Radiometer Suite**
In 2018, *Okeanos Explorer* provided a platform for collecting essential ship-based measurements needed to calibrate the Visible Infrared Radiometer Suite (VIIRS) satellite ocean color measurements (https://jointmission.gsfc.nasa.gov/viirs.html). VIIRS provides remote-sensing data that are critical for assessing broadscale sea surface temperatures, harmful algae blooms, risk to coral habitats, ocean productivity, and weather forecasts.

**CRITICAL MAPPING SUPPORT OF SUCCESSFUL ROV DIVE OPERATIONS**
With half of the expeditions last year spent as joint ROV/mapping cruises, mapping data played a critical role in ensuring safe and effective ROV dive operations. Interesting features (e.g., seamounts, mounds, canyons, potential shipwrecks) identified through mapping efforts typically serve as the primary basis for selecting ROV dive targets (Figure 3). Mapping team support is particularly important when the need arises to change a dive site at the last minute due to unfavorable wind, weather, or current conditions. This happened with some regularity for ROV dives in the vicinity of the strong Loop Current in the Gulf of Mexico and in the Gulf Stream current offshore of the southeast US coast.

![Depth (m)](image)

Figure 3. ROV planning scene for Dive 8 (Richardson Scarp) of the 2018 Windows to the Deep expedition offshore of the southeast US coast. This dive track (yellow line) was mapped the night before the dive was conducted, with the science team selecting the biggest and steepest slope in the area to examine the geology and maximize chances to observe attached fauna on hard substrates.
coast. Mapping data are quickly utilized to generate a new dive location plan to meet the desired scientific objectives while optimizing ship and ROV orientations relative to wind and current.

Careful use of mapping data is particularly important when planning an ROV dive in the vicinity of morphological features or anthropogenic structures with the potential to entangle or damage the ROVs. Dives are planned to avoid known (charted) subsea cable routes and other man-made obstructions (Figure 4), as well as confined canyons that could be hazardous in the event of equipment or power failures.

ADVANCING THE TELEPRESENCE MAPPING PARADIGM

OER continued to explore the benefits of telepresence-enabled mapping ("telemapping") cruises on Okeanos Explorer. A robust computer network and a high-bandwidth ship-to-shore satellite connection enables the OER mapping team to lead mapping cruises from shore. Data collection is overseen at sea by a small team of experienced survey contractors, while high-level planning and decision-making can be handled by the onshore expedition coordinator. Using computer networks and specialized software at the Exploration Command Center at the University of New Hampshire, multibeam data sets are downloaded from the ship for onshore data cleaning and processing that has historically been done at sea. Onshore students (see Explorer-in-Training program information on pages 114–115) stand watch to monitor the ship’s sonar performance in real time (Figure 5), as well as to post-process multibeam, subbottom, and water column sonar data to generate value-added mapping products that can be shared rapidly with the broader scientific community. Successful telemapping surveys were conducted in this manner for the ship’s long transit from Hawai’i to Panama, and for a mapping cruise off the southeast US coastline in support of DEEP SEARCH project priority areas.

Given the success of these efforts, telemapping operations have been prototyped and can now be replicated on other offshore or shore-based scientific platforms with comparable satellite bandwidth and data sharing capabilities. Live streaming of sonar acquisition screens provides real-time monitoring of survey operations, while processed sonar files (and derivative products such as cleaned bathymetric grids) are produced on shore and made publicly available within 24 to 48 hours of data collection. This paradigm has great potential to expand the number of shoreside participants in a mapping survey by providing exceptional educational opportunities for marine scientists, ocean mappers, and interested citizen scientists. While ocean mapping is often somewhat of a “behind the scenes” aspect of ocean exploration, telemapping could provide a mechanism for engaging more people and delivering mapping products to scientists more quickly and directly than has been conventionally possible.