Sponsored Projects

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Sponsored Projects

NOAA's Office of Ocean Exploration and Research

Introduction

By Nathalie Valette-Silver, Frank Cantelas, Chris Beaverson, Amanda N. Netburn, James Murphy, Kelley Elliott, Stephen R. Hammond, Yvette Jefferson, and Joyce Woodford

NOAA's Office of Ocean Exploration and Research sponsors projects that explore and characterize the deep ocean. OER's mission is further leveraged through competitive grants and cooperative agreements to universities and nonprofit and for-profit organizations, as well as through intra- and interagency agreements with other parts of NOAA and other federal agencies. These efforts complement the systematic exploration conducted by NOAA Ship *Okeanos Explorer*, the only US vessel dedicated to exploring the largely unknown ocean (see pages 76–77).

OER publishes a Federal Funding Opportunity (FFO) annually that invites submission of proposals focused on ocean exploration, including maritime exploration for, and of, culturally important submerged sites, and technological innovations with the potential for increasing the pace and scope of ocean exploration. Projects are selected based on a competitive community-standard process of mail and in-person peer review, coupled with programmatic selection factors that are published in the FFO.

Funded projects benefit from proactive OER support, including assisting with cruise planning, fulfilling federal administrative reporting requirements, and communicating project discoveries and results through OER's website. Consistent with OER's open data policy, all data are made publicly available after quality and accuracy are assured.

Over the past 10 years, OER's competitive program supported 79 projects for a total of $24 million. In fiscal year 2018, OER supported 10 projects—seven focused on technology, two on archaeology, and one on exploration—for a total of $4.5 million (Figure 1). In June 2018, OER published a fiscal year 2019 FFO focused on exploration of the ocean in support of America's Blue Economy. Selected proposals will be announced in summer 2019.

In 2018, OER partnered with NOAA's National Centers for Coastal Ocean Science (NCCOS) and Office of National Marine Sanctuaries to announce two additional FFOs focused on the study of mesophotic coral ecosystems for a project up to four years in duration in American Samoa, and up to five years in the Hawaiian Archipelago. These FFOs build on a partnership begun with NCCOS in fiscal year 2006 to improve the understanding of these poorly known ecosystems found from 30 m to 150 m depth in the tropics and subtropics. Together, we have been able to shed light on these regions, which suffer from being too shallow for deep technologies and too deep for shallow technologies.

Highlights from a few of the seagoing projects funded through the fiscal year 2017 competition and executed during the 2018 (e.g., Figure 2) year follow.

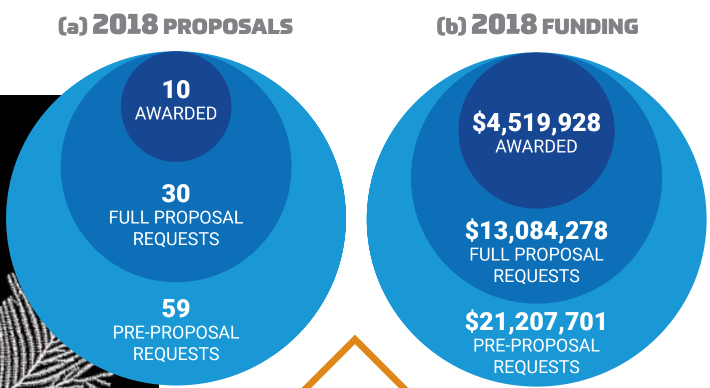


Figure 1. (a) Number of projects proposed vs. selected in 2018. (b) Funding amounts requested vs. awarded in 2018.

Figure 2. Octocoral (sea fan) with many associated brittle stars seen during the Océano Profundo 2018 expedition off Puerto Rico.

Cooperative Institute for Ocean Exploration, Research, and Technology

By Joshua Voss and Shirley Pomponi

NOAA's Cooperative Institute for Ocean Exploration, Research & Technology (CIOERT) is led by Florida Atlantic University's Harbor Branch Oceanographic Institute in partnership with the University of North Carolina Wilmington, the University of Miami, SRI International, and OER. CIOERT activities focus on three themes: exploration of continental shelf edge frontiers, research on vulnerable coral and sponge ecosystems, and development of advanced underwater technologies.

CIOERT has expanded water column exploration capabilities by developing new technologies to study the mesopelagic ocean. An integrated array of novel optical sensors created by CIOERT researchers, coupled with existing sensing technologies, has been developed to explore the distributions and dynamics of mesopelagic organisms at scales ranging from microbes to large nekton (Figure 1). The state-of-the-art system combines eight complementary technologies, including a novel digital holographic microscope (HOLOCAM), a next-generation Spatial Plankton Analysis Technique (SPLAT) camera to image bioluminescent organisms, and a new laser imager for marine life. The new mesopelagic exploration package was deployed during the March 2018 NOAA Ship *Okeanos Explorer* Gulf of Mexico Technology Demonstration expedition.

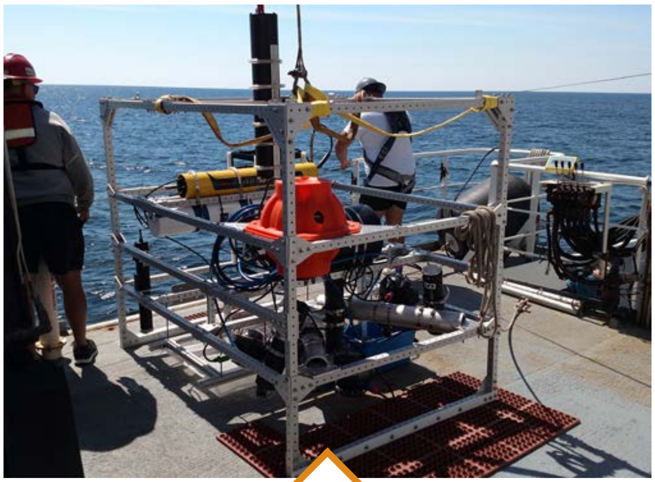


Figure 1. CIOERT's integrated mesopelagic exploration package being readied for deployment on *Okeanos Explorer* in the western Gulf of Mexico. *Credit: Twardowski Lab, CIOERT, FAU Harbor Branch*

CIOERT's efforts to explore and characterize mesophotic coral reef ecosystems via ROV and technical diving continued in July 2018 with a cruise to the Northwestern Gulf of Mexico (NWGOM) aboard R/V *Manta*. Employing an interdisciplinary, multiscale approach, CIOERT and Flower Garden Banks National Marine Sanctuary (FGBNMS) partners examined the connectivity processes that drive coral reef community structure, biodiversity, and ecological persistence in the NWGOM (Figure 2). In addition to demonstrating well-connected coral populations in the NWGOM and describing a novel strategy for light limitation in coral-algal symbiosis, CIOERT's research expeditions in the NWGOM have provided critical information regarding a proposed expansion of FGBNMS boundaries.

To advance exploration of deep coral and fisheries habitats in the South Atlantic Bight, CIOERT partnered with NOAA Fisheries to complete their seventh cruise aboard NOAA Ship *Pisces* in May 2018. In total, 29 ROV dives were conducted to evaluate benthic and fisheries communities associated with seven marine protected areas from Florida to the Carolinas. These annual expeditions are part of a long-term exploration program to discover new areas and document changes in specific areas before and after implementation of management actions.

Shore-based science teams at Florida Atlantic University's Harbor Branch's Exploration Command Center contributed to *Okeanos Explorer*'s Gulf of Mexico and Southeastern US Windows to the Deep expeditions in 2018 by supplying information for target dive sites, assisting in species identifications, and providing telepresence outreach opportunities for high school students in Florida.

Figure 2. Technical divers descend to explore mesophotic reefs in the Flower Garden Banks National Marine Sanctuary. *Credit: Voss Lab, CIOERT, FAU Harbor Branch*

Exploration of Biodiversity and Ecosystem Structure on Seamounts in the Western CCZ

By Jeffrey C. Drazen, Matthew Church, Thomas Dahlgren, Jennifer Durden, Adrian Glover, Erica Goetze, Astrid Leitner, Craig R. Smith, and Andrew Sweetman

More than one million square kilometers of the abyssal Pacific seafloor called the Clarion-Clipperton Zone (CCZ) have been identified for possible nodule mining. Manganese nodules are a potential source of copper, nickel, cobalt, iron, manganese, and rare earth elements—metals used in electrical systems and for electronics like rechargeable batteries and touch screens. Mining is expected to destroy marine life and seabed habitats over large areas, both at sites that are directly mined as well as at adjoining areas that would be affected by sediment plumes created by mining activities. The DeepCCZ expedition was the first to explore the diversity of organisms on seafloor plains and seamounts in areas currently designated as "no-mining areas" in the western CCZ (Figure 1). A major goal is to determine whether these protected areas are adequate for conserving the region's biodiversity from destructive seafloor mining activities.

The expedition used a suite of state-of-the-art deep-sea technologies to study the biodiversity and ecology of abyssal organisms. Twelve dives were conducted with the University of Hawai'i's ROV *Lu'ukai*, which used robotic arms and deep-sea cameras to photograph and collect animals, manganese nodules, and sediments from greater than 4 km depth. An autonomous respirometer measured biological activity and food web structure of deep-sea sediment communities. Baited stereo cameras attracted and measured the mobile predators at the top of the deep-sea food chain (Figure 2). Water filters were deployed autonomously to the seafloor to capture the larvae of the benthic fauna and evaluate connectivity. Samples for subsequent DNA analyses were collected from the environment, and from individual animals, to test new approaches for assessing biodiversity and ecological functions of microbes and animals living in sediments, on manganese nodules, and in the overlying waters. DNA samples will also aid in the identification and description of the many new species, and in assessing their occurrence across the abyssal Pacific Ocean.

The data and samples are expected to substantially improve understanding of the biodiversity and ecology of the vast and poorly studied CCZ. More than 100 species of large animals were collected or videotaped at the seafloor (Figure 3). Many of these animals appear to be newly discovered species. In addition to being used to assess the adequacy of conservation measures, these data will also be incorporated into a regional synthesis of the CCZ to be used to make science-based recommendations to the International Seabed Authority and other stakeholders concerning environmental protection and management for deep-sea mining in the CCZ.

We thank OER, the Gordon and Betty Moore Foundation, the Pew Foundation, and the School of Ocean and Earth Science and Technology at the University of Hawai'i at Manoa for their support.

Figure 1. Map of the Clarion-Clipperton Zone showing exploration license areas and reserve mining areas in colored polygons. The white boxes indicate the no-mining zones called Areas of Particular Environmental Interest (APEI). Green dots are the locations of expedition dive sites in APEIs 1, 4, and 7. *Courtesy of the DeepCCZ expedition*

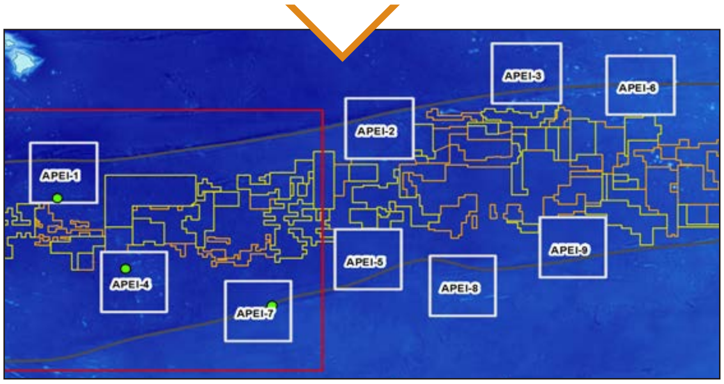


Figure 2. Very large aggregation of eels, *Ilyophis aryx*, attracted to a baited camera at a seamount in APEI 7. *Courtesy of the DeepCCZ expedition*

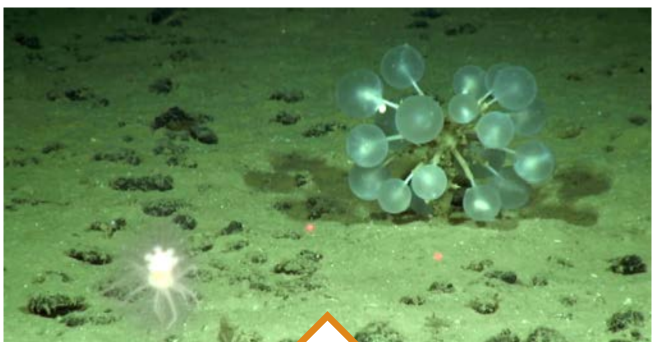


Figure 3. Two carnivorous Cladorhizid sponges at 5,000 m depth in the western CCZ. *Courtesy of the DeepCCZ expedition*

Kiska: Alaska's Underwater Battlefield

By Andrew T. Pietruszka, Eric J. Terrill, and Mark A. Moline

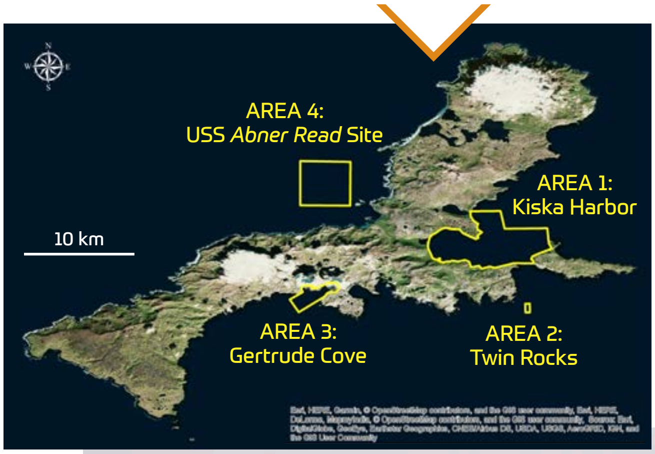
In July 2018, Scripps Institution of Oceanography and University of Delaware scientists spent two weeks conducting a remote-sensing survey to locate and document World War II-era submerged archaeological sites in the waters off of Kiska Island, Alaska, one of the most remote islands in the Aleutian chain.

The Aleutian campaign was the sole World War II campaign fought on North American soil, and Kiska Island is one of the few US territories occupied by foreign forces in the last 200 years. Kiska remains one of the best-preserved historic battlefields from World War II, and is one of only two world-wide where neither previous nor later settlement obscure military developments. In recognition of its pivotal role in the Allied-Japanese campaigns of 1942–1943, Kiska Island was designated as a National Historic Landmark in 1985. While the terrestrial component is well documented, the maritime component remained largely unexplored until the OER-sponsored expedition.

The survey focused on four distinct search areas, each relevant to a unique aspect of the battlefield's maritime cultural landscape (Figure 1). Home to the Japanese naval installation, Area 1, Kiska Harbor, was the most frequent target of the US bombing campaign. Historical records indicate many Japanese ships and aircraft, as well as US aircraft, were lost there. Area 2 encompasses the final resting place of the Japanese submarine I-7, which was lost while assisting the Japanese planned evacuation. Area 3, Gertrude Cove, garrisoned over 3,500 Imperial Army men, and it is the site of several US bomber losses and Japanese ships. Area 4 is associated with the US effort to retake Kiska. On August 18, 1943, USS *Abner Read* struck a Japanese mine while patrolling off the northwest landing beach causing the stern to break off and sink with 71 men trapped inside.

The project featured a wide spectrum of state-of-the-art marine technology. The primary tool employed was compact autonomous unmanned underwater vehicles (UUVs) equipped with side-scan sonar, magnetometers, multi-beam sonar, and low-light imaging capabilities (Figure 2). Additional coverage and high-resolution acoustic imaging were provided by a hull-mounted multibeam sonar system. About 35 km^2 were surveyed with side-scan sonar, 46 km^2 were surveyed during the multibeam survey, and the team conducted 40 cold water scuba dives. Analysis is ongoing, but several significant finds are already confirmed including the stern of USS *Abner Read*, three Japanese submarines (I-7, RO-65, and a midget submarine; Figure 3), portions of a US B-24 aircraft, and the remains of multiple Japanese and American landing craft.

Figure 1. Map of Kiska Island indicating the four areas surveyed during the Kiska submerged cultural resource survey. *Courtesy of Scripps Institution of Oceanography*



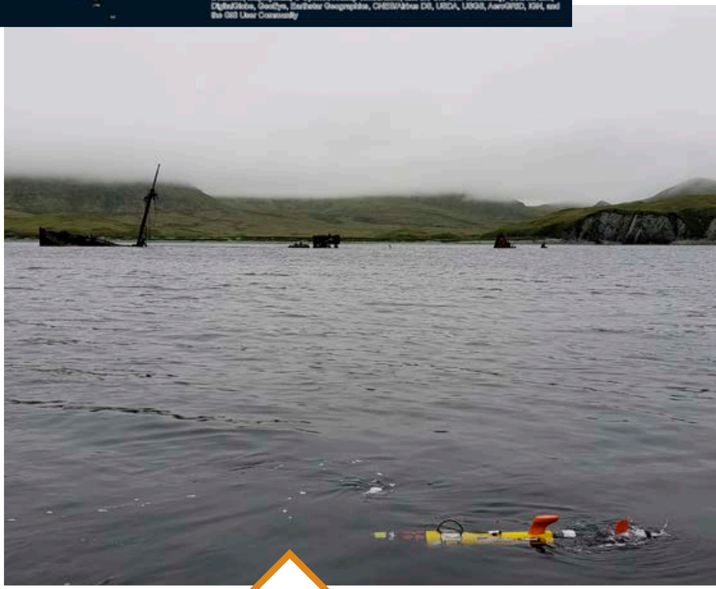


Figure 2. One of four REMUS 100 UUVs utilized during the Kiska survey to image the seafloor to detect potential archaeological sites. *Courtesy of Kiska: Alaska's Underwater Battlefield expedition, Scripps Institution of Oceanography*

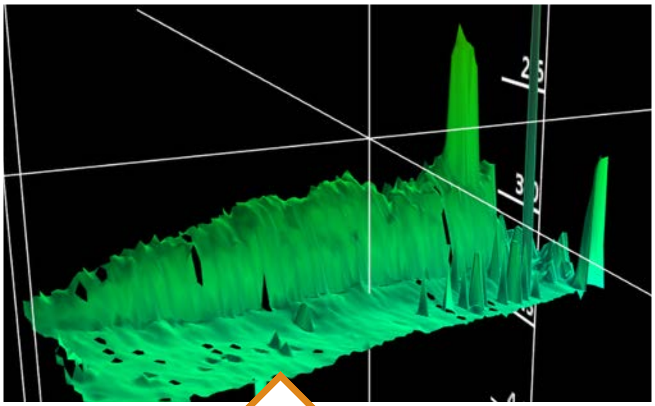


Figure 3. Preliminary multibeam sonar image of a Japanese midget submarine documented during the Kiska survey. *Courtesy of Kiska: Alaska's Underwater Battlefield expedition, Scripps Institution of Oceanography*

Aviators Down! The Search for Tuskegee and Free French World War II Aircraft in Lake Huron

By Wayne R. Lusardi

During World War II, Michigan was home to several African-American Army Air Corps units, including graduates of the Tuskegee pilot training program, and to pilots of the Free French Air Force. The pilots received training in the relative safety of the American Midwest with weather and geographical conditions that approximated what aviators could expect to encounter in Europe (Figure 1). Combat pilot training is not without risk. Mishaps, accidents, and mechanical problems caused accidents, some of which occurred over Lake Huron. A geospatial analysis of historical records determined five areas of Lake Huron within and adjacent to Thunder Bay National Marine Sanctuary where four military aircraft were lost in training accidents during World War II and two more were lost after the war.

The State of Michigan and NOAA carried out the first year of a two-year search for these aircraft aboard NOAA's R/V *Storm* using multibeam sonar, side-scan sonar, and a cesium-vapor magnetometer. Archaeologists focused their survey of Lake Huron off Alcona and Iosco Counties in Michigan over 19 calendar days from June 27 to September 26, 2018. A total of 583 acoustic and/or magnetic anomalies were recorded during the survey. Ninety-two of the targets were examined, and all but two were geological features.

One acoustic and magnetic anomaly consisted of the ground tackle from a nineteenth-century vessel, including an iron anchor and chain and wooden windlass. The artifacts were not associated with other wreckage and may instead be equipment loss. Another acoustic and magnetic anomaly consisted of a military tow target manufactured in 1956 by Schweizer Aircraft Corporation of Elmira, New York (Figure 2). Positive identification of the Aero X-27A was made following discovery of the aircraft data plate. Targets like the Aero X-27A were towed using piano wire several thousand feet behind jets and used for target practice over Lake Huron. The aluminum targets replaced the older style cloth banners used over the lakes beginning in World War I. The Aero X-27A tow target more closely simulated aerial combat, and could be landed to assess number of hits. Although the wreckage is broken and largely buried in soft sediments, it retains its original red paint on the fuselage and variable pitch wings.

Surveying in Lake Huron will continue in 2019 to complete the five survey areas. All acoustic and magnetic anomalies recorded in 2018 will be investigated to determine whether or not they originated from previously undiscovered World War II aircraft.

Figure 1. The P-39Q Airacobra, a single-seat plane that was the primary aircraft used by Tuskegee airmen over Michigan beginning in September 1943. *Courtesy of the US Army Air Corps*

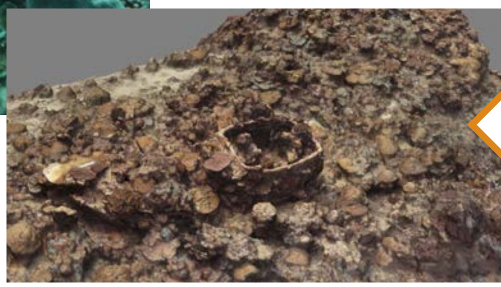
Figure 2. Michigan State Maritime Archaeologist Wayne Lusardi investigates the only aircraft found during the survey, a military tow target from the 1950s. *Courtesy of John Bright, Thunder Bay National Marine Sanctuary.* INSET. Schweizer Aircraft Corporation of Elmira, New York, manufactured 400 tow targets for the US Navy in the 1950s. How this particular target ended up in Lake Huron is unknown. *Courtesy of Paul Schweizer, Schweizer Aircraft Corporation*

Peleliu's Forgotten World War II Battlefield

By Toni L. Carrell

A Ships of Discovery science team returned to the Peleliu World War II invasion beaches to search for the remains of the amphibious landing craft, airplanes, equipment transports, and tanks lost during the battle on September 15, 1944. They also looked for any evidence of the scars from the underwater demolition team's mission to blow access routes through the shallow reef into lagoon. This was the first project to focus on the landing beaches and survey the reefs to document the biological impacts from the blasting, document the submerged archaeological sites, and explore the amphibious element of the invasion.

Kailey Pascoe, University of Hawai'i at Hilo, documenting the underwater demolition team's blast zone. *Courtesy of Ships of Discovery science team*



Three-dimensional photogrammetry image of an amphibious landing craft's turret, barely visible in the coral growth after 75 years underwater. *Courtesy Ships of Discovery science team*

The American Theatre of World War II and the KS-520 Convoy Battle

By Joseph C. Hoyt

In 2018, a collaborative team of archaeologists and explorers continued a long-term effort to locate and investigate the remains of World War II shipwrecks such as *Nordal* and *Ljubica Matkovic* off North Carolina believed to be associated with World War II's Battle of the Atlantic. Working from NOAA Ship *Nancy Foster*, Monitor National Marine Sanctuary partnered with Marine Imaging Technologies to deploy "cinema-class" ROV *Pixel* to collect high-definition video and photogrammetric information on several potential targets. The data collected during this expedition support NOAA's efforts to expand the boundaries of the Monitor National Marine Sanctuary to honor and protect shipwrecks of the World War II naval battlefield.

This partial photogrammetry model created from images collected by an ROV show a deck gun and windlass on the stern of a recently discovered but unidentified World War II era shipwreck. *Courtesy of Monitor National Marine Sanctuary*

Instrumentation to Assess the Untainted Microbiology of the Deep-Ocean Water Column

By Doug Bartlett and Alvaro Muñoz Plominsky

A study to explore deep-sea microbes' sensitivity to decompression collected samples at near in situ pressures and temperatures using a modified autonomous lander and associated seawater sampling system. Rotary actuators were used to improve control of seawater entry into titanium pressure-retaining samplers (PRSs), and multiple layers of high-density polyethylene insulation housing were fabricated to improve insulation. This new system was evaluated during a one-day cruise in the San Clemente Basin off the coast of San Diego.

Both the lander and the PRSs functioned well during sea trials (Figures 1 and 2). The lander descended to 2,000 m depth, collected a variety of seawater samples, released its ballast, and was recovered at the surface by virtue of its Iridium GPS signal. The in situ temperature was 2.6°C, and the temperature of the collected seawater samples did not rise above 7.1°C. The pressure retained within the PRSs was 62%–71% of in that situ. The activity of the microbes collected was highest when measured under the same physical conditions employed during their collection (Figure 3).

Additional samples will be collected in 2019 off the coast of Chile, down to ~ 8,000 m depth. The analyses of samples kept cold and pressurized could have profound implications for understanding the numbers, biogeochemical activities, and types of microbes in the deep sea.

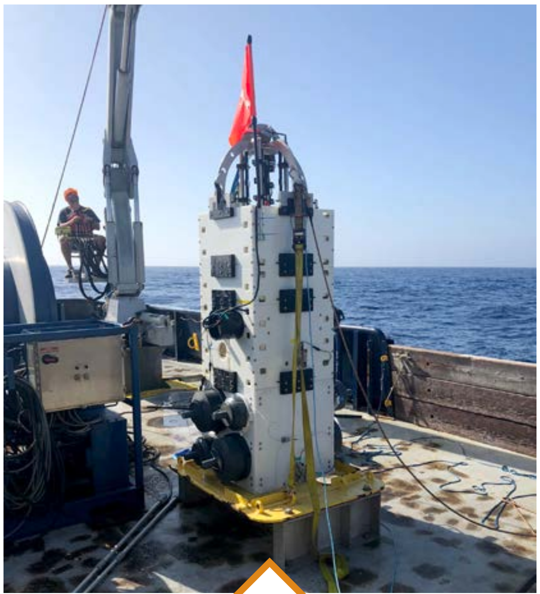


Figure 1. A view of the Bartlett lander during recovery at sea. *Image credit: Doug Bartlett, Scripps Institution of Oceanography*

Figure 2. The pressure-retaining seawater sampler outside of its housing. *Image credit: Doug Bartlett, Scripps Institution of Oceanography*

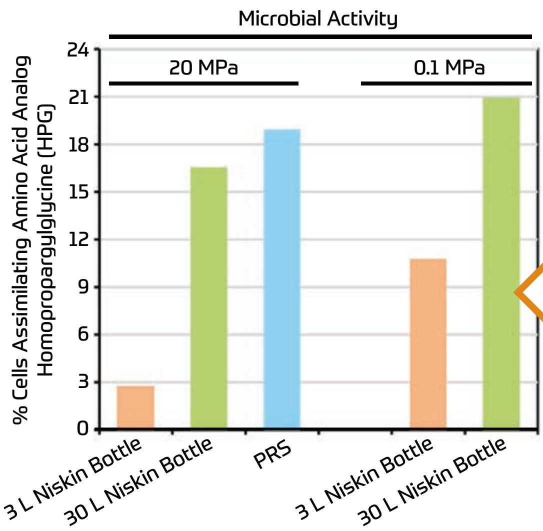


Figure 3. Measurements of the activity of collected microbial cells indicates samples recovered cold and pressurized (PRS) or just cold (30 L Niskin Bottle) have the highest activities when measured at their respective recovery conditions. In contrast, the seawater sample that was allowed to both decompress and warm (3 L Niskin Bottle) had greatly reduced microbial activity at cold temperatures and especially at cold and pressurized conditions. *Credit: Alvaro Muñoz Plominsky, Scripps Institution of Oceanography*

Comparison of Free Vehicle and Conventional CTD

By Wilford Schmidt, Danilo Rojas, Ryan Smith, and Manuel Jimenez

A series of banks south of the US and British Virgin Islands provides habitats and spawning sites for economically important fish species. Prior to 2007, when the ongoing Coral Reef Ecosystem Research study was initiated, the biological and physical processes that drive production on these banks, and the circulation connecting these areas, had not been quantified. A conventional CTD survey conducted aboard NOAA Ship *Nancy Foster* provided an excellent opportunity to ground truth the newly developed University of Puerto Rico – Mayagüez (UPRM), free vehicle (FV) in an operational setting (Figure 1).

The conventional casts used a 24-bottle rosette provided by NOAA's Atlantic Oceanographic and Meteorological Laboratory in conjunction with an SBE 9plus CTD (Figure 2). The casts were supposed to be to full water column depth, but spool problems limited the maximum depth to <3,000 m. The FV was subsequently deployed with a CTD scientific payload consisting of a full ocean depth SBE 19plus V2 CTD, augmented by inertial navigation sensors and multispectrum signaling capabilities (strobe, RF, and satellite position uplink).

The six FV deployments ranged in depth from approximately 1,100 m to 4,350 m. In one instance, the FV was programmed to "wait" on bottom for several hours while the ship conducted a plankton tow away from the deployment location. When the tow was completed, the ship returned to retrieve the concurrently surfacing FV. Figure 3 compares conventional (NF) and FV CTD temperature and salinity data. Analysis of the two data sets is ongoing, but initial indications suggest very good agreement.

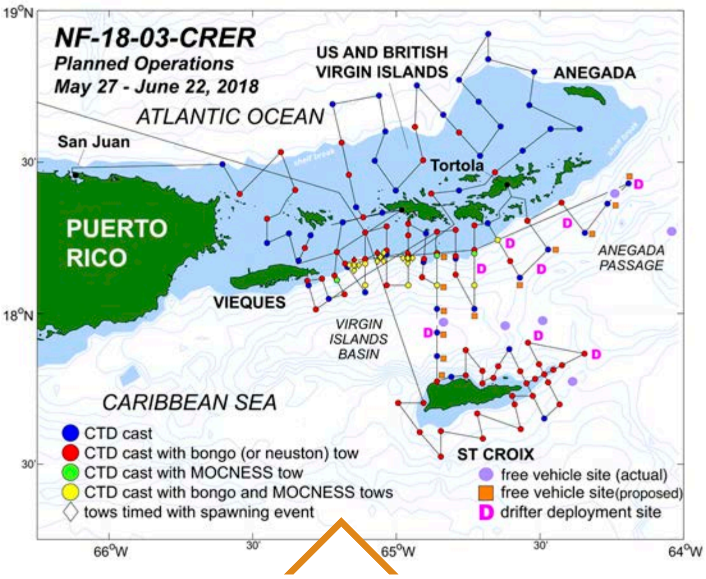


Figure 1. NF-18-03-Coral Reef Ecosystem Research (CRER) proposed activities and actual FV deployment locations. *Credit: NOAA, CRER*

Figure 2. Deployment of the Free Vehicle. *Image credit: Anonymous, NOAA Ship Nancy Foster*

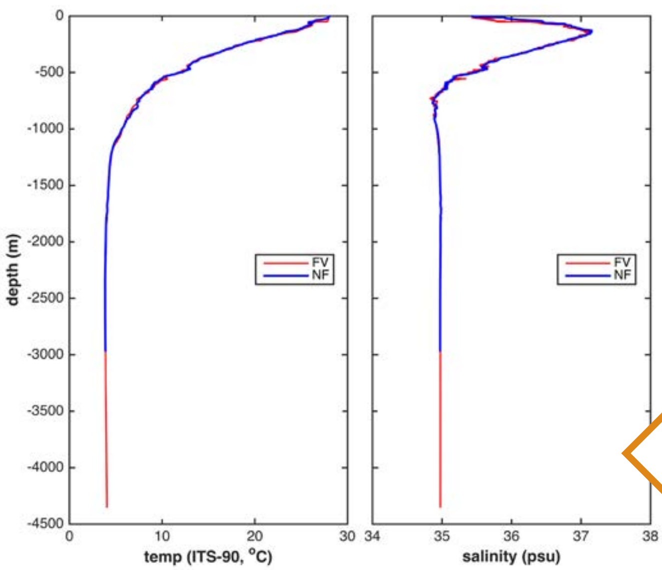


Figure 3. NF-18-03-CRER conventional and FV CTD data (June 17, 2018), 17°56.38'N, 64°51.49'W). *Credit: Wilford Schmidt, UPRM*

Midwater Acoustic Echosounding with the Wire Flyer Towed Profiling Vehicle

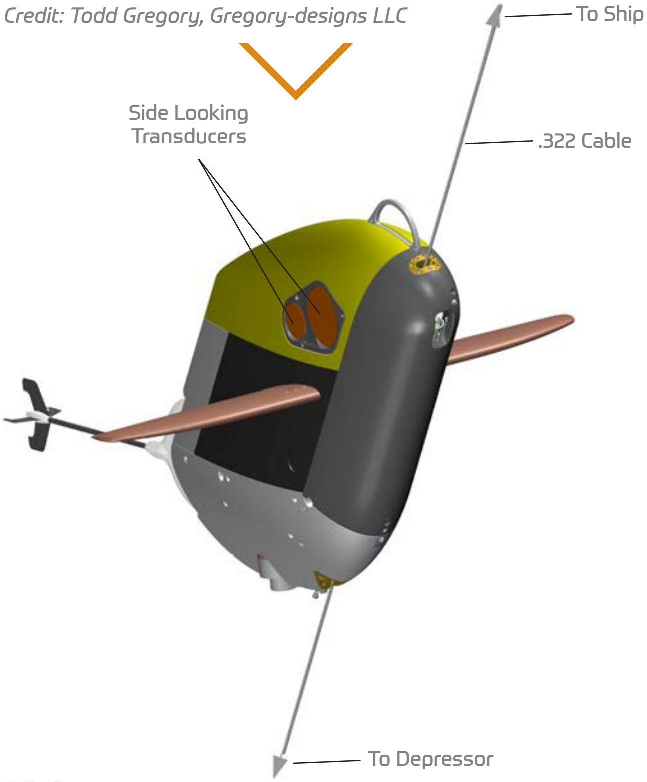
By Christopher Roman, Joe Warren, Erik Cordes, and Brad Seibel

Oxygen minimum zones (OMZs) are found throughout the world ocean. These regions are characterized by strong mesopelagic vertical oxygen gradients and hypoxic conditions that exert considerable influence on biogeochemical properties and organism distributions (Wyrtki, 1962; Karstensen et al., 2008; Wishner et al., 2018). This project integrated a dual-frequency (70 kHz and 200 kHz) EK80 echosounder into the Wire Flyer towed profiling vehicle to make detailed observations in OMZs (Roman et al., 2019). Shipboard acoustic echosounders are standard tools for measuring the abundance and distribution of marine organisms. Recently, vehicle-based acoustic systems have provided more detail at depths beyond the attenuation limits of surface systems (Benoit-Bird et al., 2016). By incorporating active acoustics on a profiling vehicle, it is possible to collect backscatter information with matching environmental data.

The Wire Flyer (Figure 1) slides up and down a towed 0.322″ CTD wire in a controlled manner using lift created by wing foils. The vehicle can achieve specific up and down velocities between 0 m s^{-1} and 2.5 m s^{-1} while profiling a prescribed region of the water column. The profiling pattern can repeat with kilometer spacing and provide spatial details that are otherwise difficult to obtain. The vehicle is equipped with sensors for temperature, salinity, oxygen, turbidity, and chlorophyll.

The echosounder and Wire Flyer were used in the Costa Rica margin OMZ to collect detailed hydrographic sections in the vicinity of several methane seeps (Figure 2). The data show a persistent acoustic scattering layer at the lower oxycline that is not affected by diel vertical migration. Further investigation of these data and future cruises will provide insight into these types of features and the links between niche midwater conditions and organism distributions.

Figure 1. The Wire Flyer vehicle slides along a standard cable using controllable wings for propulsion. The echosounder is oriented to look sideways as the vehicle profiles vertically. *Credit: Todd Gregory, Gregory-designs LLC*



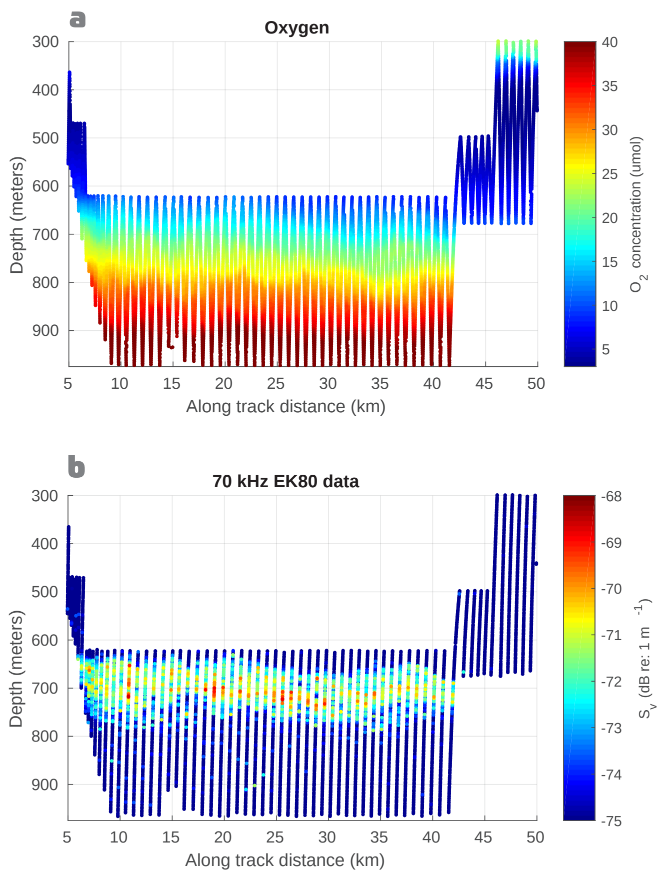


Figure 2. Example hydrographic sections showing (a) oxygen and (b) 70 kHz volume backscatter collected on an overnight tow at the Costa Rica margin (8°57′N, 84°18′W). *Credit: Christopher Roman, University of Rhode Island*

3D "Seismic Oceanography": The New Frontier in Ocean Water Column Exploration

By Leonardo Macelloni, Likun Zhang, Parsa Rad, and Zheguang Zou

Ocean mixing processes are fundamentally three dimensional (3D), thus features such as internal waves, tidal beams, solitons, and eddies are expected to change in both space and time. Their fine-scale structure is very difficult to reconstruct with the traditional sparse oceanographic observations (i.e., CTD and XBT casts, glider transects, moorings) especially in deep water.

Through this project, novel 3D images of ocean structures were constructed using high-quality 3D seismic data (courtesy of Schlumberger WesternGeco) collected in the northern Gulf of Mexico (Figure 1). A specific 3D processing workflow enhanced the inherently weak water column reflections, which were not the primary data collection targets. A seismic volume (20 km × 20 km) was created with a spatial resolution of 25 m inline, 6.25 m crossline, and a vertical resolution of about 6 m (Figure 2). Several ocean processes are observed at unprecedented resolution both laterally and vertically, including part of an eddy (Figure 3) and internal waves that are propagating and reflecting along the continental slope (Figure 2). Additionally, because the seismic survey was collected over a six-month period (from June to December 2002), we may be able to capture the temporal variability of some of these processes. Discerning the potential of 3D seismic oceanography has just begun. Beyond simply providing a novel way to visualize oceanic fine-scale structures, it can supply valuable quantitative information.

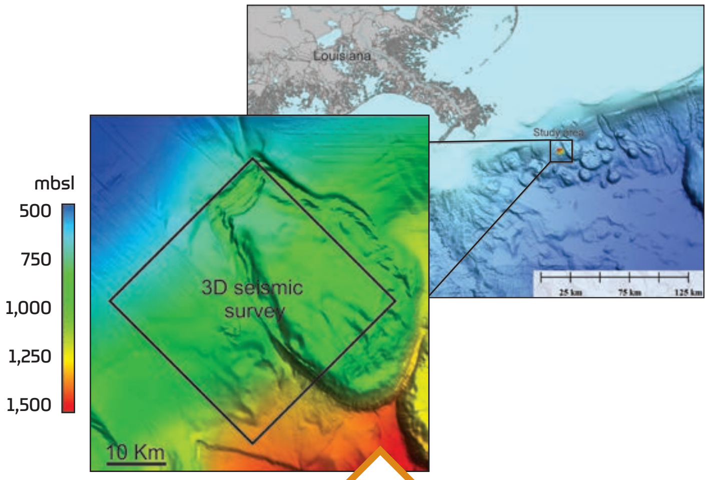


Figure 1. Location of the 3D seismic volume on the northern Gulf of Mexico continental slope. The seismic data cover an area of approximately 20 km x 20 km, water depth ranges from 800 m to 1,200 m. *Credit: Leonardo Macelloni, University of Mississippi*

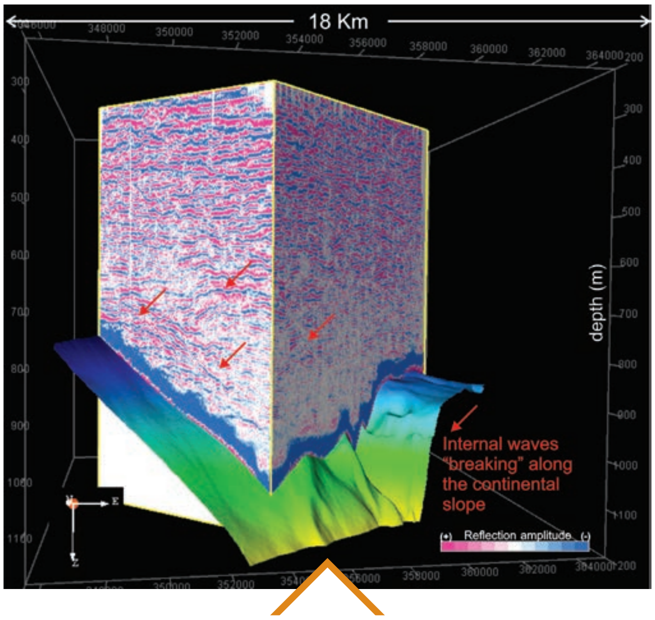


Figure 2. Tridimensional rendering of the water column 3D seismic volume, using Kingdome Vu-Pack. Internal waves captured by the seismic data are propagating and reflected along the slope. Because the acquisition geometry is designed to illuminate deep subseabed structures, seismic data optimally image water column beneath 200 m. The slope morphology from multibeam bathymetry is displayed for reference. *Credit: Leonardo Macelloni, University of Mississippi*

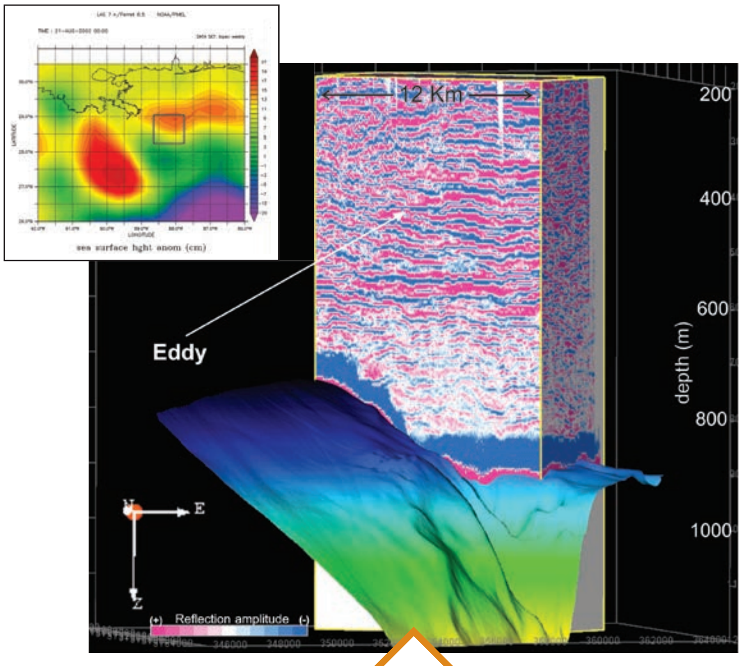


Figure 3. A portion of a Gulf eddy is captured in the seismic data. The eddy is present between 200 m and 600 m depth. Records of sea surface satellite anomalies, covering the same time window of the seismic data, confirm the presence of a large eddy in the area. *Credit: Leonardo Macelloni, University of Mississippi*