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Woods Hole Coastal and Marine Science Center

2019 Annual Report

Circular 1467

U.S. Department of the Interior
U.S. Geological Survey

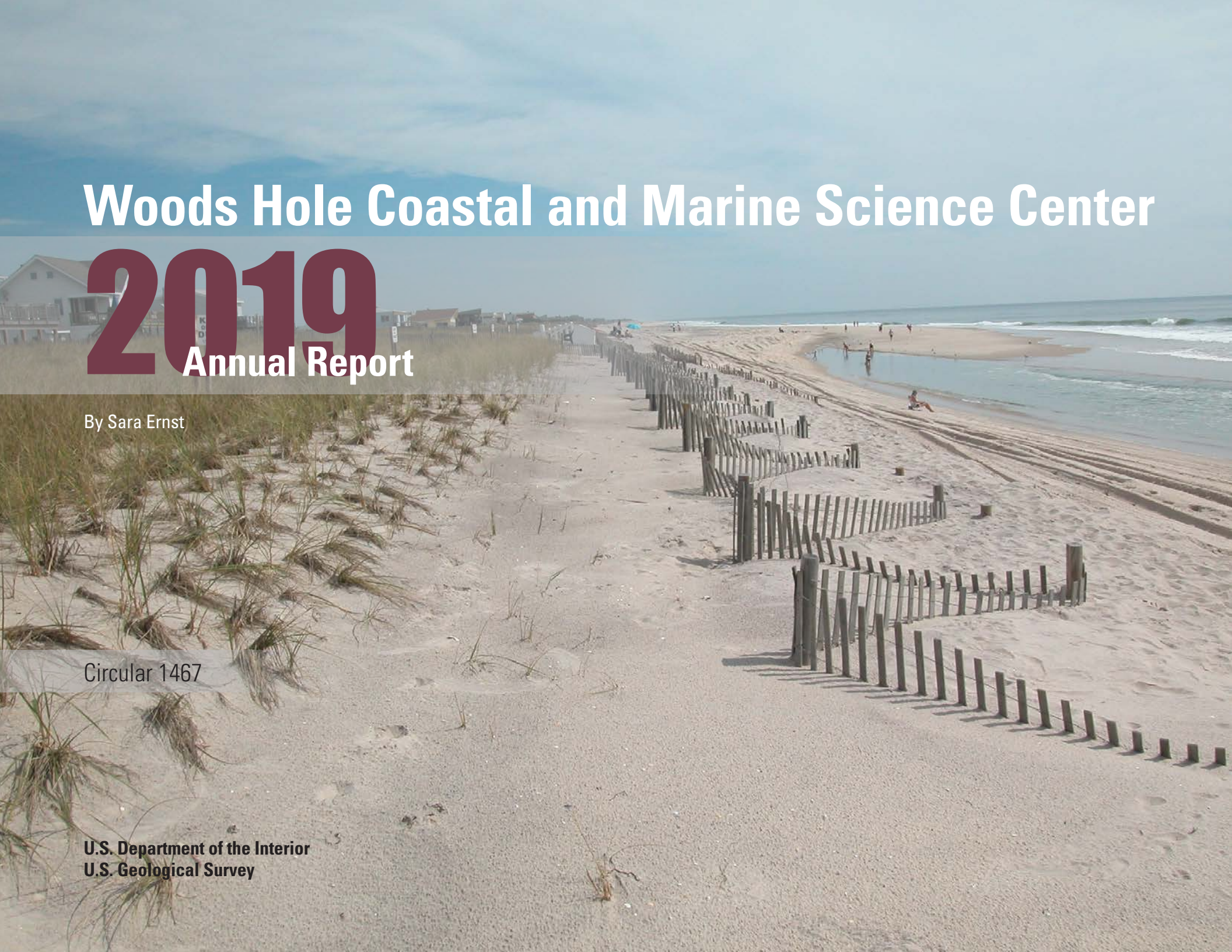
Cover. Front—Seismic subbottom profiler towed behind the survey vessel during the Cape Cod Bay sea-floor mapping cruise in August 2019. In collaboration with the Massachusetts Office of Coastal Zone Management, the U.S. Geological Survey Woods Hole Coastal and Marine Science Center continued its 17-year-long effort of mapping the Massachusetts nearshore sea floor.

Back—Large photograph: Eric Moore, Wayne Baldwin, and Tommy O'Brien deploying a multichannel seismic streamer onboard the research vessel *Pelican* during a 2013 seismic cruise in the Gulf of Mexico, as part of the U.S. Geological Survey (USGS) Gas Hydrates Project. Small photographs: Tommy at work throughout his career with the USGS. Tommy's last trip to sea in his 36 years working on marine seismic and sea-floor mapping technology in Woods Hole was in 2019, on a cruise where the Queen Charlotte Fault was imaged offshore southeastern Alaska and western Canada. Tommy passed away in January 2020.

Woods Hole Coastal and Marine Science Center

2019 Annual Report

By Sara Ernst



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U.S. Department of the Interior
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U.S. Department of the Interior
DAVID BERNHARDT, Secretary

U.S. Geological Survey
James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia: 2020

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Suggested citation:
Ernst, S., 2020, Woods Hole Coastal and Marine Science Center—2019 annual report: U.S. Geological Survey Circular 1467, 36 p., https://doi.org/10.3133/cir1467.

ISSN 1067-084X (print)
ISSN 2330-5703 (online)
ISBN 978-1-4113-4373-3

All photographs by the U.S. Geological Survey.

Page i: Fire Island, New York.

Contents

Sunrise on Cape Cod Bay with a peek inside the processing van on deck of research vessel *Warren Jr.*

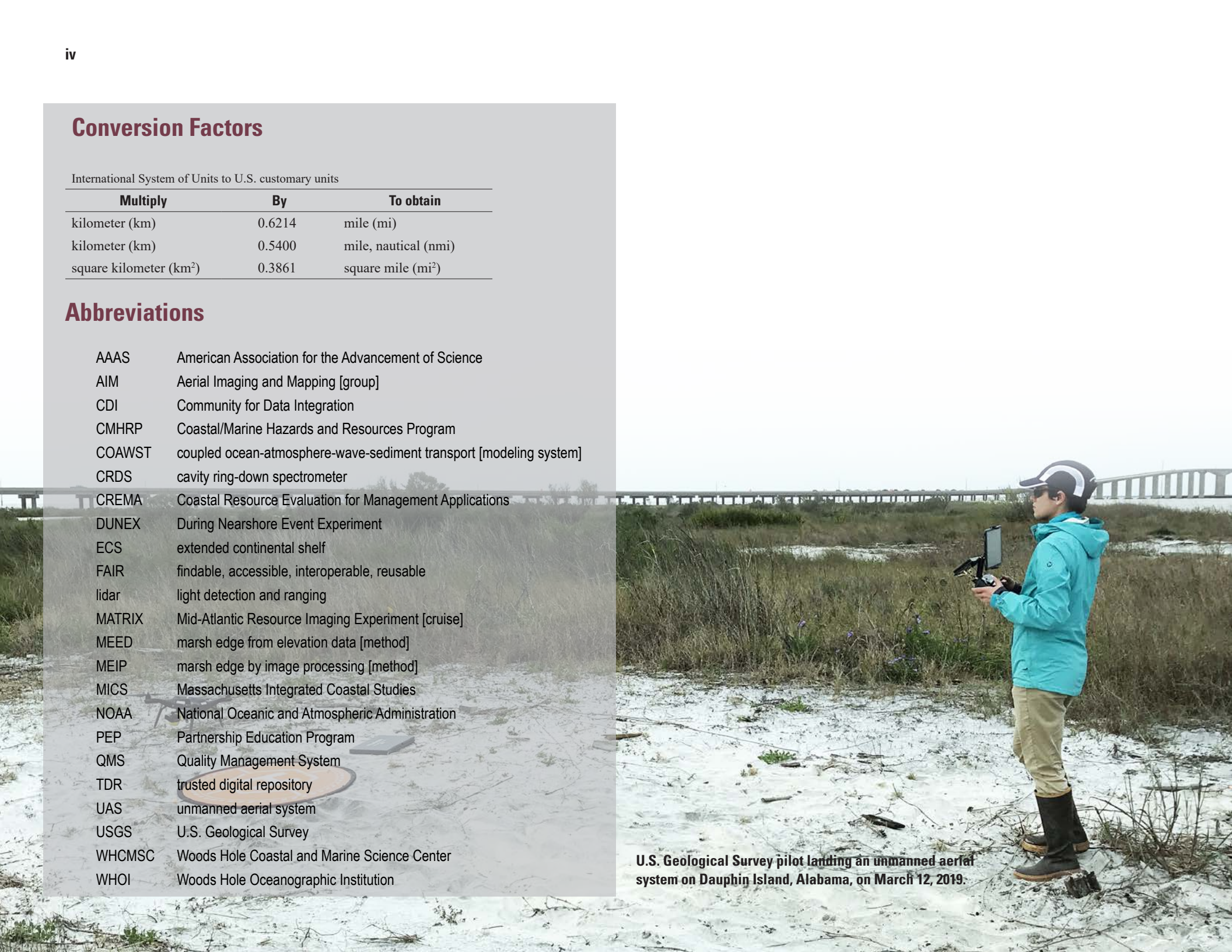
Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
square kilometer (km^2)	0.3861	square mile (mi^2)

Abbreviations

AAAS	American Association for the Advancement of Science
AIM	Aerial Imaging and Mapping [group]
CDI	Community for Data Integration
CMHRP	Coastal/Marine Hazards and Resources Program
COAWST	coupled ocean-atmosphere-wave-sediment transport [modeling system]
CRDS	cavity ring-down spectrometer
CREMA	Coastal Resource Evaluation for Management Applications
DUNEX	During Nearshore Event Experiment
ECS	extended continental shelf
FAIR	findable, accessible, interoperable, reusable
lidar	light detection and ranging
MATRIX	Mid-Atlantic Resource Imaging Experiment [cruise]
MEED	marsh edge from elevation data [method]
MEIP	marsh edge by image processing [method]
MICS	Massachusetts Integrated Coastal Studies
NOAA	National Oceanic and Atmospheric Administration
PEP	Partnership Education Program
QMS	Quality Management System
TDR	trusted digital repository
UAS	unmanned aerial system
USGS	U.S. Geological Survey
WHCMSC	Woods Hole Coastal and Marine Science Center
WHOI	Woods Hole Oceanographic Institution



U.S. Geological Survey pilot landing an unmanned aerial system on Dauphin Island, Alabama, on March 12, 2019.

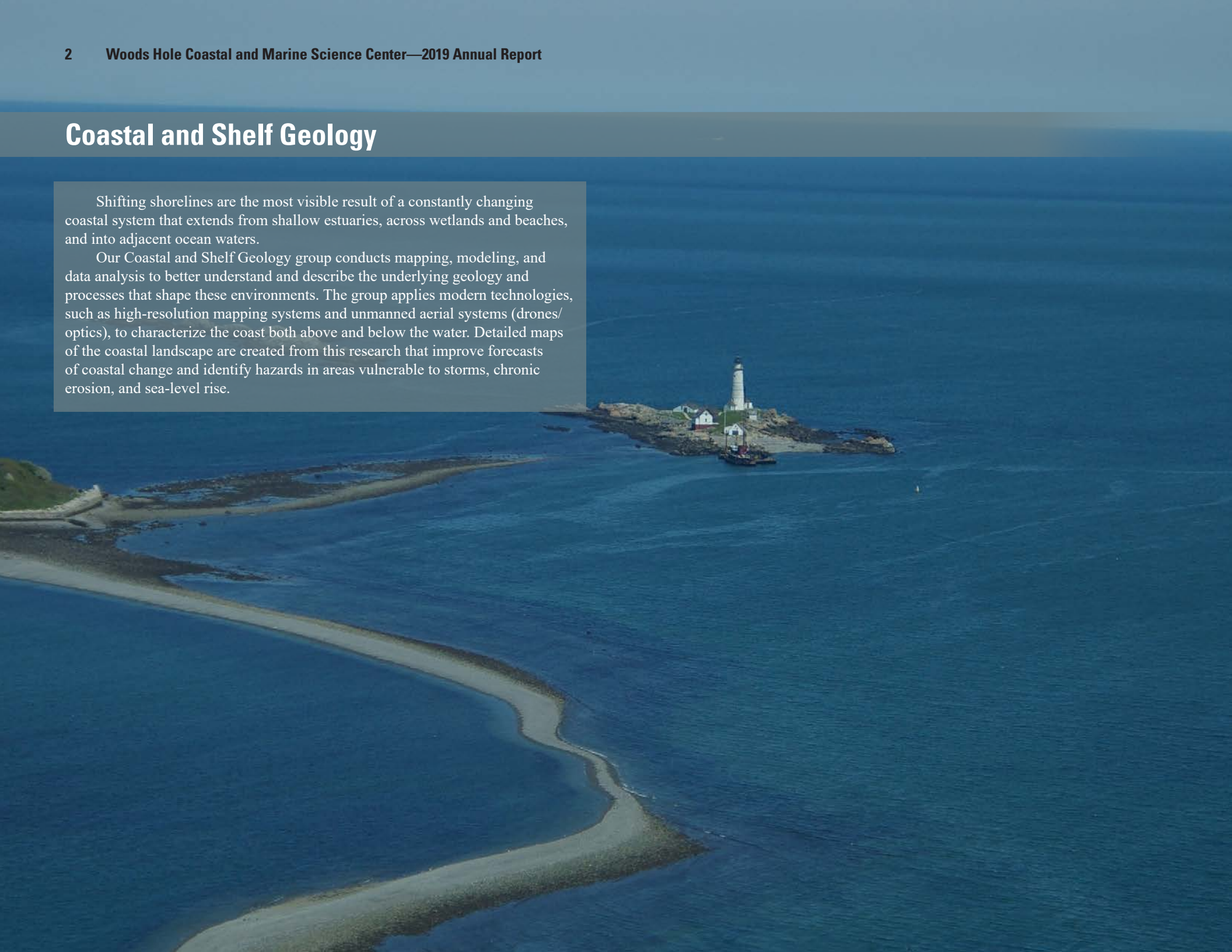
Coastal and Marine Science Based in Woods Hole, Massachusetts

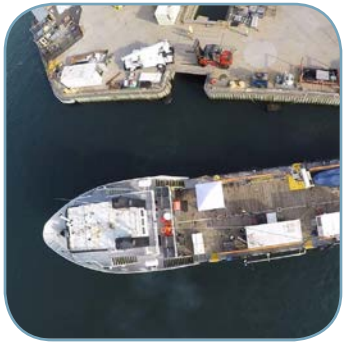
The U.S. Geological Survey (USGS) Woods Hole Coastal and Marine Science Center (WHCMSC) in Woods Hole, Massachusetts, is one of three centers serving the mission of the USGS Coastal/Marine Hazards and Resources Program (CMHRP). Since its authorization by Congress in 1962, the CMHRP has served as the primary Federal program for marine geology and physical science research and is responsible for the Nation's entire coastal and marine landscape. The center's staff of about 100 conducts scientific research throughout the United States and in international waters to describe and understand the processes shaping coastal ecosystems, such as dunes, beaches, salt marshes, and lakes, and marine ecosystems, like the continental shelf and the deep sea. The center's research products are used by other Federal agencies, State and local entities, private organizations, and the public to make informed decisions about the use, management, and protection of our coastal and marine resources.

Coastal and Shelf Geology

Shifting shorelines are the most visible result of a constantly changing coastal system that extends from shallow estuaries, across wetlands and beaches, and into adjacent ocean waters.

Our Coastal and Shelf Geology group conducts mapping, modeling, and data analysis to better understand and describe the underlying geology and processes that shape these environments. The group applies modern technologies, such as high-resolution mapping systems and unmanned aerial systems (drones/optics), to characterize the coast both above and below the water. Detailed maps of the coastal landscape are created from this research that improve forecasts of coastal change and identify hazards in areas vulnerable to storms, chronic erosion, and sea-level rise.



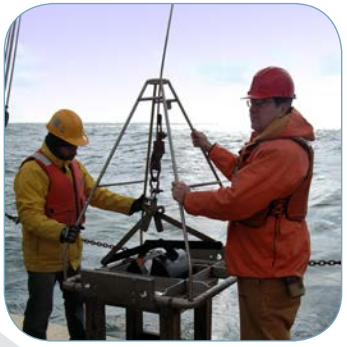


Cape Cod Bay Photographs, Video, and Sediment Sampling

In September 2019, a sampling survey was conducted to ground-truth data from an August geophysical survey. The Sea Floor Mapping Group team visited 49 sampling sites to collect photographs, video, and sediment samples distributed across the study area. The sediment samples were analyzed to determine grain-size and other physical properties at the center's Sediment Laboratory. The integration of the sampling data, along with data derived from the coincident geophysical survey, help USGS scientists define the regional geologic framework of Cape Cod Bay, determine the surficial sediment distribution of the Bay, and understand the sediment dynamics and coastal processes of the area.

Shoreline Forecasting

Several sites of varying morphological diversity throughout Massachusetts, including Cape Cod Bay, were selected to provide in-depth analysis and validation of a predictive method of shoreline position forecasting. Three variations of the shoreline forecasting models are being compared and tested against simulated and measured shoreline positions. The existing databases of shoreline positions and measurement locations are undergoing a rigorous overhaul for optimization in the latest version of the shoreline change analysis software used to compute rates of change and future shoreline forecast horizons. Rates of change are being computed using a shoreline position extracted from light detection and ranging (lidar) elevation data collected in 2018.



COAWST Modeling

The MICS project continued to identify large regional storm events and determine their impact on the shoreline. As a first application, the wave fields resulting from storm winds from different directions were successfully simulated. The models have now been run for idealized compass directions and intensities. These efforts help identify what sections of the coast are most vulnerable to change.

Coastal Change Hazards and Sea-Floor-Mapping Project: Massachusetts Integrated Coastal Studies (MICS)

Highlights of 2019

To further our understanding of the processes that control sediment movement in Cape Cod Bay, the USGS, in partnership with the State of Massachusetts, initiated the Massachusetts Integrated Coastal Studies project in 2018. Through this multi-tiered research initiative, our scientists are developing and applying a coupled ocean-wave-sediment transport model for the bay at different scales by using our coupled ocean-atmosphere-wave-sediment transport (COAWST) modeling system. Planned work includes comprehensive sea-floor mapping of the bay (further detailed in the "Sea-Floor Mapping" section of this report), numerical modeling of coastal processes and their effects on coastline stability, and improved shoreline change assessments with new capabilities for predicting shoreline change. This work can help coastal zone managers better understand how, where, and why sediment is transported in western Cape Cod Bay.

Sea-Level Rise Hazards and Decision Support

Highlights of 2019

Sea-level rise will have a variety of future effects on the coast, including land loss from inundation and erosion; migration of coastal landforms and environments; increased water elevation, inland extent, and duration of storm-surge flooding; wetland losses; changes in coastal groundwater movement in relation to land; and effects on human development, infrastructure, and social systems. This project brings together multidisciplinary scientists from USGS and other organizations to assess, model, and predict the effects of sea-level rise on the Nation's coasts. The project synthesizes information on coastal environments and uncertainties as well as our current knowledge of coastal processes into an analytic framework for evaluating the likelihood of various sea-level rise effects. Researchers with this project also work with decision makers and State, academic, and nonprofit collaborators and stakeholders to ensure that the research outcomes are applicable and useful to managers who face decisions about whether to avoid, mitigate, or adapt to future hazards.

Historical Changes to Piping Plover Habitat—Results Published

Piping plovers (*Charadrius melodus*) are a federally protected species and serve as a key indicator species for other shorebirds; their well-being indicates habitat quality and the likelihood that other shorebirds will be successful in the same area. The project used the plover habitat availability probabilistic model (a Bayesian belief network) developed by USGS to evaluate historical changes in plover habitat, specifically because of Hurricane Sandy and subsequent barrier island recovery. Results were published in a paper and an accompanying press release.

Forecasting Barrier Island Characteristics and Piping Plover Habitat

Integrated Bayesian belief networks are being used to forecast barrier island characteristics and associated piping plover habitat under several possible SLR scenarios at 21 study areas along the U.S. Atlantic coast (Maine to North Carolina). An open-file report and several accompanying data releases were published documenting methods and derived characteristics.

National Resources Preservation

The National Resource Preservation Project secured additional National Park Service funding in 2019 to explore the effect of coastal change on sea-beach amaranth at Assateague Island National Seashore. Funding will support this research through 2021, and additional internal collaborative opportunities through During Nearshore Event Experiment (DUNEX) and Coastal Resource Evaluation for Management Applications (CREMA) projects will be explored.

Paper On Relationship Between Elevation and Land Cover

The Sea-Level Rise Hazards and Decision Support research team is exploring both regional and local changes to the coastal landscape. Datasets produced in this effort were directly incorporated in web utilities and assessments exploring both coastal resiliency and conservation via The Nature Conservancy's resilient coastal sites and the North Atlantic Landscape Conservation Cooperative's Nature's Network. The project published a paper on the relation between elevation and land cover in the model and on how, through Bayesian inference, this relation can be used to reduce uncertainty.

Plum Island Temporal Study

The AIM group continued its repeat aerial surveys in the Plum Island estuary and Parker River National Wildlife Refuge, Massachusetts. Aerial surveys over 3 years (February/March 2017, 2018, and 2019) are being conducted to assess marsh stability by measuring the amount of slumping along the banks of the tidal channels.

Support for Coastal Resource Evaluation for Management Applications Project

As part of the Coastal Resource Evaluation for Management Applications (CREMA) project, the AIM group provided support for multiple USGS St. Petersburg Coastal and Marine Science Center UAS flights on Dauphin Island, Alabama. Dauphin Island is the only barrier island providing protection to many of Alabama's coastal natural resources.

Survey Looking at Vegetation Classification/Index

In collaboration with the Marine Biological Laboratory in Woods Hole, Massachusetts, the AIM group conducted UAS aerial surveys looking at vegetation, for purposes of classification and indexing, surrounding a Marine Biological Laboratory gas flux tower in Nelson Island Creek, Rowley, Massachusetts.

Other Efforts

Members of the AIM group responded to the Hurricane Dorian rapid-response deployment in South Carolina; helped plan and conduct surveys for the UAS aquatic airshow in southern Maine to demonstrate noncontact discharge measurements; provided teaching assistance to train new USGS drone pilots at A–450 classes held in Fort Collins, Colorado; and continued to lead the regional UAS capability team coordinating communication and collaboration among members of the UAS community.

Aerial Imaging and Mapping

Highlights of 2019

The Aerial Imaging and Mapping (AIM) group provides unmanned aerial system (UAS) services to collect coastal and nearshore data and supports a variety of USGS WHCMSC and partner science projects. These data and derivative products are also used by coastal managers and other stakeholders for informed decision making and determining coastal management and policies that prepare the Nation for extreme events, natural hazards, and the effects of climate change. UAS technology provides a rapid and cost-effective solution for mapping coastal environments and assessing short- and long-term changes. The interdisciplinary nature of the data collected and the breadth of applications of UAS technology make it applicable to multiple scientific investigations.

The AIM group continues to lead the USGS Northeast Region UAS working group, exploring new research applications and developing UAS platforms and data-processing methods to facilitate USGS publication of UAS data. The AIM group has hosted national training classes and continues to assist the USGS National Unmanned Aircraft Systems Project Office in teaching basic UAS training to new drone pilots.

Sediment Transport

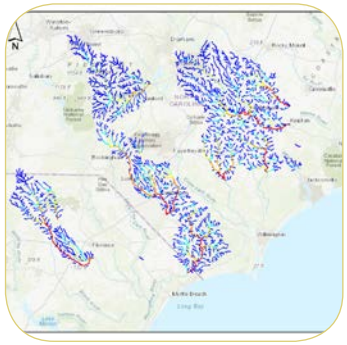
Coastal systems are dynamic—they change constantly as a result of the movement of sediment caused by waves, wind, currents, and tides, as well as storms and sea-level rise. The ability to predict how the coast will respond to these forcing conditions can mitigate hazards, such as loss of infrastructure, tourism and recreational use, and effects on marine habitats. Our center uses cutting-edge oceanographic equipment to observe and measure the processes that transport sediment within the coastal ocean. These observations are used to develop computer models to better understand the past, present, and future states of coastal systems. The models developed at the center vary in scale, ranging from local estuaries or barrier islands to the entire U.S. Atlantic coast, and take advantage of modern high-performance computing. This combination of observations and modeling improves hazard and resource assessments that provide coastal managers with important information on the coastal system for them to use in making knowledge-based decisions.

COAWST Training

A semiannual training workshop was held for users and developers of the coupled ocean-atmosphere-wave-sediment transport (COAWST) modeling system. The in-person training attracted academic and government scientists from around the world, and many others contributed remotely.

Enhanced COAWST Capabilities

COAWST was enhanced to hindcast and forecast coastal hazards during extreme events. The infragravity wave model (InWave) integrated into COAWST was updated to account for variations in incoming wave sets in time and space. Sediment transport routines driven by waves and currents from the nearshore to the dunes were improved to account for beach and dune erosion and for alongshore bar-building and migration.



COAWST Application of Hurricane Florence

COAWST is being expanded to include WRF_Hydro, a hydrologic rainfall-runoff model, to enable predictions of how rainfall flows over land and into creeks, rivers, and the ocean. An application of COAWST, including WRF_Hydro, is planned to study the effects of compound flooding—the nonlinear combination of river flooding and ocean storm surge—during Hurricane Florence (2018) in North Carolina. Results can inform hazard guidance, emergency preparedness, and resource management.

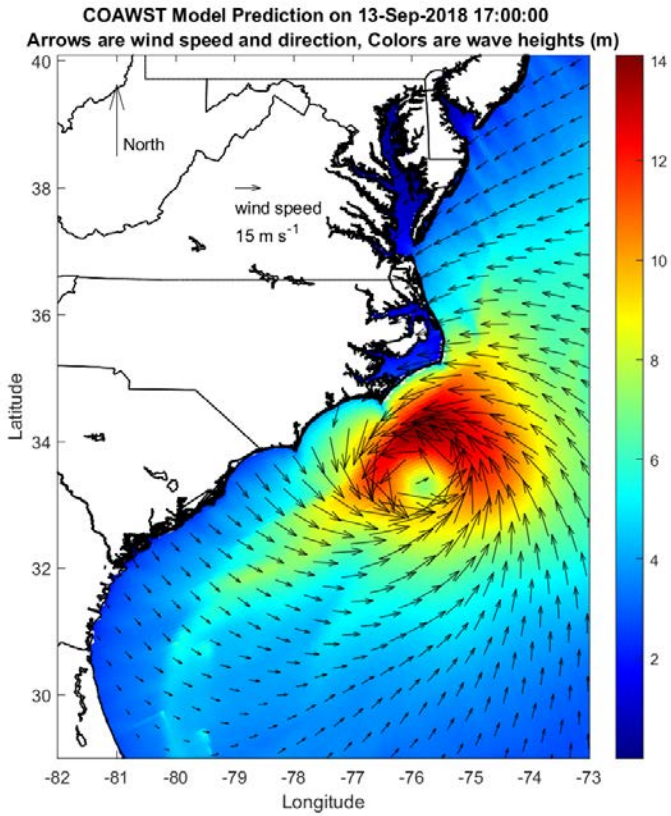
More COAWST Applications

COAWST was used to study how waves and currents during Hurricane Matthew (2016) interacted with the Gulf Stream, affecting breaching south of Matanzas Inlet, Florida. This COAWST application was compared with an application to Fire Island, New York, during Hurricane Sandy (2012) to identify mechanisms for barrier island breaching due to large waves and high water levels. Results were presented at conferences, workshops, and university seminar series.

Cross-Shore and Inlets Processes

Highlights of 2019

Understanding the exchange of water, sediment, and biological particles between the inner shelf and back-barrier estuaries provides critical information for determining extreme water levels, the formation and maintenance of inlets, barrier island evolution, and pollutant and larval transport. These connections are controlled by cross-shore processes including wave-driven inner-shelf and nearshore processes, dune overtopping, breaching, transport through existing and new inlets, and estuarine circulation. The Cross-Shore and Inlets Processes project objectives are to further our understanding and increase our ability to predict the evolution of the form and shape of the coast from estuaries to the continental shelf.



Coastal Model Application and Field Measurements

Highlights of 2019

This project supports the development and application of open-source coastal models with several objectives:

1. improve the code of numerical sediment-transport models by implementing new or improved algorithms;
2. obtain measurements of coastal ocean processes to test and verify models;
3. develop new instruments or analytical techniques to collect these measurements; and
4. develop software tools and standards to facilitate analysis, comparison, and visualization of observations and models.

Study sites are selected for characteristics needed for model development and testing, as well as to address issues of national or regional importance.

Sand Transport by Asymmetrical Waves

Waves propagating into shallow water become asymmetrical, with near-bottom velocities and accelerations that are typically stronger in the onshore direction. This can generate shoreward sand transport and help beaches recover from storm erosion. Scientists are working to simulate this process in the coupled ocean-atmosphere-wave-sediment transport (COAWST) modeling system using a bedload transport formula that incorporates wave asymmetry.

Sandwich Town Neck Beach Modelling

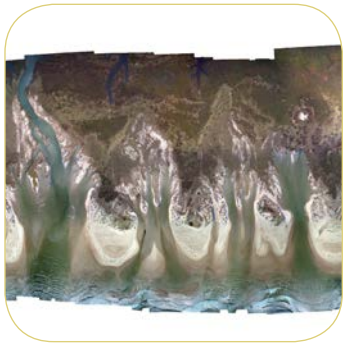
Town Neck Beach in Sandwich, Massachusetts, has been mapped 14 times since 2016 to capture seasonal variability of the beach and morphology changes after nor'easters. Erosion patterns have varied along the beach, and numerical models are now being used to investigate the processes that cause this variability.

CoastCam Network Moving to USGS Cloud

A network of about 10 CoastCam stations has been established by CMHRP colleagues in Santa Cruz, California, and St. Petersburg, Florida, over the last few years. Each station contains one or more cameras designed to image the surf zone and record changes in beach and nearshore topography. Stations upload images to the web via cellular modems, and websites allow the public to view the beach a few minutes after the images are acquired. This year, with the help of USGS Cloud Hosted Solutions, the Remote Sensing Coastal Change project began to upload the images to the USGS Cloud, where the latest images are publicly available. The CoastCam team also plans to move processing and analyses capabilities for CoastCam images to the Cloud.

CoastCam Station Established at Cape Cod National Seashore

A new CoastCam station was established at Head of the Meadow Beach, North Truro, Massachusetts, in the Cape Cod National Seashore. The camera overlooks the beach from atop a remote sandy bluff about a quarter of a mile from the parking lot. This camera is recording beach and nearshore conditions in an area shared by beachgoers, shorebirds, seals, and sharks.



Cloud Processing of Coastal Imagery with Disaster Relief Funds

Supplemental disaster relief funds are being used to develop methods of rapid, cloud-based analysis and change assessment for images of coastal hurricanes and nor'easters. Tens of thousands of images were obtained along the North Carolina coast before and after Hurricane Dorian in late summer and autumn of 2019. These images were uploaded to the USGS Cloud and have been processed by using Cloud computing capabilities to provide accurate digital elevation models that can be used to quantify change. Images from North Core Banks, a barrier island in Cape Lookout National Seashore, show huge volumes of erosion (as much as 10 percent of the island) associated with sound-side flooding in the wake of Hurricane Doriann.

Remote Sensing Coastal Change

Highlights of 2019

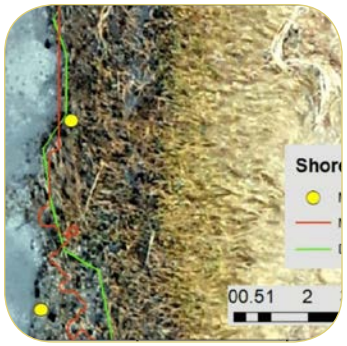
The Remote Sensing Coastal Change project began in 2017 as a multicenter collaboration intended to advance USGS Coastal/Marine Hazards and Resources Program applications of remote-sensing techniques to coastal change problems. The project has a technical focus on adapting instruments and methods from other fields to support the USGS mission. Two early, major components have been the use of drones and manned aircraft for collecting imagery and the use of structure-from-motion photogrammetry for measuring topography. The project, in conjunction with the USGS Community for Data Integration (CDI), sponsored a short course, attended by more than 40 USGS scientists, on the use of deep neural networks for classifying coastal imagery and detecting coastal change.

Estuarine Processes, Hazards, and Ecosystems

Highlights of 2019

Several interdisciplinary projects aim to collect basic observational data on estuarine processes, develop numerical models of these processes, and apply the models to understand the past, present, and future states of estuaries. Wetland synthesis efforts produce geospatial data layers that are used to evaluate dynamics and change in these critical environments.

Study sites include Ogunquit, Maine; West Falmouth Harbor, Massachusetts; Great South Bay, New York; Jamaica Bay, New York; Barnegat Bay, New Jersey; Chincoteague Bay, Maryland/Virginia; Blackwater National Wildlife Refuge, Maryland; and tidal wetlands along the Pacific coast.



New Methods Developed To Calculate Salt Marsh Shoreline Location

The marsh edge from elevation data (MEED) method calculates the abrupt elevation change at the edge of most salt marshes. The marsh edge by image processing (MEIP) method finds the unvegetated/vegetated line. Both methods calculate a line that closely follows the edge of vegetation seen in imagery. They provide accurate, efficient, and objective ways to track salt marsh shorelines with spatially intensive data over large spatial scales, which is necessary to evaluate geomorphic change and wetland vulnerability. A paper was published detailing these two methods.

Erosion Experiments

Sediment Transport Group personnel provided expertise and equipment to conduct erosion experiments on sediments containing harmful algae cysts with Woods Hole Oceanographic Institution (WHOI) collaborators at a salt pond site in the Cape Cod National Seashore.

Field Operations

Sediment Transport Group personnel completed seven field operations, including deployments, turnarounds, and recoveries, at Stone Harbor and Thompsons Beach, New Jersey, as part of a multiyear, multilocation project funded by the National Fish and Wildlife Foundation monitoring of beach marsh environments. The group also completed 12 field operations in Wellfleet, Massachusetts, as part of a multiyear, multilocation project funded by the Natural Resource Preservation Program of the National Park Service.

Numerous Publications

The estuaries group published eight papers in 2019 in the following journals: Remote Sensing, Journal of Geophysical Research: Biogeosciences, Estuaries and Coasts, Ecological Engineering, Advances in Water Resources, Journal of Geophysical Research: Oceans, Natural Hazards and Earth System Sciences, and Journal of Marine Science and Engineering.

Sediment Transport Group personnel installing the new CoastCam station at Head of the Meadow Beach, North Truro, Massachusetts, in the Cape Cod National Seashore. The installation of the cameras, batteries, and solar panels was challenging. Sleds were used to transport gear across the beach, and ladders were used to ascend the bluff while protecting it from erosion.

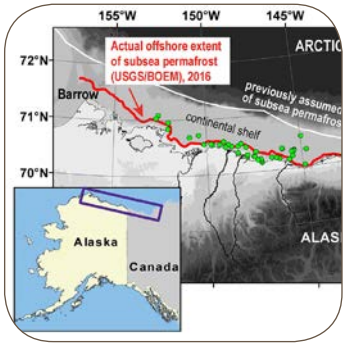
Energy and Geohazards

Energy and geohazards research at the center is focused on three themes: gas hydrates (naturally occurring ice-like deposits made of water and gas), earthquake and tsunami hazards, and the sea floor beyond 200 nautical miles from shore, known as the extended continental shelf (ECS).

USGS scientists work together to study the formation and distribution of gas hydrates in nature, the potential of hydrates as an energy resource, and the possible environmental effects of gas hydrates when they break down and release methane (a potent greenhouse gas) into sediments, the ocean, or the atmosphere. The USGS works closely with other Federal agencies on implementing national gas hydrate research priorities and has been a leader in gas hydrates research for more than three decades.

Underwater earthquakes can generate tsunamis that cause hazards for coastal communities. Scientists at the center study the recent history of underwater earthquakes and tsunamis and evaluate the future potential and probable impacts of such events on a regional basis. Their research results are used in evaluations of earthquake risk zoning, public disaster education and preparedness, and engineering and building codes.

The Energy and Geohazards group also works with other Federal agencies to explore and define the limits of the U.S. ECS. Further understanding of the resource potential of these vast areas in the Arctic, Atlantic, and Pacific Oceans will improve natural resource management and promote economic prosperity.



Subsea Permafrost and Gas Hydrates

The Gas Hydrates Project collaborated on publishing a map of Northern Hemisphere subsea permafrost, whose distribution has implications for the locations of relic gas hydrate deposits formed before the continental shelves of the high Arctic were inundated by Holocene sea-level rise.

Mid-Atlantic Resource Imaging Experiment (MATRIX)

The USGS-led MATRIX project was the first modern multichannel seismic program to constrain the distribution of deepwater gas hydrates on the U.S. mid-Atlantic margin. In 2019, the USGS delivered two versions of the processed multichannel seismic data to the Bureau of Ocean Energy Management in advance of a data release; mapped the regional bottom simulating reflectors that mark where gas hydrates occur in the sediments; estimated thermal conditions in sediments of the U.S. mid-Atlantic bight based on the seismic data; and used machine learning to automate mapping of bottom-simulating reflectors in the data.

Physical Properties of Hydrate-Bearing Sediments

Domestic and international collaborative opportunities leveraged USGS resources to shape our understanding of how and where reservoir-quality gas hydrate is likely to form, and how to most effectively access the sequestered methane as an energy resource. Locations included the Gulf of Mexico, Korea, and other locations around the globe as part of the International Gas Hydrate Code Comparison project.

Special Journal Issue Completed & Special Volume Published

WHCMSC scientists coauthored the intro and multiple articles for a special issue of the Journal of Geophysical Research: Solid Earth on the physical properties of hydrate-bearing sediments. The USGS Gas Hydrates Project was also instrumental in the publication of a 746-page special volume of Marine and Petroleum Geology, which serves as the compilation of scientific results for India's National Gas Hydrate Program Expedition NGHP–02 (offshore eastern India). Two of the three primary journal editors for the special volume, including the lead editor, were from the project, and 12 of the 47 papers in the volume were led or coauthored by researchers from our center.

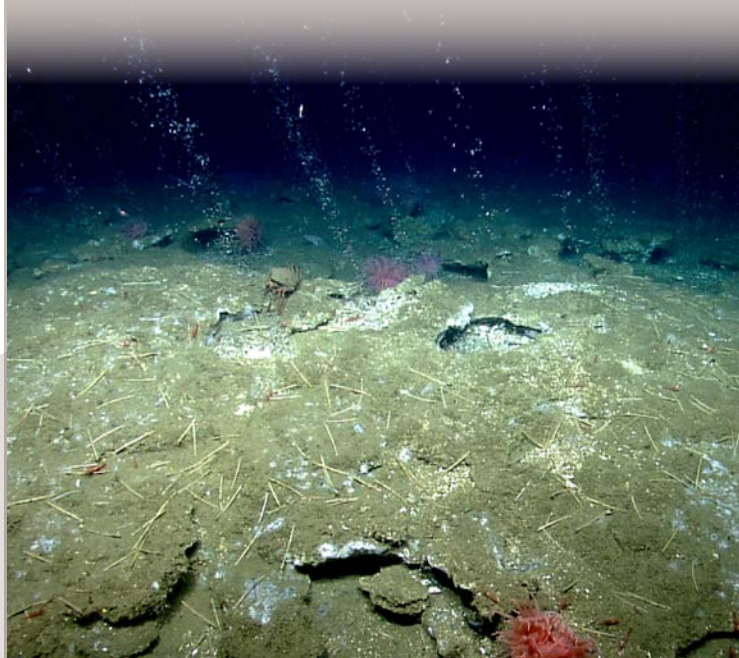
Gas Hydrates Project

Highlights of 2019

The USGS Gas Hydrates Project focuses on the study of natural gas hydrates in deepwater marine systems and permafrost areas. The project has three primary goals:

1. evaluate methane hydrates as a potential energy source;
2. investigate the interaction between methane hydrate destabilization and climate change at short- and long-time scales, particularly in the Arctic; and
3. study the spatial and temporal connections between submarine slope failures and gas hydrate dynamics.

The Gas Hydrates Project conducts multidisciplinary field studies, participates in national and international deep drilling expeditions, and maintains a laboratory program focused on hydrate-bearing sediments.



Biogeochemistry and Environmental Feedbacks of Gas Hydrate Systems

Highlights of 2019

Gas Hydrates Project scientists address questions related to the production and fate of methane in evaluating the resource potential of gas hydrate and the environmental effects of methane release from the sea floor. The key to these capability advances has been the development of analytical methods that enable critical measurements that have been employed in domestic and international collaborations. Some investigations were conducted in gas hydrate-bearing systems, and others were performed in proxy locations for settings where gas hydrate has been implicated with sea-floor methane discharge.

Gas Hydrate Investigations—Geochemistry for Energy Resource Studies

Phase I of the Alaska North Slope hydrate test well project was completed in December 2018 and January 2019. The center's geochemistry group analyzed soil cuttings from the hydrate-bearing well for hydrocarbon gas content and the stable carbon isotope of methane by using a custom-designed gas chromatograph and the USGS discrete sample analysis system.

Environmental Effects of Methane Released from the Sea Floor

A USGS technician from the Gas Hydrates Project participated on a survey aboard the Swedish icebreaker *Oden* in August 2019 to measure seawater methane from Thule, Greenland, up the Ryder Glacier in far northwestern Greenland, an area with mostly unexplored conventional hydrocarbon basins and gas hydrates. The data collected represent the most extensive set of observations for gas release from the sea floor and the exchange between the oceans and atmosphere for this part of the world.

Instrument Development to Support Field and Lab Studies

A provisional patent was issued to center personnel for the USGS discrete sample introduction module, which interfaces with a cavity ring-down spectrometer (CRDS) that measures gas concentrations and stable isotope ratios. Scientists and technicians with the Gas Hydrates Project also designed and constructed a CRDS with Picarro, Inc (the Picarro G2201–i). The instrument, used with the USGS discrete sample introduction module, allows for the simultaneous analysis of ratios of methane (C1) to ethane (C2) and of methane stable carbon isotopes from natural gas samples. An automated, 16-channel mesocosm analysis module that interfaces with the Picarro G2201–i CRDS was designed, constructed, and successfully tested to measure carbon dioxide production rates from ocean water microbial cultures. This device can also be used to measure methane production rates with terrestrial soil and marine sediments related to gas hydrate studies in the future. This project was in collaboration with the Woods Hole Oceanographic Institution.

Seismic Imaging Survey of Cascadia Subduction Zone

After three cruises in 2018 and 2019, the Woods Hole and Pacific Coastal Marine Science Centers jointly completed a high-resolution multichannel seismic survey of the entire U.S. portion of the Cascadia submarine forearc (offshore northern California, Oregon, and Washington). The new seismic imaging will provide detailed mapping of offshore faults and subduction-related deformation, and this mapping can directly inform earthquake and tsunami hazard and rupture models.

Development of Rapid-Response Ocean Bottom Seismograph

WHCMSC scientists and engineers are working with the Woods Hole Oceanographic Institution (WHOI) on a new ocean bottom seismograph designed for rapid mobilization to record short-lived phenomena such as earthquake aftershocks and island volcanic eruptions. Large, permanent offshore arrays are costly, and much of the sea floor is not well monitored by seismic instruments. The new, small, nimble instruments will enable targeted deployments in remote and often poorly instrumented locations during high-value periods of active seismicity.

Recovery of Ocean Bottom Seismograph

In September 2019, a WHCMSC and WHOI team recovered six intermediate-period ocean bottom seismographs from the continental slope offshore Georges Bank, which is between Cape Cod, Massachusetts, and Cape Sable Island, Nova Scotia. The instruments had been deployed for about 10 months to record background, ambient seismic noise. The data are being used to measure the in-situ shear wave speed of sea-floor sediments, which is a proxy for shear strength. Shear strength is a key parameter in determining how the sea floor shakes during earthquakes and how likely the slope is to fail in a submarine landslide. Shear strength measurements are difficult to make directly without disturbing sediments, but this passive acoustic method can be used to evaluate sea-floor properties without disturbing the seabed.

Marine Geohazards Sources and Probability

Highlights of 2019

The Marine Geohazards Sources and Probability project has three primary objectives:

1. quantify marine hazards, such as earthquakes, landslides, tsunamis, and volcanoes in marine and coastal environments by using geological and geophysical data, interpretations, and models;
2. understand the underlying processes of these marine hazards to inform hazard estimations; and
3. develop reliable deterministic and probabilistic estimates of the hazards to be used by engineers and policymakers.

Extended Continental Shelf Project

Highlights of 2019

The USGS Extended Continental Shelf (ECS) Project supports the U.S. Department of State in identifying the outer limits of the U.S. ECS. Within its ECS, a coastal nation can exercise its sovereign rights to manage, preserve, or exploit nonliving and sedentary living resources. The United Nations Convention on the Law of the Sea specifies the criteria and conditions under which nations justify their outer limit boundaries. The USGS uses geologic framework studies and estimates of sediment thickness in its ECS studies. The ECS Interagency Task Force and its Executive Committee (consisting of the U.S. Department of State, the National Oceanic and Atmospheric Administration [NOAA], and the U.S. Department of the Interior) provide guidance to the project for priorities in boundary delineation. The project is currently in phase 3, in which the past 10 years of data collection are being synthesized into documentation of proposed U.S. ECS outer limits.

Bering Sea Extended Continental Shelf

USGS developed the geologic background chapter, finalized sediment thickness values, and created associated seismic images for inclusion in the document being prepared by the ECS Project Office to explain the position of the United States on its ECS boundary in the Bering Sea. Following external review by experts in Law of the Sea criteria, the USGS is revising its chapter, as well as completing associated metadata, providing updated reference citations, assembling copies of all citations used, revising figures and seismic images as recommended, and providing mapping data to the ECS Project Office for final cartography.

Gulf of Mexico Extended Continental Shelf

A draft submission document for the eastern Gulf of Mexico was prepared in 2018, with USGS contributions on framework geology, sediment thickness points, and surficial geology. The draft submission document was favorably reviewed by external experts, and the ECS Executive Committee decided to make the eastern Gulf of Mexico the first region in which a full submission package (all text, figures, data, metadata, appendices, and supporting documentation) would be completed.

Other Regions of Extended Continental Shelf

The USGS ECS text documentation for the Arctic region underwent USGS review in 2019 in preparation for completing the full documentation package. Preliminary work was completed on both the Atlantic and Pacific regions of ECS, for which draft documentation has now been completed and reviewed.

In collaboration with retired U.S. Geological Survey (USGS) personnel and a colleague from the Geological Survey of Canada, scientists of the Energy and Geohazards group at the Woods Hole Coastal and Marine Science Center published a legacy marine heat flow dataset for the high Arctic Ocean. Between 1963 and 1973, the USGS collected 356 heat flow measurements from an ice island as it drifted over the Canada Basin, the Alpha-Mendeleev Ridge, the Nautilus Basin, and nearby areas. These data had never been published and substantially increased the amount of thermal information available for the high Arctic Ocean in locations that, to this day, have never again been surveyed. The USGS led a manuscript for the Journal of Geophysical Research: Solid Earth and publicly released both the heat flow data and an unpublished report written by the originating scientists in the 1970s.

Science buildings and living quarters occupy Fletcher's Ice Island, a floating ice mass in the Arctic Ocean inhabited by U.S. scientists in the mid-20th century. A person standing in the shadow of a building at center left provides perspective for this photograph, taken from a helicopter in 1967.

Environmental Geoscience

Our coasts include a range of environments that provide essential habitat for a variety of plants and animals. From wetlands to estuaries to coastal margins, these ecosystems deliver critical benefits and services to society. Research by the Environmental Geoscience group at the center is focused on key ecosystem functions and drivers of ecosystem change. Knowledge gained through fieldwork is used to model and map the effects of changing environmental conditions caused by sea-level rise and climate change, as well as the effects of expanding coastal infrastructure on critical ecosystems. This work provides data, products, and decision support to Federal, State, and local organizations and individuals tasked with managing these vital ecosystems for future resilience.

Delaware's Diked Wetlands and the Bringing Wetlands to Market Project

The Environmental Geosciences group led a workshop on research and assessment for Delaware's diked wetlands, which served as an initial meeting for the new project related to Delaware's managed coastal wetlands. The group also participated in planning and executing the Blue Carbon In Our Backyard Conference, which wrapped up 9 years of research and end-user engagement within the Bringing Wetlands to Market project. They presented results and served as discussion panelists.

Research Highlighted By the American Association for the Advancement of Science (AAAS)

The AAAS highlighted the Environmental Geosciences group's research on carbon cycling within the Herring River in Wellfleet, Massachusetts, with attention to the potential to reduce methane emissions through restoration of impounded wetlands. The AAAS conducted in-person video interviews and field site videos with participants from the group and developed widely disseminated video and storyboard products.

New Device Developed

Center scientists developed a novel device that couples oxygen regulation with high-frequency ultrasonic flow measurements. The device makes possible nuanced and accurate measurements of submarine groundwater discharge and of fluxes of the nutrients that drive eutrophication of coastal waters.

Requests for Data, Guidance, and Discussion

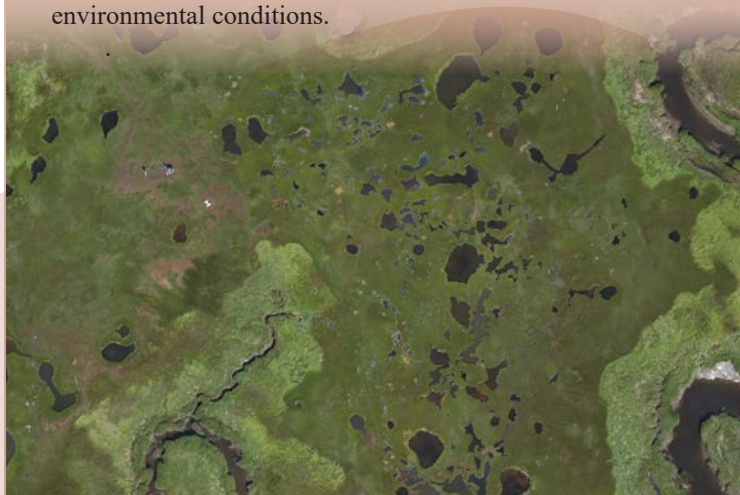
The Environmental Geosciences group provided their expertise to legislators during the development of the Climate Stewardship Act of 2019 and the Blue Carbon for Our Planet Act. Additionally, they provided expertise for governmental agencies and nonprofit organizations in Massachusetts regarding the proposed Herring River restoration, the development of guidance for coastal wetland management to support greenhouse gas emission reduction goals, and the development of a coastal wetland initiative.

Biogeochemical Drivers of Wetland Persistence and Feedbacks on Coastal Hazards

Highlights of 2019

Tidal wetlands provide critical services to society, including protection of infrastructure from coastal hazards and protection of habitat for economically important species. A large fraction of U.S. tidal wetlands, however, has been lost or degraded during recent centuries as a result of human actions, largely related to development and use of coastal lands. Feedback and interactions among natural and human influences have altered the stability and persistence of coastal wetlands. Decisions regarding hydrological management can alter the balance of organic-matter production and retention, and thus management actions can either promote wetland resilience or cause catastrophic loss of elevation, putting coastal infrastructure at increased risk of flooding or storm damage.

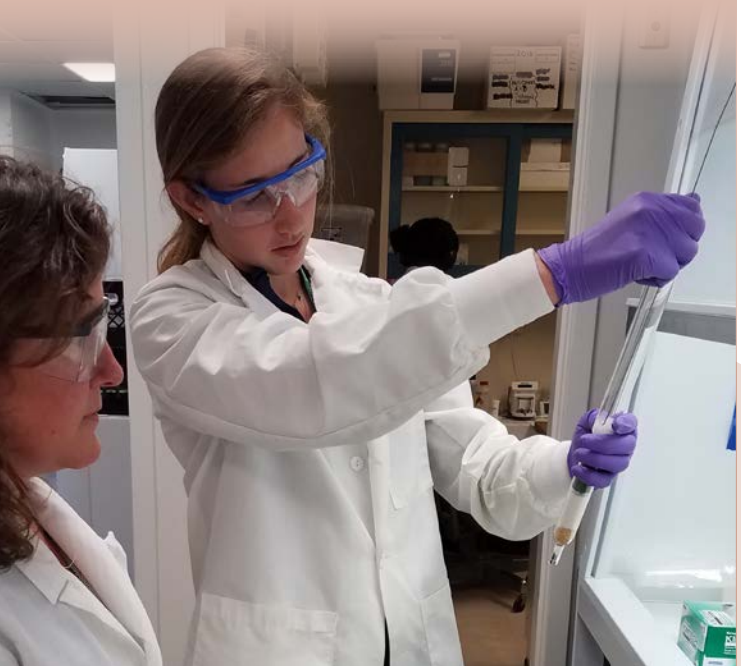
Results from the Biogeochemical Drivers of Wetland Persistence and Feedbacks on Coastal Hazards project provide guidance to Federal (National Park Service, U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers), State, local, and private land owners and managers regarding stability and persistence of coastal wetlands under a range of hydrological management conditions and changing environmental conditions.



Analytical Laboratories

Highlights of 2019

The Core Laboratories Project is a research support service of the center, providing analytical and technical infrastructure and supporting a range of projects associated with coastal biogeochemical processes, coastal groundwater, climate-hydrates, and sedimentology. Support includes technician time, as well as the procurement of general equipment and consumables needed to operate and maintain the analytical spaces and instrumentation. Laboratory methods and techniques are continually refined and developed to meet project objectives and to provide new capabilities.



Geochemistry Lab: Project Support

The Geochemistry Lab provided analyses in support of the Herring River Restoration Project, Great Barnstable Marsh project, and Diked and Restricted Wetlands project. Carbon content of marsh sediments was measured to observe the effects of marsh disturbances (that is, restrictions or nutrient loading) on carbon storage dynamics. Pore water samples from these marshes were measured for dissolved carbon species, as well as methane and sulfide, to improve understanding of carbon cycling dynamics in affected wetlands.

Sediment Lab: Enhanced Facilities/Analytical Capabilities

Lab personnel have been developing technology and methods for measuring density of discrete sediment samples using a gas pycnometer. They have also continued to develop corer-mounted camera systems and a deep-water multicoring system to enhance sample-collection operations at sea.

Sediment Lab: Project Support

The Sediment Lab continues to support the USGS component of the National Oceanographic Partnership Program's DEEP SEARCH project by providing sample analyses for the joint-effort coring program to contribute to a holistic characterization of the "Mud Patch" on the continental shelf off southern New England. Data have been synthesized and are being prepared for release to the Office of Naval Research in a comprehensive report. The lab also prepared and analyzed samples for the USGS Gas Hydrates Project, Stellwagen Bank habitat-mapping program, Marine Geohazards project, coastal Massachusetts mapping project, and the Sediment Transport program.

Woods Hole Partnership Education Program (PEP) and the Quality Management System (QMS) Pilot Implementation Project

The Sediment and Geochemistry Labs provided analytical resources and training to visiting students in the Woods Hole Partnership Education Program (PEP). Both labs are also participating in the QMS Pilot Implementation project by providing a hands-on peer review of the QMS requirements outlined for the Ecosystems, Natural Hazards, and Water Resources mission areas of the USGS.

U.S. Geological Survey staff member Sandra Brosnahan surveys elevation in a cattail marsh in the Herring River estuary, part of the Cape Cod National Seashore in Massachusetts.

Sea-Floor Mapping

The Sea Floor Mapping Group provides support for nearly every project at the center and works closely with the other two Coastal/Marine Hazards and Resources Program (CMHRP) science centers in St. Petersburg, Florida, and Santa Cruz, California. Working across diverse environments, our technical team uses acoustic geophysical techniques to collect detailed information about the sea floor, such as its shape, sediment composition and distribution, and underlying geologic structure and sediment. Sea-floor video, photographs, sediment cores, and samples are also collected to provide a comprehensive foundation for studies of sediment and contaminant transport, landslide and tsunami hazards, gas hydrates and methane and carbon flux, benthic habitat quality, sediment availability, shoreline change, and coastal evolution. Managers, policymakers, and other stakeholders use the map products derived from these studies to inform coastal and ocean resource-management decisions.

Delmarva Regional Study

The project contributed an invited paper to a special issue of Geosciences. The study used collected data to map the geomorphology and sediment texture of about 5,400 square kilometers of the continental shelf. Results are used to identify sediment sources, inform resource management, link sea-floor environments to sediment texture, improve understanding of sea-floor structure, and demonstrate how ocean mapping resources can be useful beyond their original intent to maximize the footprint and scientific impact of a study.

Massachusetts Sea-Floor Mapping Project

The Sea Floor Mapping Group completed a geophysical survey of Cape Cod Bay in August 2019 and a sampling survey in September. The mapping effort covered about 550 square kilometers and collected over 4,700 trackline-kilometers of geophysical data, including 570 kilometers of multichannel seismic data. This was the first-ever comprehensive, high-resolution geophysical survey of Cape Cod Bay and the first systematic bathymetric mapping of the entire bay since the 1930s. Photographs, video, and grab samples were collected at 49 locations. Also, an open-file report and data release were published.

New Jersey Coastal Evolution

The Sea Floor Mapping Group processed and published data from the 2018 mapping of the inner continental shelf in areas adjacent to Little Egg Inlet and the Edwin B. Forsythe National Wildlife Refuge in New Jersey. The high-resolution geophysical data are used to create new maps of the geology and sediment distribution and to develop probabilistic models of the vulnerability of the system to storms, sea-level rise, and human activities. The WHCMSC continues to provide scientific information and consultation on a range of coastal hazards issues in the region.

Lake Superior Stamp Sands

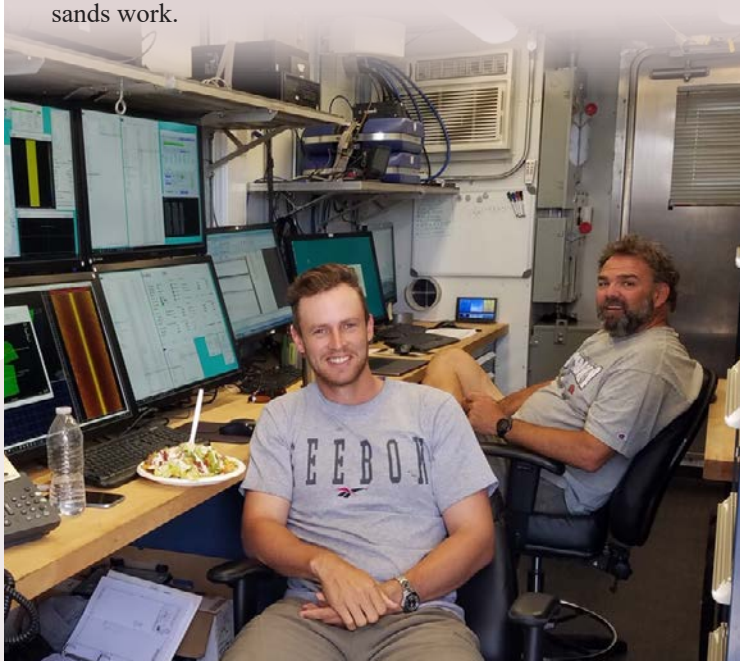
The Sea Floor Mapping Group processed and prepared the high-resolution mapping data collected in 2018 to determine the distribution and thickness of historical mine tailings on the bottom of the lake, for upcoming publication. The WHCMSC continues to build on existing partnerships and is working closely with USGS colleagues at the Great Lakes Science Center to develop new methods to track the migration of mine tailings across the floor of Lake Superior.

Geologic Mapping: Links to Coastal Vulnerability and Hazards

Highlights of 2019

The objectives of the geologic mapping project are to characterize a region's resources and potential coastal hazards through understanding of the region's geologic framework. This work provides baseline datasets and derivative interpretive maps that offer a geospatial basis for scientific research and provide critical information to planners and decision makers who oversee the management of resources and mitigation of hazards in the coastal ocean. Also, geologic mapping project scientists conduct scientific analysis and develop cutting-edge methodologies to examine these data and later communicate their results to the scientific community and the public.

Currently the project consists of several tasks: (1) a Delmarva regional study; (2) completing the Massachusetts geologic mapping project and preparing for the next phase (Massachusetts Integrated Coastal Studies [MICS]); (3) a study offshore the Edwin B. Forsythe National Wildlife Refuge in New Jersey; and (4) Lake Superior stamp sands work.



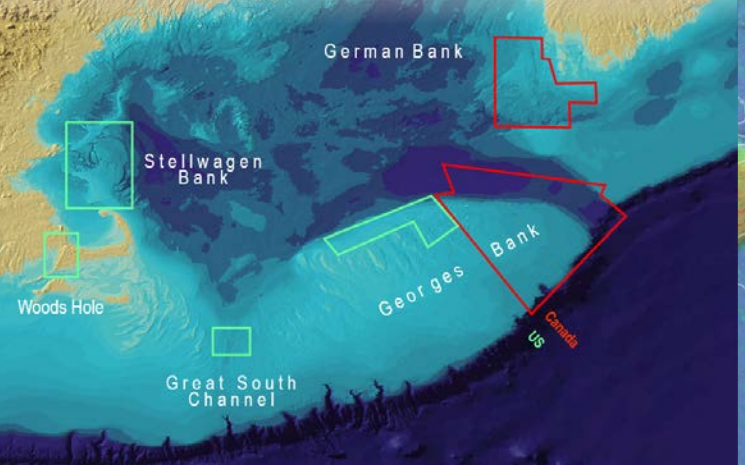
National Sea-Floor Mapping and Habitat Studies

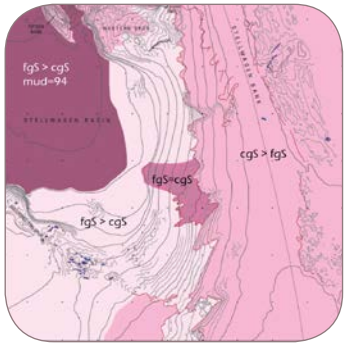
Highlights of 2019

The National Sea-Floor Mapping and Habitat Studies—Atlantic project has two objectives: to produce high-resolution geologic substrate maps of the seabed and to collaborate with NOAA and academic scientists to better understand the role geologic substrates play in determining the distribution and ecology of fishery species.

This project produces a series of online interpretive maps that show the distribution of geologic seabed substrates and processes in the Stellwagen Bank 20 miles offshore from Boston, Massachusetts, at a scale of 1:25,000. The maps serve as the template for a new approach to seabed mapping.

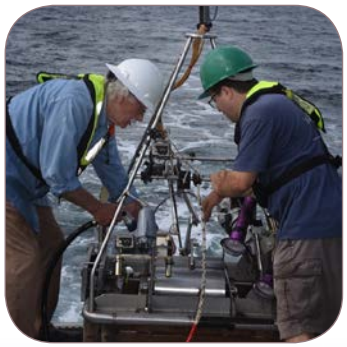
The maps provide a framework for scientific research in the region and for managing fishery resources and infrastructure. Stellwagen Bank is the principal habitat in the eastern Gulf of Maine for sand lance, a schooling fish which is the primary food resource for marine mammals, seabirds, and most of the bank's commercial fishery species, including cod, haddock, and tuna. Geologic substrate mapping will determine the extent of suitable habitat for the species and provide a basis for assessing the size of the sand lance population and identifying its dependence on seasonal changes of water-column properties.





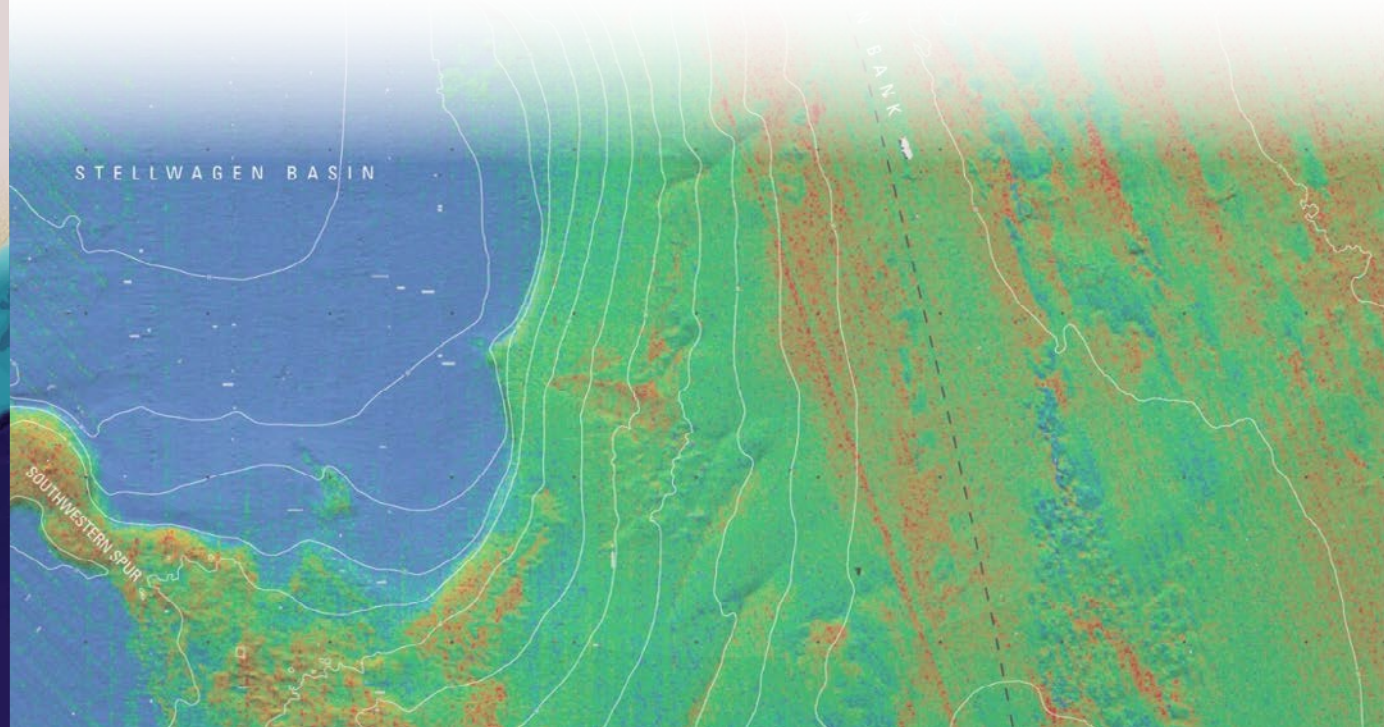
Seabed Mapping

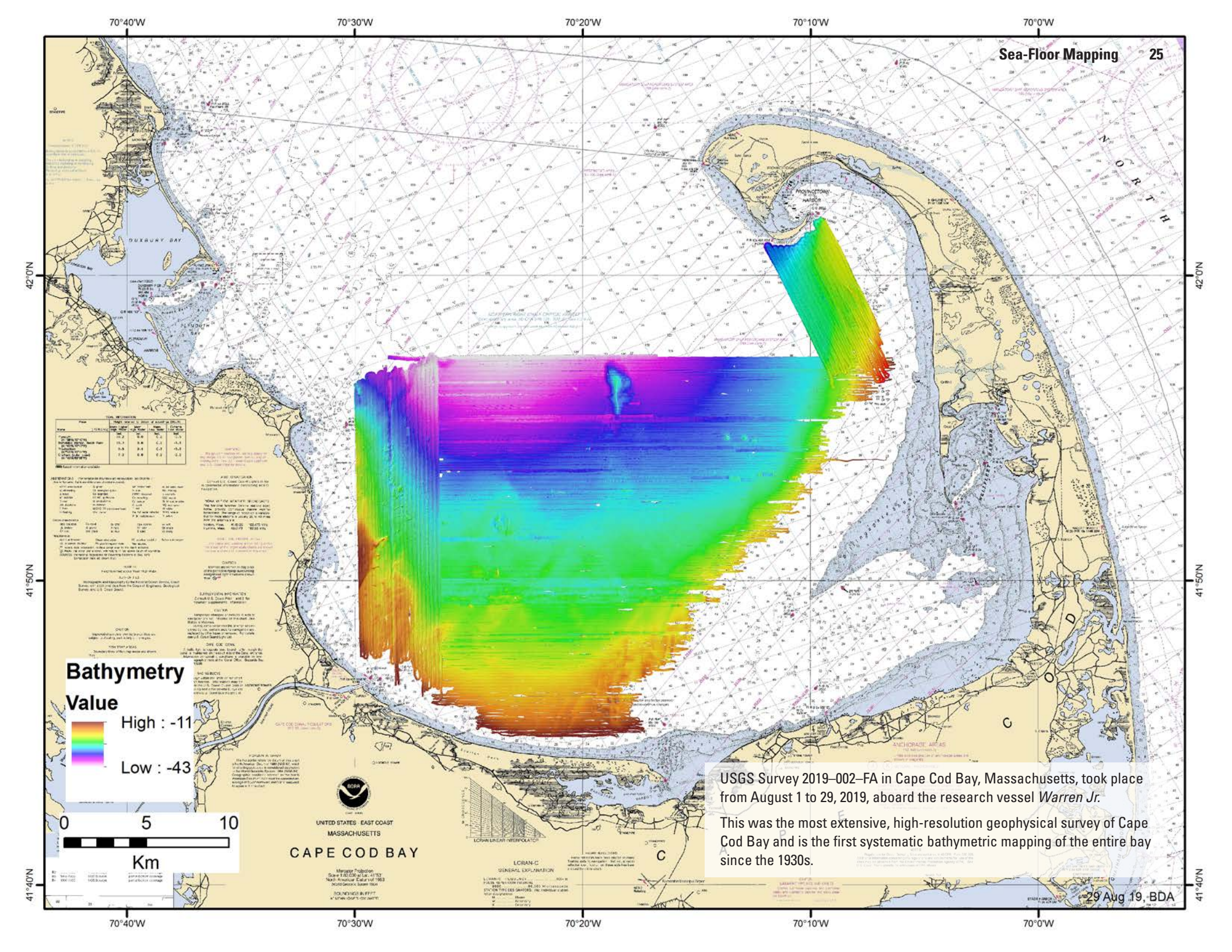
The third map series, quadrangle 2, was compiled and is available for use, and the fourth map series, quadrangle 3, has been compiled and will be available for use in the near future. Each quadrangle is represented by a series of maps showing seven interpretations of its physical characteristics: (1) sun-illuminated seabed topography, (2) seabed ruggedness, (3) backscatter intensity, (4) geologic substrates, (5) sediment mobility, (6) dominance of coarse- or fine-grained sand, and (7) substrate mud content. The methodology developed by this project is described in a paper published in 2019.



Sand Lance Samples and Imagery

In collaboration with scientists of NOAA's Stellwagen Bank National Marine Sanctuary, cruises surveyed the seasonal distribution of sand lance on the bank in May and July 2019 by collecting sand lance, seabed sediment samples and imagery, and water-column properties. Sand lance were found to be concentrated on the southern part of Stellwagen Bank. All cruise data are compiled, archived, and published in digital, online field activity data reports—in 2019, 16 data reports were compiled.





USGS Survey 2019–002–FA in Cape Cod Bay, Massachusetts, took place from August 1 to 29, 2019, aboard the research vessel *Warren Jr.*

This was the most extensive, high-resolution geophysical survey of Cape Cod Bay and is the first systematic bathymetric mapping of the entire bay since the 1930s.

29 Aug 19, BDA

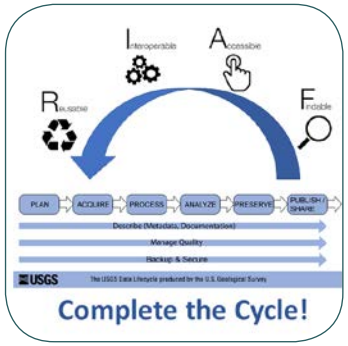
Information Science

Data collected for analysis by USGS scientists are in demand by scientists at other agencies and universities; resource managers and policymakers at Federal, State, and local levels; and the public. The Information Science group at the center is responsible for managing and maintaining the scientific data, ensuring that they are readily available in a variety of formats and online systems. The group also assists stakeholders in understanding their data needs and locating useful products.

Additionally, members of this group produce physical and electronic information products, manage social media accounts, highlight research efforts by writing articles and social media posts, organize and participate in outreach activities, and maintain the center's web presence.

Community for Data Integration Workshop

Center staff worked with colleagues from across the USGS to organize, lead, and participate in the 2019 CDI Workshop in Boulder, Colorado. Specifically, the group organized and led five sessions, gave four 60-second "lightning" talks and six full-length talks, and presented nine posters. These in-person meetings, held every 2 years, are a crucial step for focusing people, funding, and Bureau-wide efforts across the USGS on data-integration tools and services, data information management, and computational methods.



FAIR Data

USGS staff started a project, funded by the CDI, to develop a FAIR (findable, accessible, interoperable, reusable) roadmap for the USGS. FAIR is an international set of principles to promote multiple use of data. Using the FAIR principles would improve the value of USGS data and tools by increasing their ease-of-use in downstream applications. Creating FAIR data would also promote USGS integrated science—readily available and compatible resources make projects easier because they can be integrated efficiently. Roadmap elements will include (1) the present status of USGS application of FAIR principles, (2) USGS goals for achieving compliance with the principles, (3) obstacles and opportunities on the path to these goals, and (4) the process for managing USGS progress (and unexpected obstacles and opportunities). The project team began by inviting a cross-section of USGS staff to a workshop to identify concerns and opportunities. The roadmap document and workshop report are still in development.

Community for Data Integration

Highlights of 2019

The Community for Data Integration (CDI) is a group in which members can expand their expertise in all aspects of working with scientific data. The CDI focuses on opportunities to share information across disciplines and organizational structures, invigorating cross-boundary communication. The CDI is funded and led by the USGS, but it is open to all who generate, use, and communicate about scientific information.

The CDI supports community collaboration that forms around common interests, helps address challenges, and identifies solutions that enable data-integration efforts. The CDI annually holds a competitive proposal process to award seed funds for projects that focus on data integration for interdisciplinary research, innovative data management, and advanced technology.

Data Management and Preservation

Highlights of 2019

As a permanent resource, the data USGS collects and uses are vital. Good data management enables sharing and reuse of data, and it reduces data redundancy and costs in terms of time and money. Well-documented data that are easily accessed may be integrated readily into a new project or dataset.

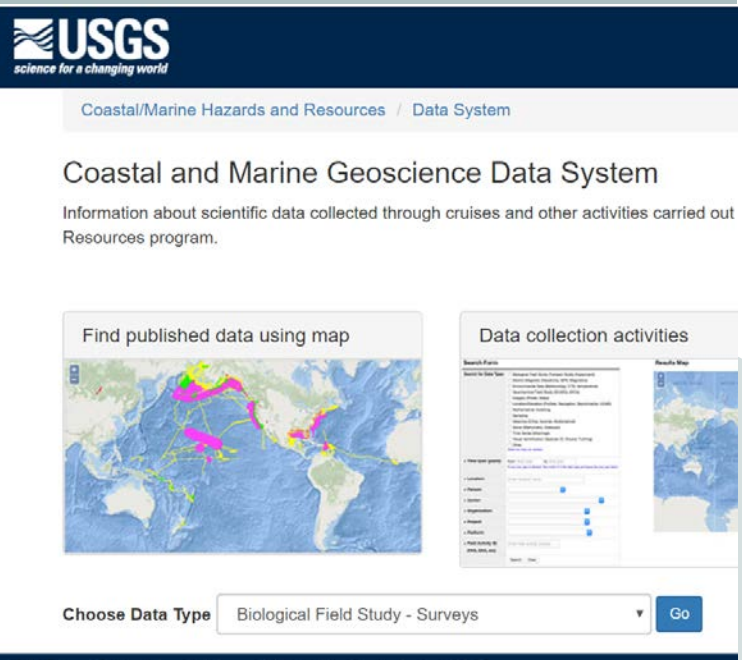
Best practices of data management attempt to define, document, and use consistent standards and procedures. The goal is to provide the information resources needed for efficient program operations. Staff at the WHCMSC and the other Coastal/Marine Hazards and Resources Program (CMHRP) centers collaborate to provide consistency within data management activities.

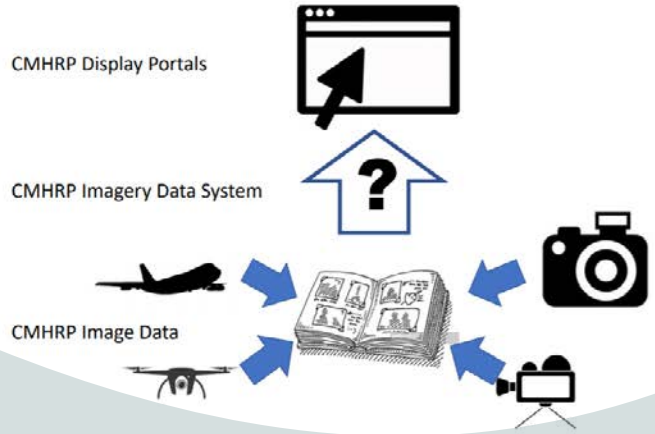
CMHRP Imagery Data System

The imagery data system is being developed to preserve and organize the CMHRP's large volume of digital imagery data. The system is being designed to enable discovery and access and to be a flexible data source, adaptable to future innovations in display portals as new presentation technologies become available. It will support research and communication on topics including coastal response to storms, sea-level rise, changing wave climate, geologic resources (such as sand deposits and seabed minerals), and identifying and managing protective features (such as marshes, dunes, beaches, and reefs). The project team held a workshop as the first step in developing the imagery data system. The workshop brought together staff from across the program to consider the requirements that the system would need to meet, prioritize those requirements, and identify existing USGS infrastructure that can be leveraged. The imagery data system was one of the coastal change hazard enhanced funding projects awarded in 2019.

USGS Coastal and Marine Geoscience Data System

The Coastal and Marine Geoscience Data System, which contains information about scientific data collected through cruises and other activities carried out by the USGS CMHRP program, received USGS trusted digital repository (TDR) certification. The USGS TDR certification process adheres to the international CoreTrustSeal certification approach, which includes 16 criteria for evaluating trustworthy data management, infrastructure, and stewardship. TDRs establish and maintain reliable and secure digital infrastructure for managing, archiving, and providing open access to stored assets, and they apply sustainable data management practices that follow the USGS Science Data Lifecycle Model to ensure that data are properly curated beyond the projects in which they were generated.





U.S. Geological Survey scientist Seth Ackerman shows students at the Children's School of Science how the Sea Floor Mapping Group collects data to create maps of the sea floor. This outreach activity brought these aspiring summertime scientists dockside in Woods Hole, Massachusetts, as the research vessel *Warren Jr.* was loaded with survey gear for the August 2019 Cape Cod Bay mapping survey.

2019 Publications

Journal Articles (34)

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Demopoulos, A.W.J., McClain-Counts, J.P., Bourque, J.R., Prouty, N.G., Smith, B.J., Brooke, S., Ross, S.W., and Ruppel, C.D., 2019, Examination of *Bathymodiolus childressi* nutritional sources, isotopic niches, and food-web linkages at two seeps in the US Atlantic margin using stable isotope analysis and mixing models: Deep-Sea Research Part 1, v. 148, p. 53–66, https://doi.org/10.1016/j.dsr.2019.04.002.

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Donatelli, C., Ganju, N.K., Kalra, T.S., Fagherazzi, S., and Leonardi, N., 2019, Changes in hydrodynamics and wave energy as a result of seagrass decline along the shoreline of a microtidal back-barrier estuary: Advances in Water Resources, v. 128, p. 183–192, https://doi.org/10.1016/j.advwatres.2019.04.017.

Gonneea, M.E., Maio, C.V., Kroeger, K.D., Hawkes, A.D., Mora, J., Sullivan, R., Madsen, S., Buzard, R.M., Cahill, N., and Donnelly, J.P., 2019, Salt marsh ecosystem restructuring enhances elevation resilience and carbon storage during accelerating sea-level rise. Estuarine, Coastal and Shelf Science, v. 217, p. 56–68, https://doi.org/10.1016/j.ecss.2018.11.003.

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Publishing support provided by the Pembroke Publishing Service Center
Editing by Jonas Casey-Williams
Design and layout by Susan L. Meacham

ISSN 1067-084X (print)
ISSN 2330-5703 (online)
https://doi.org/10.3133/cir1467

ISBN 978-1-4113-4373-3

Ernst—Woods Hole Coastal and Marine Science Center—2019 Annual Report—Circular 1467