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Woods Hole Coastal and Marine Science Center

2021 Annual Report

Circular 1495

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

Cover. Front—In June 2021, Jin-Si Over and Jen Cramer from the Woods Hole Coastal and Marine Science Center trained to become drone pilots for the U.S. Department of the Interior in Rifle, Colorado.

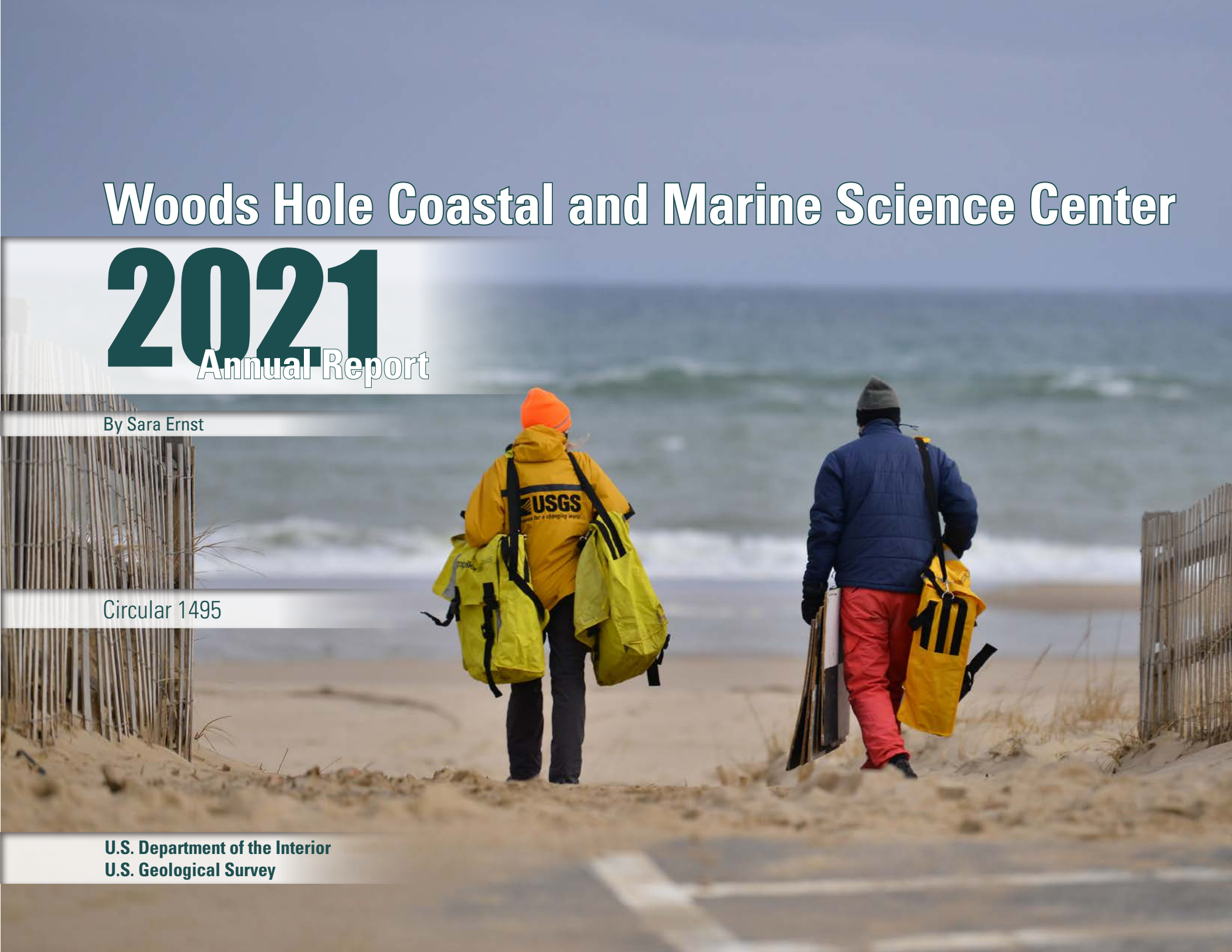
Back—Physical Scientist Jen O'Keefe Suttles approaches an eddy flux tower at Great Barnstable Marsh on a cold winter day in January 2021. This eddy flux tower measures the exchange of carbon between the atmosphere and the wetland, which is minimal during the winter, when plants are not photosynthesizing. The eddy flux tower allows us to make rapid and continuous measurements of greenhouse gas fluxes, which help inform marsh management and can lead to decisions that more effectively promote marsh resilience.

Title page. In February of 2021, scientists from the U.S. Geological Survey Woods Hole Coastal and Marine Science Center and Woods Hole Oceanographic Institution conducted nearshore bathymetric surveys on Cape Cod National Seashore, Massachusetts. Bathymetry is the measurement of the depth of water. By collecting bathymetric data, mapping the morphology, or shape, of the shoreface and beach, and collecting data about the waves, currents, wind, and the movement of sediment, scientists can learn more about the dynamic processes shaping our coasts. The knowledge gained from these nearshore studies can improve computer-derived simulations of coastal flooding and shoreline change to help communities identify potential hazards in areas vulnerable to storms, chronic erosion, and sea-level rise.

Woods Hole Coastal and Marine Science Center

2021 Annual Report

By Sara Ernst



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U.S. Geological Survey, Reston, Virginia: 2022

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Contents

Scientists from the U.S. Geological Survey Woods Hole Coastal and Marine Science Center using a helium-powered kite-balloon at Head of the Meadow Beach and Marconi Beach in the Cape Cod National Seashore, Massachusetts. A digital camera is attached to the helium-powered kite-balloon. Photographs of the beach surface are collected as scientists walk the kite along the beach on planned tracks. The photographs are then used to create a digital elevation model of the beach surface by using structure-from-motion photogrammetry.

Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
square kilometer (km^2)	0.3861	square mile (mi^2)
square kilometer (km2)	247.1	acre

Abbreviations

AIM	Aerial Imaging and Mapping [group]
CMHRP	Coastal and Marine Hazards and Resources Program
COAWST	Coupled Ocean-Atmosphere-Wave-Sediment Transport [modeling system]
DUNEX	During Nearshore Event Experiment
ECS	extended continental shelf
lidar	light detection and ranging
NAGT	National Association of Geoscience Teachers
NCA	National Climate Assessment
NOAA	National Oceanic and Atmospheric Administration
PEP	Partnership Education Program
RV	research vessel
SEABOSS	Seabed Observation and Sampling System
SFMG	Sea Floor Mapping Group
SSF	Summer Student Fellowship
STEP–UP	Secondary Transition to Employment Program-USGS Partnership
TWL&CC	Total Water Level and Coastal Change [forecast viewer]
UAS	unmanned aerial system
URGE	Unlearning Racism in Geosciences
USGS	U.S. Geological Survey
UVVR	unvegetated-vegetated marsh ratio
WHCMSC	Woods Hole Coastal and Marine Science Center
WHOI	Woods Hole Oceanographic Institution

Sunrise over Cape Cod Bay, Massachusetts.

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 and 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.

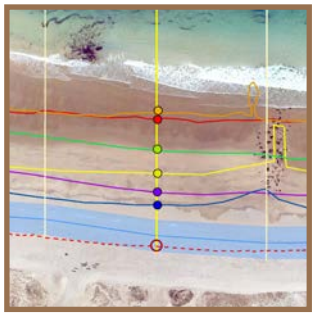
Coastal and Shelf Geology

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.

The 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), to characterize the coast above and below the water. Detailed maps of the coastal landscape that are created from this research are used to improve forecasts of coastal change and identify hazards in areas vulnerable to storms, chronic erosion, and sea-level rise.

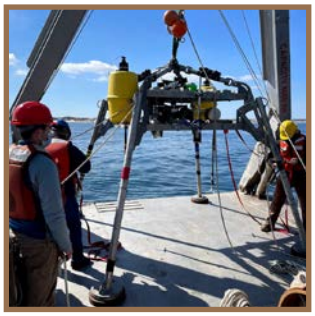
Processing and Interpreting Data From Cape Cod Bay

In August 2019, the project successfully completed geologic sea-floor and subsurface mapping within Cape Cod Bay. The mapping effort covered about 550 square kilometers, collected over 4,700 trackline-kilometers of geophysical data, including 570 kilometers of multichannel seismic data, and collected sea-floor photographs, videos, and grab samples to validate the geophysics. In 2021, progress was made in processing and interpreting the terabytes of data collected. Preliminary interpretations correspond to modeling and shoreline change observations. The data release is forthcoming.



Comparing Shoreline Forecasting Models

Several sites of varying morphological diversity throughout Massachusetts, including Cape Cod Bay, were selected to provide in-depth analysis and validation of two predictive methods used to forecast future shoreline positions. The two shoreline forecasting models are being compared and tested against measured shoreline positions at the study sites. Rates of change were computed by using a shoreline position extracted from light detection and ranging (lidar) elevation data collected in 2018, and the shoreline data and resulting rates were published in two data releases.



Measuring Data Offshore Sandy Neck Beach

Instrumentation was installed offshore of Sandy Neck Beach in western Cape Cod Bay to measure surface waves, water levels, currents, temperature, salinity, suspended-sediment concentrations, and bottom stresses. The data are intended to be used to calculate cross-shore sediment fluxes, to be compared with numerical model results for calibration, to help determine processes of sediment movement in the bay, and to improve understanding of the effects of coastal change during storms. Numerical simulations can show how the combination of waves and currents transport sediment in the bay. Nearshore sediment fluxes can be analyzed and compared to computed shoreline change data to ascertain the processes driving coastal change. This investigation can help coastal zone managers have a better idea of how, where, and why sediment is transported in the western Cape Cod Bay system.

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

Highlights of 2021

The USGS, in partnership with the Commonwealth of Massachusetts, initiated the Massachusetts Integrated Coastal Studies project in 2018 to further research the processes that control sediment movement in Cape Cod Bay. Through this multitiered research initiative, USGS 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, 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 2021

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 levels, 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 the 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 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.

Index of Coastal Vulnerability to Sea-Level Rise

The project continues to revise the nearly 20-year-old Coastal Vulnerability Index, which assesses the susceptibility of the Nation's coast to sea-level rise. The project received funding from the Great Lakes Restoration Initiative to expand this work to the Great Lakes region in an interagency effort.

"Coastal Effects" Chapter of Fifth National Climate Assessment

A project scientist was invited to serve as a coauthor on the national "Coastal Effects" chapter of the Fifth National Climate Assessment (NCA). The NCA aims to inform natural resource and utility managers, public health officials, emergency planners, financial risk managers, and other stakeholders as they consider climate-related risks in their decision making.

Publications

Project staff published two papers. The first explores the role of land cover diversity and composition in landscape response to sea-level rise across the northeastern United States. The second demonstrates regional differences in habitat selection patterns along the U.S. Atlantic coast. Companion papers, which have been submitted for journal review, document a linked Bayesian belief network methodology to forecast future suitable habitat for *Charadrius melodus* (piping plover) at Fire Island National Seashore under several possible sea-level-rise scenarios.

Collaborative Coastal Change Hazards Efforts

The project secured additional National Park Service funding to explore the effect of coastal change on *Amaranthus pumilus* (seabeach amaranth, a threatened annual plant species) at Assateague Island National Seashore off the coast of Maryland and Virginia. The project continued collaborating with other Federal partners to develop an assessment of vulnerability based on nearshore geomorphology for the Great Lakes, which would provide coastal science expertise in the development of a framework for evaluating the vulnerability of coastal bluffs to erosion. Project staff also collaborated with other USGS staff in drafting a white paper and developing a cross-center, cross-project effort to investigate long-term coastal change in response to future total water levels.

Completed Two Drone Data-Collection Events

The AIM group completed an accuracy assessment of the Ricoh GRII, a large-sensor compact camera, on the Woods Hole Oceanographic Institution (WHOI) Quissett campus in Woods Hole, Massachusetts. They also traveled to Geneseo, New York, to fly drones over agricultural fields to look for drainage tiles as part of an Ohio-Kentucky-Indiana Water Science Center project.

New Drone Pilots

Two new USGS staff members joined the AIM group after completing the U.S. Department of the Interior's A–450 Small Unmanned Aircraft System Basic Remote Pilot Course, offered by the USGS National Uncrewed Systems Office, in Colorado in May 2021.

Leadership and Operational Capabilities

The AIM group continued to lead the USGS North Atlantic and Appalachian Region UAS Capability Team and was designated a hub of the National Uncrewed Systems Office. The group also moved forward with securing a testing facility on the Joint Base Cape Cod, Massachusetts, in conjunction with the National Oceanic and Atmospheric Administration (NOAA) Northeast Fisheries Science Center UAS capability team.

Data Release Published

A data release was published based on aerial imagery collected during UAS operations in Massachusetts and Maine between March and September 2018. The images collected support science and data needs in wetland research, topographic mapping, and land cover detection at the center.

Aerial Imaging and Mapping

Highlights of 2021

Unmanned aerial system (UAS) technology provides a rapid and low-cost solution for mapping coastal environments and assessing short- and long-term changes. The interdisciplinary nature of the data collected and the breadth of its applications make UAS technology applicable to multiple scientific investigations. The center's Aerial Imaging and Mapping (AIM) group is developing the capability to provide operational remote-sensing support to coastal, estuarine, and lacustrine research using UAS technology. Group responsibilities include data acquisition, processing, and publication of UAS-collected data products and working collaboratively with the U.S. Department of Interior/USGS UAS operators to explore new UAS technology, sensor development, and new techniques of data acquisition. This capability supports the Remote Sensing Coastal Change project, the Coastal Change Hazards programmatic focus, the national UAS project office, and other Bureau-wide remote-sensing projects. High-resolution imagery and elevation maps created from the remote-sensing data are used in change-detection studies (for example, to detect coastal erosion), hurricane damage assessments, and natural disaster responses, and the imagery and maps support situational awareness for emergencies. Collecting data remotely by UAS technology is an efficient and often safer alternative to collecting data by hand.

Sea-Floor Mapping

Highlights of 2021

The Sea Floor Mapping Group (SFMG) maintains a center-wide capability that supports many of the center's projects and works closely with the other two Coastal and Marine Hazards and Resources Program (CMHRP) science centers in St. Petersburg, Florida, and Santa Cruz, California. The SFMG is a team of geologists, engineers, electronics technicians, physical scientists, and geographers with expertise in the acquisition, processing, and analysis of marine, coastal, and lacustrine geophysical and geologic data. Working across diverse environments, the technical team uses acoustic 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 validate the acoustics and 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.

Outer Cape Cod Mapping

In collaboration with the National Park Service Cape Cod National Seashore, the SFMG completed field operations to provide sea-floor and geologic maps of the nearshore of outer Cape Cod, Massachusetts, an area of white shark habitat. The Cape Cod National Seashore is concerned with visitor safety and interactions between the public and white sharks in this dynamic shallow-water environment. This mapping will support additional research with collaborators from the Center of Coastal Studies in Provincetown, the Massachusetts Division of Marine Fisheries, and the Atlantic White Shark Conservancy.

Outreach

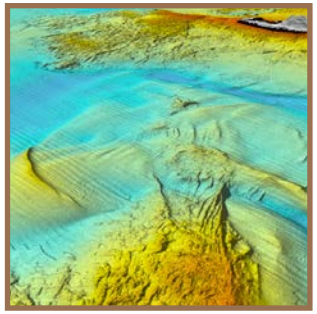
The center hosted 25 children and culture keepers from the Mashpee Wampanoag Tribe's Preserving Our Homelands summer camp for a field trip focused on introducing the students to Cape Cod geology and hydrology through an informational talk and guided exploration of distinctive glacial landforms in the Beebe Woods conservation area in Falmouth, Massachusetts.

Research and System Development

(1) The center worked with a boat design service company to design a new research vessel (RV) to replace the RV *Rafael* and build on its capabilities while increasing efficiency, ergonomics, and safety. (2) Design of the new Seabed Observation and Sampling System (SEABOSS) 2.0 was completed in 2021, and fabrication will continue in 2022. The system has been installed on an existing SEABOSS frame and is awaiting field testing before the final steps are taken towards completion. (3) In collaboration with the Pacific Coastal and Marine Science Center, the SFMG assembled a new hydrophone acquisition system for measuring sparker seismic source signatures and determining source amplitude decay versus offset during field tests. (4) Woods Hole Coastal and Marine Science Center (WHCMSC) scientists and technical staff continued designing a multicorer system to operate in settings from shelf to deepwater to collect multiple high-quality, minimally disturbed sediment cores in one deployment. The multicorer will also house additional sensors and a precision acoustic positioning system. The design includes extensive software and hardware development to integrate all subsea systems, allowing communication, data transfer, and power support.

Delmarva Regional Study

The Sea Floor Mapping Group continued to work collaboratively with the Bureau of Ocean Energy Management, State agencies, universities, and other regional stakeholders to deepen understanding of the coasts and continental shelves and to help partners incorporate many recent USGS data releases and publications into their own studies.

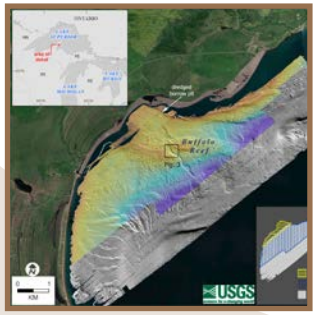


Massachusetts Sea-Floor Mapping Project

The Commonwealth of Massachusetts used the 2,940 square kilometers of sea-floor mapping data acquired by the Sea Floor Mapping Group between the New Hampshire and Rhode Island borders to review the Massachusetts Ocean Management Plan, and the National Oceanic and Atmospheric Administration (NOAA) used the data to update the Nation's navigation charts. The offshore wind and support industries are using the data and interpretive products in the siting of energy transmission and support infrastructure.

New Jersey Coastal Evolution

The Sea Floor Mapping Group published data from the 2019 mapping of the inner continental shelf in areas adjacent to Little Egg Inlet and the Edwin B. Forsythe National Wildlife Refuge. The high-resolution geophysical data will be 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 on management timescales (annual to decadal). The group also continued to coordinate with U.S. Fish and Wildlife Service, the U.S. Army Corps of Engineers, the New Jersey Department of Environmental Protection, and Stockton University by providing scientific information and consultation on a wide range of coastal hazards issues in the region.



Lake Superior Stamp Sands

In a joint effort with the USGS Great Lakes Science Center, the WHCMSC mapped an area of Lake Superior that has been—and continues to be—greatly affected by a legacy of copper mining in the region. Geophysical, photographic, and sampling data were collected to support efforts to determine changes in substrate since a baseline survey in 2005 and the previous USGS survey in 2018 and to develop new methods of assessing the concentration of stamp sands (waste materials from the mines) in bottom sediments, which can help Federal, State, local, and Tribal partners decide on the best mitigation measures.

Geologic Mapping: Links to Coastal Vulnerability and Hazards

Highlights of 2021

The objective of the geologic mapping project is 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. Geologic mapping project scientists also 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) The Delmarva regional study; (2) completing the Massachusetts Sea-Floor Mapping project and preparing for the next phase (Massachusetts Integrated Coastal Studies); (3) a study offshore the Edwin B. Forsythe National Wildlife Refuge in New Jersey; and (4) Lake Superior stamp sands work.

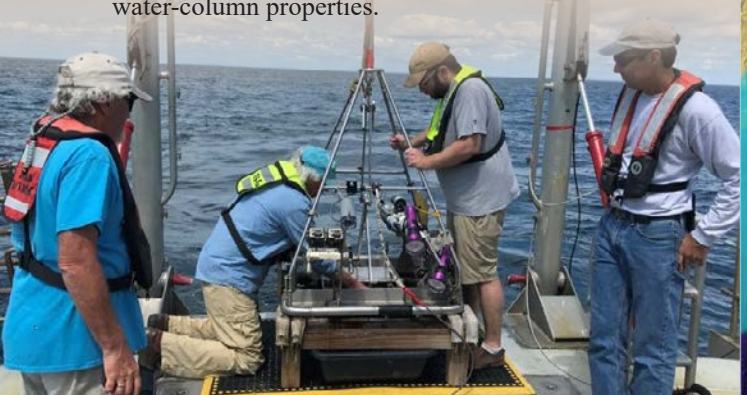
National Sea-Floor Mapping and Habitat Studies

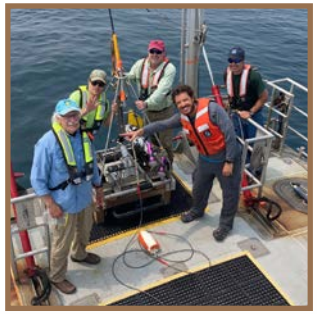
Highlights of 2021

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 NOAA Stellwagen Bank National Marine Sanctuary 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.

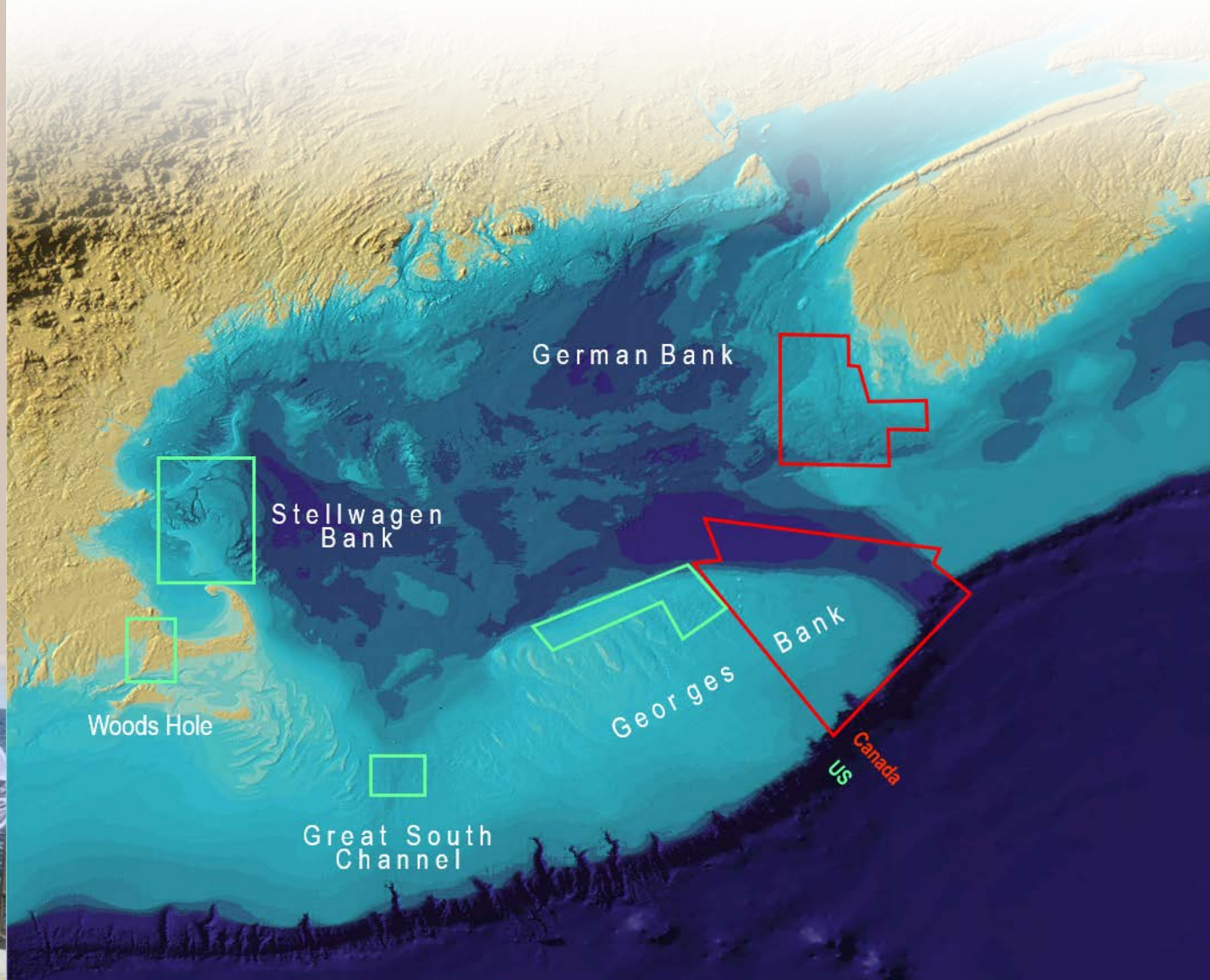
The maps provide a framework for scientific research in the region and for managing fishery resources and infrastructure. Stellwagen Bank is the principal habitat in the eastern Gulf of Maine for *Ammodytes dubius* (sand lance), a schooling fish that is the primary food resource for marine mammals, seabirds, and most of the bank's commercial fishery species—including *Gadus morhua* (cod), *Melanogrammus aeglefinus* (haddock), and *Thunnus thynnus* (bluefin tuna). Geologic substrate mapping can 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.





Sampling Survey Conducted in Stellwagen Bank National Marine Sanctuary

WHCMSC scientists and technical staff conducted a Seabed Observation and Sampling System (SEABOSS) survey in collaboration with NOAA's Stellwagen Bank National Marine Sanctuary to acquire sea-floor samples, video, and photographs within the Stellwagen Bank National Marine Sanctuary. This is part of a long-term sampling effort to map the seasonal distribution of sand lance within the sanctuary. During this field season, WHCMSC scientist Page Valentine collected his 5,000th sample!



U.S. Geological Survey Research Geologist, Page Valentine (left), collects his 5000th sample within the National Oceanic and Atmospheric Administration Stellwagen Bank National Marine Sanctuary alongside Seth Ackerman (middle) and Brian Andrews (right). Page has been mapping the geologic substrates of Stellwagen Bank and studying the ecology of fish and invertebrate species that inhabit the bank's sandy substrates off Boston, Massachusetts, for many decades.

Gas Hydrates and Geohazards

Gas hydrates and geohazards research at the center is focused on three themes: gas hydrates (naturally occurring icelike 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 a natural 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 effects 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.

USGS scientists also work with other Federal agencies to explore and define the limits of the U.S. ECS. Further understanding of the resource potential of the vast areas of the U.S. ECS in the Arctic, Atlantic, and Pacific Oceans can improve natural resource management and promote economic prosperity.

Novel Geochemical Instrumentation

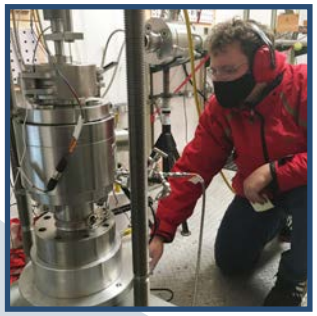
Instrumentation developed by project scientists is described in a paper published in Environmental Science & Technology. This patent-pending instrumentation makes it possible to obtain stable carbon isotopic measurements on methane at sea or in a field setting in real time. Normally these complex analyses can require weeks or months and are only carried out after the expedition. Stable carbon isotopic data provide information about whether the source of methane gas is microbial activity or processes that heat up organic matter in the sediments.

Deep Ocean Methane Bubble Dynamics

Scientists from the California Institute of Technology and WHCMSC published a paper in the Journal of Geophysical Research. This paper discusses how the formation of hydrate shells around methane bubbles emitted from the sea floor may allow methane to reach shallower depths as the bubbles ascend through the water column. This process could have important implications for the effect of sea-floor methane bubble release on ocean chemistry and possibly on atmospheric methane concentrations.

Marine Sediments Recording Past Methane Dynamics

A collaborative group of scientists published a paper in Geochemistry, Geophysics, and Geosystems. The paper presents a new approach to identifying intervals of altered sediment that mark past positions of the sulfate-methane transition, which reflects the vigor of past methane seepage. This analysis can be used to constrain gas hydrate degradation or methane seep events.



High-Stress Triaxial Permeameter for Testing Hydrate-Bearing Pressure Cores

Pressure coring, a type of coring that preserves gas hydrates in recovered sediments by maintaining the material at its original pressure, is now the most used technique to study the reservoir properties of hydrate-bearing geologic formations. The center runs a stand-alone pressure core analysis laboratory and has been developing a range of new pressure cells and modified tools to handle pressure cores from the Alaskan North Slope and the northern Gulf of Mexico. One of the newest tools is a high-stress triaxial permeameter, which measures how fluid flows through hydrate-bearing sediments subjected to stresses, such as sediments hundreds of meters below the sea floor or in tundra surface.

Gas Hydrates Project

Highlights of 2021

Naturally occurring gas hydrate is an icelike combination of water and (usually) methane gas that forms in sediments below the sea floor and in areas of continuous permafrost when pressure and temperature conditions are appropriate. Gas hydrate traps a large quantity of the methane in the global system. The USGS Gas Hydrates Project includes scientists at the USGS Woods Hole Coastal and Marine Science Center (WHCMSC); the USGS Central Energy Resources Science Center in Denver, Colorado; the USGS Earthquake Science Center at Moffett Field, California; and the Pacific Coastal and Marine Science Center in Santa Cruz, California. In evaluating the resource potential of gas hydrate and the environmental effects of methane released from the sea floor, USGS Gas Hydrates Project scientists address questions related to the production and fate of methane.

Law of the Sea—Outer Limits of the U.S. Continental Margins

Highlights of 2021

The USGS Law of the Sea project is part of a Federal interagency effort to identify the regions beyond 200 nautical miles from shore where the United States can manage resources found on and below the sea floor. These areas, called the extended continental shelf (ECS), are determined by scientific and legal criteria set forth in the United Nations Convention on the Law of the Sea. U.S. interests are served by knowing the outer limits of its ECS and where these limits may overlap with neighboring countries. The main goal of the interagency project is to develop a submission package that describes the outer limits of the U.S. ECS.

This effort is led by the U.S. Department of State. The USGS contributes knowledge of geology and sediment thickness, and the National Oceanic and Atmospheric Administration (NOAA) contributes knowledge of the morphology and bathymetry of the U.S. continental margins.

Fiscal year 2021 marks the start of a 2-year transition, in which the project downsizes to an outreach phase and then a maintenance phase and changes from a stand-alone project to a task within the Global Minerals Project. The maintenance phase ends when the treaty body reviewing the ECS makes recommendations on the U.S. outer limits. During both phases, the USGS is responsible for supporting the U.S. Department of State when it meets with foreign countries about the U.S. submission, publishing research from data acquired by the project, documenting and archiving data used by the USGS to identify the outer limits, and staying abreast of (1) new geoscience research within our proposed ECS and (2) recommendations by the treaty body that reviews ECS outer limits, either of which might alter the U.S. approach to its outer limits.

Finalized Outer-Limit Points for the Atlantic Ocean and the Northern Mariana Islands

The project finalized the outer-limit points for the remaining two core regions: the Atlantic Ocean and the Northern Mariana Islands. Documentation of both regions underwent external review during a virtual workshop held in June 2021. The suggestions for improving the text, figures, and documentation have been incorporated into the two final submission packages. Considerable effort has been spent on identifying errors and uncertainty associated with each of the outer-limit points in the Atlantic.

Preliminary Executive Summary

A preliminary executive summary document that describes and lists the outer-limit points of each of the seven core regions was developed and approved by the USGS, NOAA, and the U.S. Departments of State and Interior. Final approval and publication of the document is forthcoming.

Paper Published

A paper on the tectonics of rifting along the Atlantic margin was published in early 2021. Compiling metadata for seismic and geologic data from all regions is ongoing.

2021 North Atlantic Stepping Stones: New England and Corner Rise Seamounts Expedition

From June 20 through July 29, 2021, NOAA Ocean Exploration, in partnership with the USGS, the U.S. Fish and Wildlife Service, and other organizations and universities, conducted a telepresence-enabled ocean exploration to collect baseline information about unknown and poorly understood deepwater areas off the eastern U.S. coast and high seas. USGS scientists from the Woods Hole and Pacific Coastal and Marine Science Centers served as the geology science coleads for the expedition. From land, they worked with multidisciplinary ship- and shore-based scientists to develop remotely operated vehicle dive plans, lead and narrate "Live Dive" events for a worldwide audience, and coordinate science outcomes. The team mapped about 40 seamounts, 20 of which had little to no preexisting data since many of them had yet to be explored until this expedition. The remotely operated vehicle and mapping data collected during this expedition can help fill gaps in collective understanding of the North Atlantic seamount chains and provide scientists and managers with a better understanding of the diversity and distribution of deepwater habitats in this region, allowing for informed resource management decisions.

Seismic Experiment in the Cascadia Subduction Zone

In collaboration with the Woods Hole Oceanographic Institution (WHOI) and the U.S. Ocean Bottom Seismic Instrument Center, WHCMSC scientists led part of a multiship seismic experiment to image the megathrust and submarine forearc of the Cascadia Subduction Zone from offshore Oregon to offshore Vancouver Island, British Columbia. The research effort was part of a larger collaborative effort involving many academic institutions and the USGS Earthquake Hazards Program. The project included three main components: (1) the research vessel (RV) *Marcus G. Langseth* towed a sound source and hydrophone streamer to record sound reflected from deep below the sea floor; (2) ocean-bottom seismographs were deployed at 120 sites offshore to record the RV *Langseth*'s sound source; and (3) hundreds more seismometers were deployed onshore, also recording the RV *Langseth*. Together, these data are being used to create structural and physical models of the Cascadia Subduction Zone. The ocean-bottom seismograph data provide key measurements of how near-surface sediments and rocks respond to strong shaking during large megathrust earthquakes.

Marine Geohazards Sources and Probability

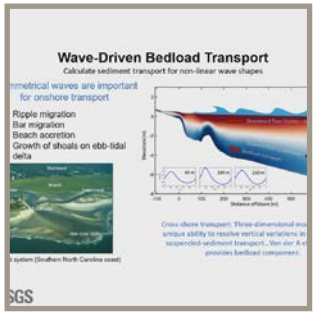
Highlights of 2021

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.

Coastal and Estuarine Dynamics

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. Scientists at the center use 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 use in making knowledge-based decisions.



COAWST Training Workshop

The center hosted a virtual COAWST modeling system training for users from around the world in May 2021. Each of the 4 days consisted of lectures to describe a model component, a tutorial to demonstrate development of a coupled application, and an opportunity for user support in breakout rooms. These trainings enhance the user community, as well as the modeling system itself.

Modeling Storms and Morphological Change

Modelers in the Coastal and Estuarine Dynamics group completed the Increasing the Fidelity of Morphological Storm Impact Predictions project, funded by the Office of Naval Research. Simulations of storm-induced breaches at Fire Island, New York, and Matanzas, Florida, were completed by using newly developed model components for infragravity waves and transport by shoaling waves. The comparison of simulations with detailed before and after observations showed that the models improved when land cover and back-barrier water levels were represented correctly. USGS modelers and colleagues published a review paper assessing the state of coastal morphological models.

Cross-Shore and Inlets Processes

Highlights of 2021

Understanding the exchange of water, sediment, and biological particles between the inner shelf and back-barrier estuaries is critical 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.

Project tasks include (1) leading the development of the Coupled Ocean-Atmosphere-Wave-Sediment Transport (COAWST) modeling system; (2) identifying regional locations where shoreline change is dominated by cross-shore sediment processes; (3) investigating the processes that create new inlets (breaching) and the dynamics that control inlet stability and closure; (4) investigating controls on the exchange of flows and material transport through inlets, specifically the interaction of waves with the vertical structure of the currents, on the sediment transport into the bay, ebb shoal effects, and sediment bypassing; and (5) communicating project findings through publications and outreach and by providing access to data and model results via the Coastal Change Hazards Portal.

Total Water Level and Coastal Change

Highlights of 2021

The Next Generation Total Water Level and Coastal Change Forecast project is a collaborative effort between all three USGS Coastal and Marine Hazards and Resources Program (CMHRP) Coastal and Marine Science Centers (Woods Hole, Massachusetts; St. Petersburg, Florida; and Santa Cruz, California) to validate, improve, and expand forecasts and uncertainty estimates from the USGS Total Water Level and Coastal Change (TWL&CC) Forecast Viewer. The TWL&CC Forecast Viewer is a web-based platform that includes a multiday forecast based on model simulations of tides, storm surge, offshore wave conditions, and local coastline characteristics. The model is deployed on approximately 4,700 kilometers of open, sandy coastline on the Atlantic and gulf coasts, with ongoing expansion to the Pacific coast and nonsandy environments. It is the only national-scale, real-time model for coastal change. Scientists from each of the three centers aim to assess forecast skill by comparing the forecasts to observations, improve forecasts by incorporating new data and theory into the model, develop spatially varying and ensemble versions of the model that include uncertainty estimates, and improve quantification of coastal hazards. Model improvements are incorporated into the TWL&CC forecasts developed jointly by the USGS and the National Oceanic and Atmospheric Administration (NOAA) and into the TWL&CC Forecast Viewer.

Second CoastCam Installed at Marconi Beach

The Coastal and Estuarine Dynamics group installed a second CoastCam and a meteorological station at Marconi Beach in Cape Cod National Seashore, Wellfleet, Massachusetts. The cameras are part of the USGS Remote Sensing Coastal Change project to study the beach and nearshore environment shared by beachgoers, shorebirds, seals, and sharks.

Conducted Topographic and Bathymetric Surveys

The group conducted successful winter surveys of topography (elevation of landforms above sea level) with a helium-powered kite-balloon and bathymetry (depths of landforms below sea level) with an autonomous boat at Marconi Beach in Wellfleet, Massachusetts (year 1), and Head of the Meadow Beach in North Truro, Massachusetts (year 2).

Modeled Total Water Level in Cape Cod and Massachusetts Bay

The total water level elevation in Cape Cod and Massachusetts Bay was modeled by using COAWST. The modeled water levels were compared with the products of TWL&CC forecasts, and an evaluation of the sources of uncertainty is underway. Sediment transport convergence patterns during specific events were also simulated to understand the evolution of coastal dynamic processes.

Outer Banks Overflight Efforts Continue

Data collection in the Outer Banks of North Carolina and publication of related imagery and products continued as part of rapid response to storms and recovery monitoring after Hurricane Florence (2018) and Dorian (2019). Two flights were conducted in 2021, making it a total of 12 overflights so far. Data from these flights were used to develop workflows for image processing and machine-learning methods for image classification and automatic processing of digital elevation models. This work was supported by the Additional Supplemental Appropriations for the Disaster Relief Act of 2019 (Public Law 116–120, 113 Stat. 871).

Open-File Report Published

An important open-file report was published, providing an authoritative standard workflow for photogrammetric processing of imagery using structure-from-motion photogrammetry (a technique used to measure coastal change along shorelines). This is another product supported by the Additional Supplemental Appropriations for Disaster Relief Act of 2019 (Public Law 116–120, 113 Stat. 871).

DUNEX Pea Island Experiment

The USGS, including scientists from the Woods Hole Coastal and Marine Science Center, participated in the multiagency DUNEX (During Nearshore Event Experiment) project in the Outer Banks of North Carolina, September through October 2021. The project team chose Pea Island National Wildlife Refuge as a study location to investigate and characterize the magnitude and timing of changes to coastal morphology (such as dunes and shorelines), bathymetry, and land cover after a storm.

Remote Sensing Coastal Change

Highlights of 2021

The Remote Sensing Coastal Change project began in 2017 as a multicenter collaboration intended to advance USGS Coastal and Marine Hazards and Resources Program applications of remote-sensing techniques to coastal change problems. The work at the center has focused on rapid response to coastal events, advancing the capability to process imagery by using structure-from-motion photogrammetry (a technique that is used to create high-resolution digital models of surface elevation), developing USGS Cloud Hosting Solutions, and investigating the integration of machine learning into workflows.

Estuarine Processes, Hazards, and Ecosystems

Highlights of 2021

Estuaries are dynamic environments where complex interactions between the atmosphere, ocean, watershed, ecosystems, and human infrastructure take place. They serve as valuable ecological habitat and provide numerous ecosystem services and recreational opportunities. However, they are modified by physical processes such as storms and sea-level rise, and effects of human activity such as nutrient loading threaten ecosystem function within estuaries. The Estuarine Processes, Hazards, and Ecosystems project collects basic observational data on these physical processes and anthropogenic effects, develops numerical models of these data, and applies models to understand the past, present, and future states of estuaries. Collaborative endeavors are led from the Woods Hole Coastal and Marine Science Center and include participation from other USGS offices, other Federal and State agencies, and academic institutions.

Developed Method to Assess Salt Marsh Vulnerability Nationwide

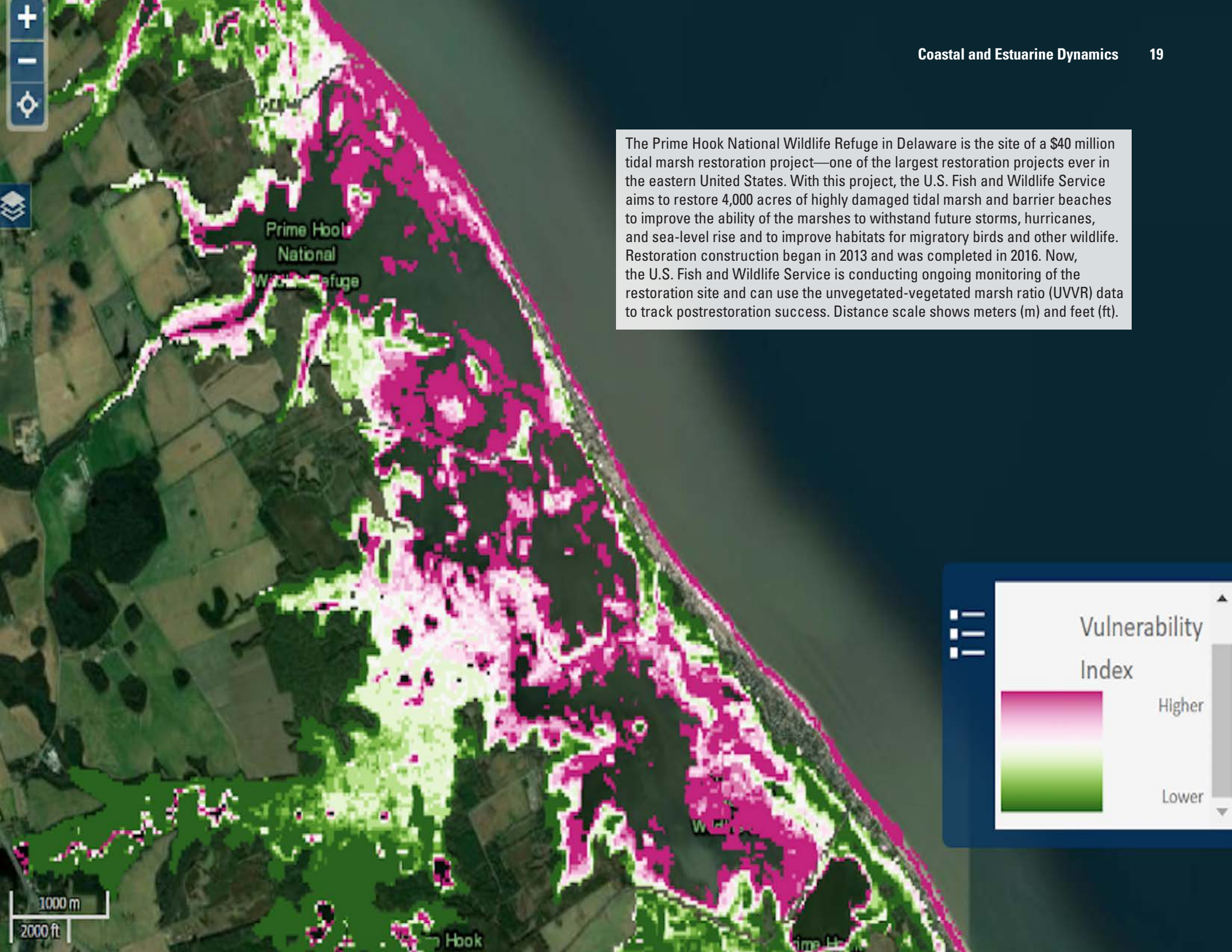
The estuaries group has shown that marsh resilience can be evaluated by using a metric called the unvegetated-vegetated marsh ratio (UVVR), defined as the ratio of unvegetated area to vegetated area across an entire marsh system. In 2021, the group developed a method to assess salt marsh vulnerability nationwide with this metric using Landsat 8 satellite imagery at a 30-meter resolution. The estuaries group mapped the coastal wetlands of the contiguous United States with Landsat 8 imagery from 2014 to 2018. This map enables State managers and the U.S. Department of the Interior to get broad assessments of the most vulnerable marshes without requiring site-specific studies. These nationwide UVVR data are displayed in an interactive map in the USGS Coastal Change Hazards Portal and in the team's "U.S. Coastal Wetland Synthesis" geonarrative. The data are available for download in the USGS ScienceBase data repository.

COAWST Model Incorporated Wetlands and Seagrass

Recent observation studies have addressed the role of submerged aquatic vegetation meadows in modifying current velocity, sedimentation, and nutrient cycling. To represent these dynamic processes in a numerical model, the presence of submerged aquatic vegetation and its effect on hydrodynamics (currents and waves) and sediment dynamics was incorporated into the open-source Coupled Ocean-Atmosphere-Wave-Sediment Transport (COAWST) model.

Detailed UVVR Mapping of the Chesapeake Bay and Massachusetts

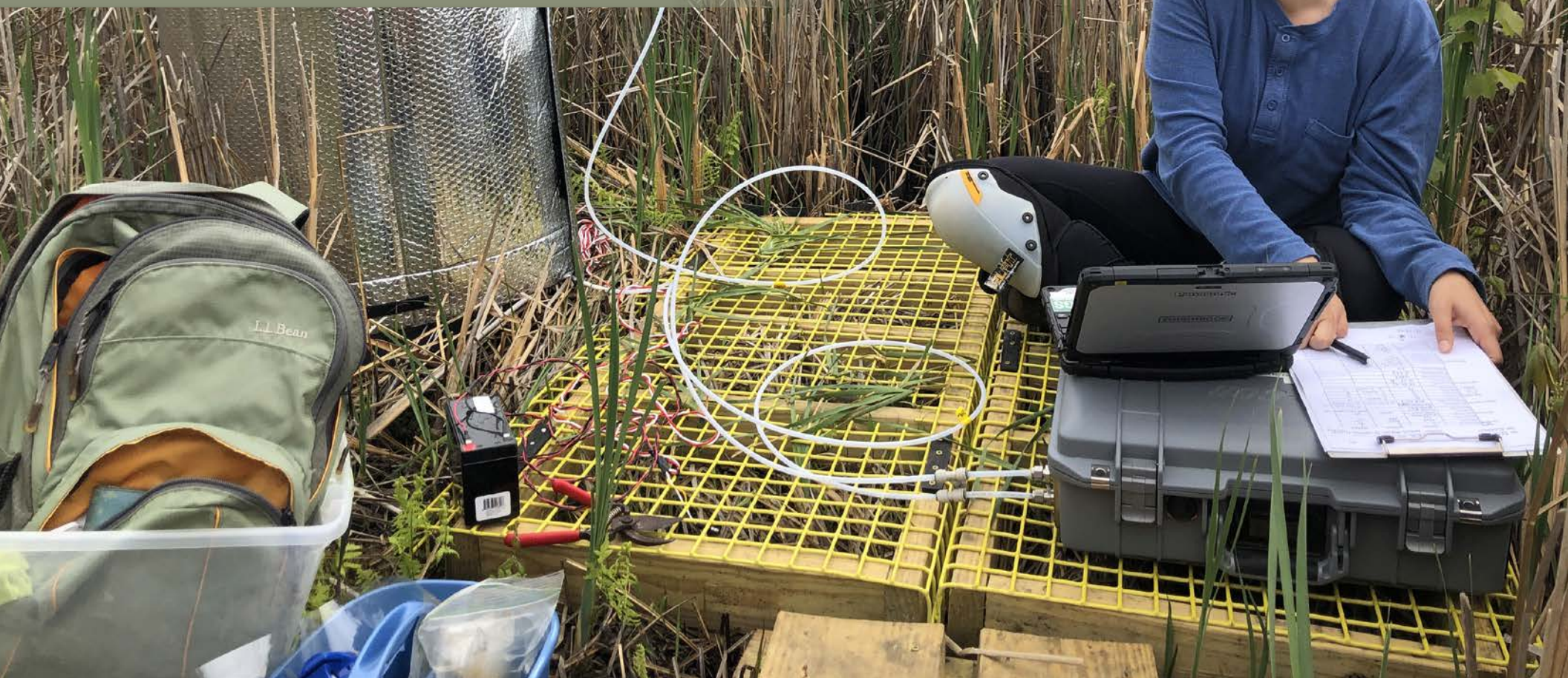
The estuaries group completed wetland synthesis products for the Blackwater salt marsh complex in the Chesapeake Bay, Maryland, and in Massachusetts. Metrics for resiliency, including UVVR, marsh elevation, and tidal range, were calculated for smaller units delineated from digital elevation models, providing the spatial variability of physical factors that influence wetland health. These data were added to the "U.S. Coastal Wetland Synthesis" geonarrative under the "Synthesis Sites" tab, and all related data releases were updated.



The Prime Hook National Wildlife Refuge in Delaware is the site of a $40 million tidal marsh restoration project—one of the largest restoration projects ever in the eastern United States. With this project, the U.S. Fish and Wildlife Service aims to restore 4,000 acres of highly damaged tidal marsh and barrier beaches to improve the ability of the marshes to withstand future storms, hurricanes, and sea-level rise and to improve habitats for migratory birds and other wildlife. Restoration construction began in 2013 and was completed in 2016. Now, the U.S. Fish and Wildlife Service is conducting ongoing monitoring of the restoration site and can use the unvegetated-vegetated marsh ratio (UVVR) data to track postrestoration success. Distance scale shows meters (m) and feet (ft).

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 Geosciences group at the center is focused on key ecosystem functions and drivers of ecosystem change. Knowledge gained through fieldwork and sample analysis 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. The Core Laboratories Project at the center provides the analytical and technical infrastructure necessary to accomplish project objectives.



Herring River Blue Carbon and Carbon Market Assessment

The Environmental Geosciences team executed three to four dozen field efforts to install and monitor two eddy covariance sensor arrays at the Herring River, Wellfleet and Truro, Massachusetts, and in model sites elsewhere on Cape Cod, Massachusetts. These sites are registered within the national AmeriFlux network and are the only two eddy covariance sites within a diked and impounded former salt marsh. Significant progress was made on modeling carbon cycle response to sea-level rise in the 21st century, under restored and nonrestored scenarios. Models, supported by field research, include hydrology, vegetation change, soil carbon and elevation change, and methane emissions.

National Scale Maps and Ditched Hydrology

National-scale maps (at 5-meter resolution) of tide elevations relative to wetland soil surfaces, as well as the status of hydrological management (including diked and drained, diked and impounded, and tidally restricted by road or railroad), are under development. This is the first time these conditions have been mapped at scale, and the products can support blue carbon assessments. Discoveries were made that show the magnitude and driving mechanisms for diminished soil accretion in salt marshes and rates of carbon accumulation as a result of nationally widespread ditching of wetlands.

Automated Change Detection in Coastal Wetlands

In collaboration with researchers at the University of Connecticut, the U.S. Fish and Wildlife Service, and USGS Climate Adaptation Science Centers, the Environmental Geosciences group developed an approach for automated change detection in coastal wetlands, based on dense time-series analysis of the full record of Landsat images. The approach is to be first implemented along the U.S. east coast from Virginia to Maine. A published manuscript detailing the approach is forthcoming.

First Report to Congress

The Environmental Geosciences team represented the USGS in drafting the first report to Congress of the Department of Energy Interagency Task Force on Carbon Capture and Storage technologies.

Sea-Level Rise and Carbon Cycle Processes in Managed Coastal Wetlands

Highlights of 2021

Our coasts are a patchwork of degraded and healthy, resilient and nonresilient salt marshes and mangroves, and persistence of these critical habitats in the 21st century depends on relatively near-term decisions regarding (1) transportation infrastructure and (2) our response to sea-level-rise hazards. Degraded wetlands behind roads and dikes can become a source of greenhouse gases, rather than a sink. The USGS Woods Hole Coastal and Marine Science Center and cooperating organizations are working with Federal land management agencies, including the U.S. Fish and Wildlife Service and the National Park Service, as well State government agencies in Massachusetts and in other States, to inform decision making regarding the role of coastal wetlands in climate change mitigation and adaptation, to assess opportunities for soil carbon sequestration and methane emissions reduction, and to integrate coastal ecosystems within programs for reducing greenhouse gas emissions.

Members of the Environmental Geosciences group participate in the Carbon Dioxide Removal Subteam within the U.S. Global Change Research Program, the Carbon Cycle Interagency Working Group, and the U.S. Fish and Wildlife Service's Nature-Based Solutions Working Group, tasked with implementation of the Department of the Interior Climate Change Action Plan.

Analytical Laboratories

Highlights of 2021

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.

The Geochemistry Lab provides high-quality geochemical data through processing and analyses of groundwater, surface water, sediment, and gas samples for a wide array of dissolved nutrients, carbon, age (determined by radiochemical dating), and stable isotopes. The Sediment Lab supports a range of projects at the center by providing data derived from grain size, mineralogy, suspended sediment, and sedimentary character analyses.

Geochemistry Lab: Project Support

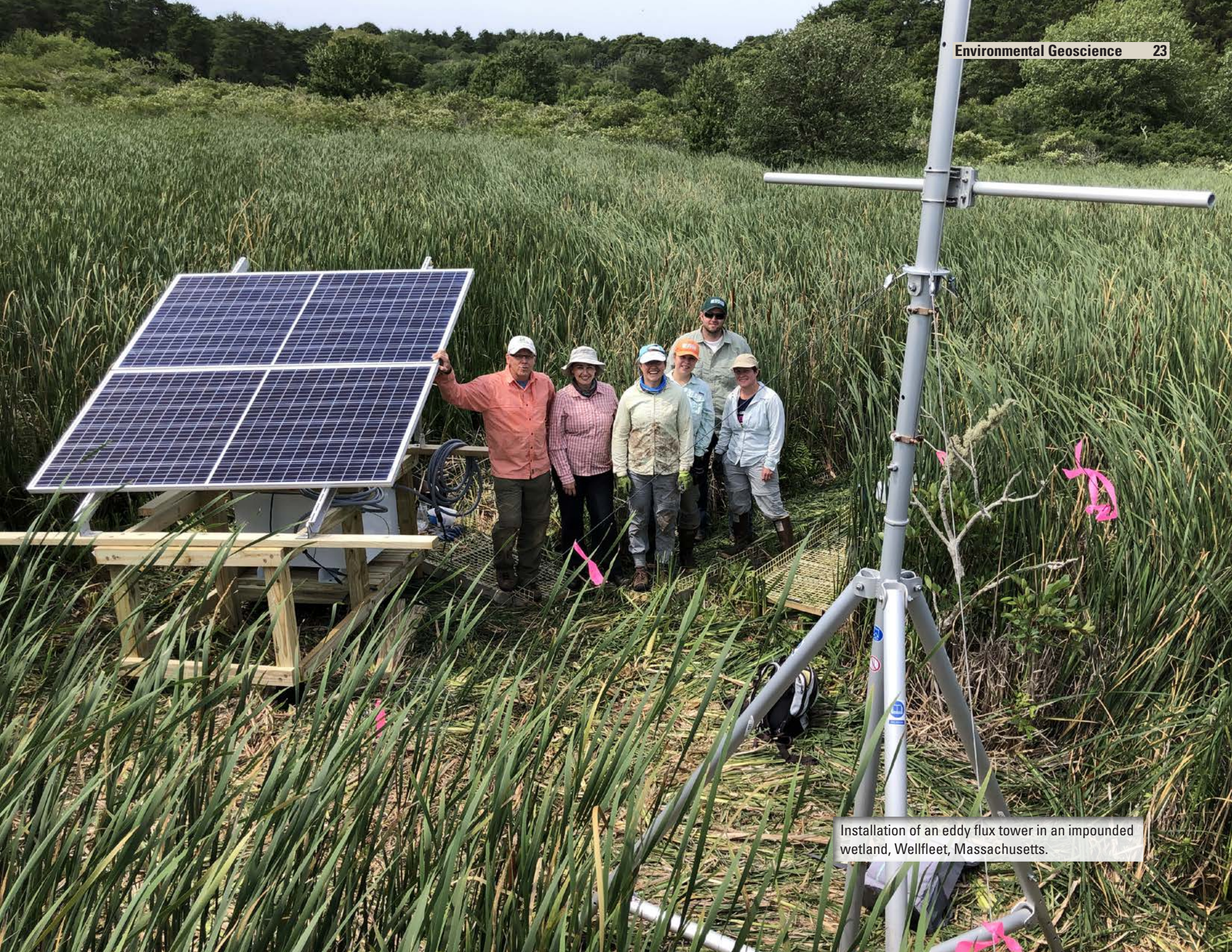
The Geochemistry Lab continued to provide analyses in support of the Herring River Restoration project, the Great Barnstable Marsh project, and the Diked and Restricted Wetlands project. Carbon content of marsh sediments was measured to observe the effects of historical management actions on carbon storage dynamics and sustainability. 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: Project Support

The Sediment Lab provided analytical data to the following projects, as well as to collaborators in the USGS Water Resources Mission Area: Massachusetts Integrated Coastal Studies, Great Lakes Coastal Hazards and Resources, and National Oceanic and Atmospheric Administration (NOAA)/USGS/Bureau of Ocean Energy Management DEEP SEARCH projects. The laboratory also contributed to the completion and publication of a journal article and comprehensive USGS data release providing sedimentological and geophysical results collected in support of the New England Mud Patch project. Additionally, the laboratory continued to expand and improve its facilities and analytical capabilities with the acquisition of a new Bruker CTX 800C X-ray fluorescence unit and new UIC CM5017 coulometer.

Quality Management System Phase 1 Implementation Plan

The Sediment and Geochemistry Labs voluntarily participated in the initial wave of the USGS Quality Management System phase 1 implementation plan. The labs worked with the Quality Management System manager for the USGS Natural Hazards Mission Area to integrate quality-assurance practices that align with the USGS Quality Management System into laboratory science and activities.



Installation of an eddy flux tower in an impounded wetland, Wellfleet, Massachusetts.

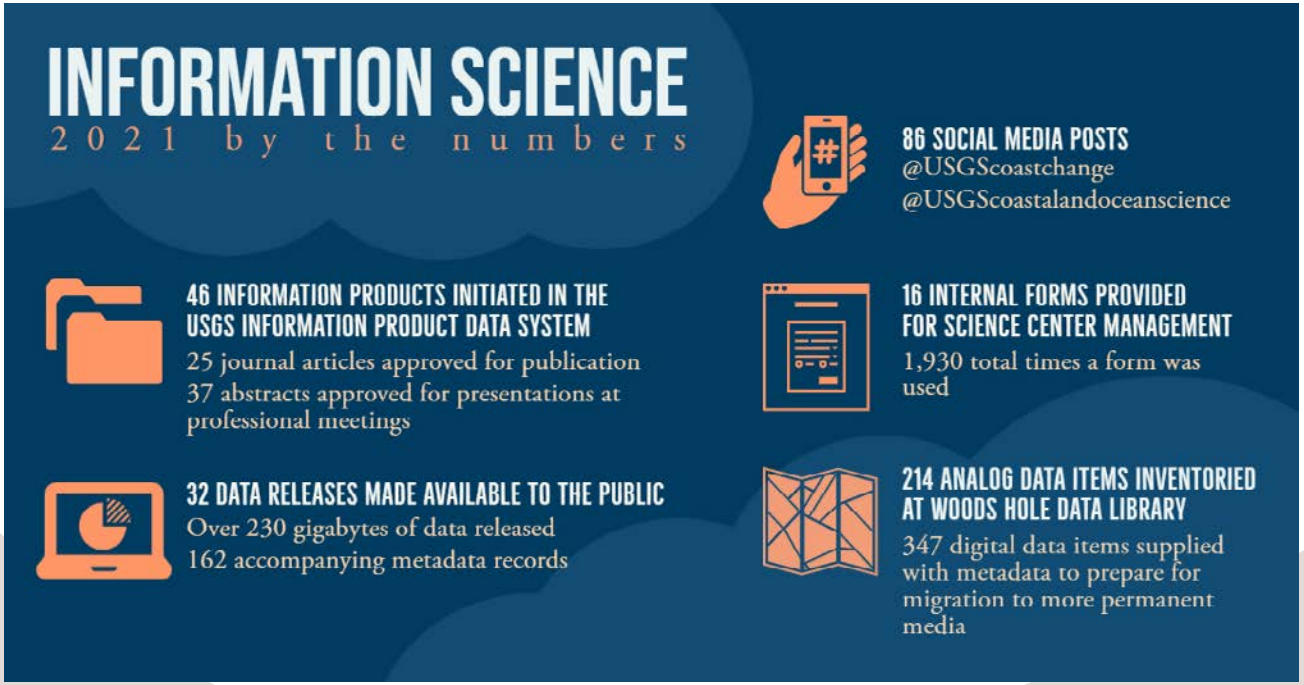
Information Science

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.

Improvements to Compass, the CMHRP Internal Data System

Compass maintains records and provides reports about USGS Coastal and Marine Hazards and Resources Program field activities, enables discovery of unpublished data via geographic or thematic searches, links publications to field activities, and allows users to develop and share data management plans for their project. Since 2020, the Compass team has continued toward unifying the Compass code base and decreasing use of previous versions to create a more streamlined system. In 2021, a new portal was introduced to the three CMHRP Coastal and Marine Science Centers. In addition to providing convenient ways for adding information about new research activities, the new Compass portal provides easy access to online sites that enable scientists to find data by geographic region, date, or the type of measurement and to explore the research reports and other publications that resulted from the data.

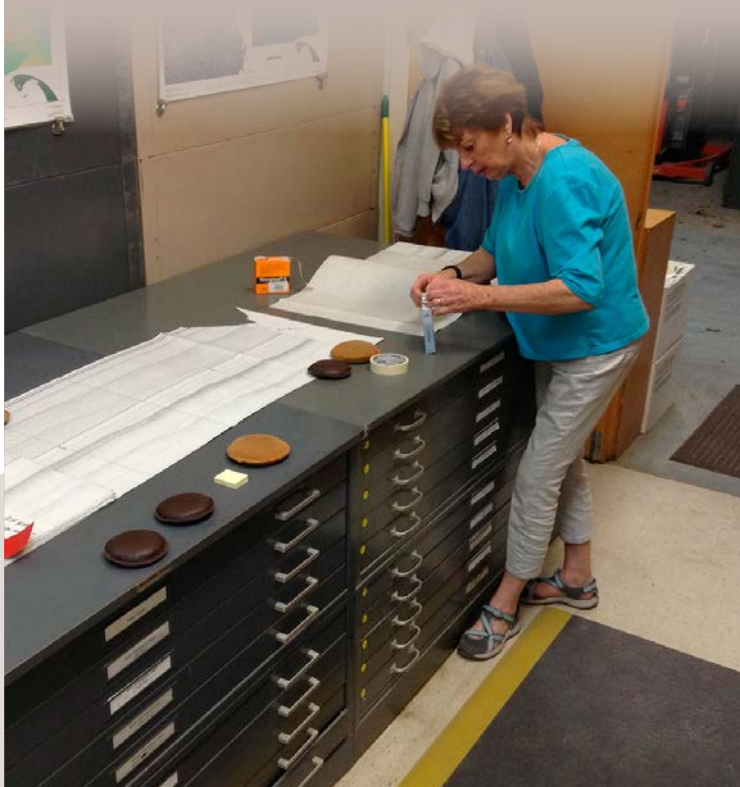


Data Management and Preservation

Highlights of 2021

As a permanent resource, the data the 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 Woods Hole Coastal and Marine Science Center collaborate with the other Coastal and Marine Hazards and Resources Program (CMHRP) centers to provide consistency within data management activities.



Diversity, Equity, and Inclusion in Woods Hole

At the Woods Hole Coastal and Marine Science Center (WHCMSC), we are committed to improving diverse representation and equity in science for the long haul. We invest time and resources to identify and address blind spots and build an inclusive culture, and we assess and correct our course as needed. Addressing systemic racism, microaggressions, and attitudes of apathy, skepticism, and resignation within the science community toward such efforts is crucial to the future vitality and viability of the USGS as an earth science agency serving the Nation.

The WHCMSC has long promoted diversity, equity, and inclusion in its many forms. In 2004, the six Woods Hole science institutions formed the Woods Hole Diversity Initiative and committed to attracting and retaining a more diverse workforce. The Woods Hole Diversity Initiative in turn established the Woods Hole Diversity Advisory Committee, made up of representatives from each organization, to recommend how the institutions can make the village of Woods Hole more diverse and inclusive. The committee plans events for Black History Month, Native American Heritage Month, and Juneteenth, hosts community discussions, supports Gays, Lesbians, and Others in Woods Hole events, and much more.

In 2009, the Woods Hole Diversity Initiative started the Partnership Education Program (PEP)—a 10-week residential program primarily for college juniors and seniors from groups underrepresented in the marine and coastal sciences who want to gain practical, scientific experience. Additionally, our center started a partnership program with the City College of New York and the University of Puerto Rico to place student interns at USGS centers across the country. The center also participates in the Secondary Transition to Employment Program-USGS Partnership (STEP–UP). Through this partnership, the USGS collaborates with school districts and other educational institutions to provide training experiences to students with disabilities.

In 2020, several WHCMSC staff members volunteered to represent the USGS Peer Support Worker program. This program was created to promote awareness and provide outreach and education on topics and policies related to antiharassment, discrimination, biases, and scientific integrity.

In 2021, the “Woods Hole Pod” and five other pods across the USGS joined over 300 pods globally for Unlearning Racism in Geosciences (URGE), a community-wide journal-reading and policy-design curriculum to help geoscientists unlearn racism and improve belonging, accessibility, justice, equity, diversity, and inclusion in geoscience. URGE brought over 3,500 participants together, providing peer-reviewed articles and live author interviews, to build awareness of systemic inequalities in their workplaces and develop antiracist systems in their institutions.

2021 Diversity Activity Highlights

Unlearning Racism in Geosciences (URGE)

The Woods Hole Pod learned that long-term efforts with underserved communities across three domains, including engagement/networking, recruitment/hiring, and retention/advancement opportunities, are necessary to create an inclusive, equitable workplace culture. The six USGS URGE pods detailed their recommendations to the USGS Executive Leadership Team and Workplace Equity, Engagement and Excellence Council in the summer and then presented at the Geological Society of America and American Geophysical Union fall conferences. URGE annual reviews chronicle progress made on URGE initiatives.

Peer Support Worker Program

The WHCMSC’s Peer Support Workers and center director responded to recommendations from the center’s telework survey to increase connectedness. This resulted in office hours being offered from core groups, including administration, information technology, publications, the center director, and the center’s Peer Support Workers, and the creation of a Microsoft Teams channel for new employees and caregivers. The Peer Support Workers also scheduled bystander intervention training for all staff, which was the second most requested training by center staff after unconscious bias training, which was held in 2020.

Woods Hole Diversity Advisory Committee

The Woods Hole Diversity Advisory Committee organized numerous events in 2021, including

- a Juneteenth celebration, including a lecture and a STEMFest Film Festival event
- the Ambrose Jearld, Jr. Lecture, titled “Collectors, Nightlights, and Allies, Oh My! Building Strong Cross-Racial Mentoring Relationships”
- a series of events in celebration of Black History Month
- the first ever celebration of the Native American Heritage Month in Woods Hole, including a panel discussion on Wampanoag Language Reclamation and a book discussion
- “Improving Diversity, Equity, and Inclusion in the Woods Hole Scientific Community: 2021 Update,” a followup to a 2018 report by Dr. Robert Livingston, a leading scholar of diversity issues at Harvard University’s John F. Kennedy School of Government

2021 Summer Student Mentorships

Each summer, scientists at the center mentor students through programs such as the Woods Hole Oceanographic Institution (WHOI) Summer Student Fellowship (SSF), the Woods Hole Partnership Education Program (PEP), the City College of New York/City University of New York partnership, and the USGS/National Association of Geoscience Teachers (NAGT) Cooperative Summer Field Training Program. Through this mentorship, students gain experience, advance skills, and interact socially and scientifically with their cohorts and the Woods Hole community. Most of the summer students in 2021 were onsite at the center for a week and then operated in a virtual capacity for the rest of the summer. Simone Gibson, however, started her mentorship in late August and continued to work onsite at the center after her internship through the NAGT program, gaining additional experience in field and laboratory methods in coastal wetlands. Simon Detmer and Nick Catanzaro both won a WHOI SSF Travel Scholarship, and each presented their work as a poster at the American Geophysical Union Fall Meeting in New Orleans, December 13–17, 2021. Thanks to the dedication of these various internship programs and mentors, it was another successful season of student mentorships. Students gained skills and experience valuable to advancing their education and their journeys to becoming scientists.

Students and Mentors

Nick Catanzaro (SSF)

- Research Mentor: Chris Sherwood
- Title: Employing Recon for Optical Wave Gauging with Deep Neural Networks in the Great Lakes Nearshore

Simon Detmer (SSF)

- Research Mentors: Uri ten Brink and Jason Chaytor
- Title: Marine Geohazards: 3D Reconstruction of Submarine Landslide

Simone Gibson (USGS/NAGT)

- Research Mentors: Kevin Kroeger and Meagan Eagle
- Title: Greenhouse Gas Cycling in Managed Coastal Wetlands

Miles Jordan (PEP)

- Research Mentor: Meagan Eagle
- Title: Trace Element Cycling within the Sage Lot Pond Subterranean Estuary

Mya Rufus (PEP)

- Research Mentors: Elizabeth Pendleton and Rachel Henderson
- Title: Data Accuracy Assessment of the Coastal Change Likelihood in the Massachusetts

2021 Publications

Journal Articles (32)

Abernathey, R.P., Augspurger, T., Banihirwe, A., Blackmon-Luca, C.C., Crone, T.J., Gentemann, C.L., Hamman, J.J., Henderson, N., Lepore, C., McCaie, T.A., Robinson, N.H., and Signell, R.P., 2021, Cloud-native repositories for big scientific data: Computing in Science and Engineering, v. 23, no. 2, p. 26–35, https://doi.org/10.1109/MCSE.2021.3059437.

Brooks, T.W., Kroeger, K.D., Michael, H.A., and York, J.K., 2021, Oxygen-controlled recirculating seepage meter reveals extent of nitrogen transformation in discharging coastal groundwater at the aquifer-estuary interface: Limnology and Oceanography, v. 66, no. 8, p. 3055–3069, https://doi.org/10.1002/lno.11858.

Chaytor, J.D., Ballard, M.S., Buczkowski, B.J., Goff, J.A.; Lee, K.M., Reed, A.H.; and Boggess, A.A., 2021, Measurements of geologic characteristics and geophysical properties of sediments from the New England Mud Patch: IEEE Journal of Ocean Engineering, early access article posted September 22, 2021, p. 1–28, https://doi.org/10.1109/JOE.2021.3101013.

Donatelli, C., Kalra, T.S. Fagherazzi, S., Zhang, X., and Leonardi, N., 2020, Dynamics of marsh-derived sediments in lagoon-type estuaries: Journal of Geophysical Research: Earth Surface, v. 125, no. 12, [article e2020JF005751], https://doi.org/10.1029/2020JF005751.

Elyashiv, H., Bookman, R., Siemann, L., ten Brink, U.S., and Huhn, K., 2020, Numerical characterization of cohesive and non-cohesive 'sediments' under different consolidation states using 3D DEM triaxial experiments: Processes, v. 8, no. 10, [article 1252], https://doi.org/10.3390/pr8101252.

Fu, X., Waite, W.F., and Ruppel, C.D., 2021, Hydrate formation on marine seep bubbles and the implications for water column methane dissolution: Journal of Geophysical Research: Oceans, v. 126, no. 9, [article e2021JC017363], https://doi.org/10.1029/2021JC017363.

Garcia-Tigreros, F., Leonte, M., Ruppel, C.D., Ruiz-Angulo, A., Joung, D.J., Young, B., and Kessler, J.D., 2021, Estimating the impact of ancient methane on ocean pH and dissolved inorganic radiocarbon along the U.S. Mid-Atlantic Bight: Journal of Geophysical Research: Biogeosciences, v. 126, no. 1, [article e2019JG005621], https://doi.org/10.1029/2019JG005621.

Gentemann, C.L., Holdgraf, C., Abernathey, R., Crichton, D., Colliander, J., Kearns, E.J., Panda, Y., and Signell, R.P., 2021, Science storms the cloud: AGU Advances, v. 2, no. 2, [article e2020AV000354], https://doi.org/10.1029/2020AV000354.

Greene, J.A., Tominaga, M., and Miller, N.C., 2020, Along-margin variations in breakup volcanism at the Eastern North American Margin: Journal of Geophysical Research: Solid Earth, v. 125, no. 12, [article e2020JB020040], https://doi.org/10.1029/2020JB020040.

He, R., Wang, J., Pohlman, J.W., Jia, Z., Chu, Y.X., Wooller, M.J., and Leigh, M.B., 2021, Metabolic flexibility of aerobic methanotrophs under anoxic conditions in Arctic lake sediments: The ISME Journal, open access article posted July 9, 2021, https://doi.org/10.1038/s41396-021-01049-y.

Johnson, J.E., Phillips, S.C., Clyde, W.C., Giosan, L., and Torres, M.E., 2021, Isolating detrital and diagenetic signals in magnetic susceptibility records from methane-bearing marine sediments: Geochemistry, Geophysics, Geosystems, v. 22, no. 9, [article e2021GC009867], https://doi.org/10.1029/2021GC009867.

Joung, D., Ruppel, C., Southon, J., and Kessler, J.D., 2021, Elevated levels of radiocarbon in methane dissolved in seawater reveal likely local contamination from nuclear power: Science of the Total Environment, version of record posted October 2, 2021, https://doi.org/10.1016/j.scitotenv.2021.150456.

Kalra, T.S., Ganju, N.K., Aretxabaleta, A.L., Carr, J.A., Defne, Z., and Moriarty, J.M., 2021, Modeling marsh dynamics using a 3-D coupled wave-flow-sediment model: Frontiers in Marine Science, v. 8, [article 740921], https://doi.org/10.3389/fmars.2021.740921.

Kalra, T.S., Ganju, N.K., and Testa, J.M., 2020, Development of a submerged aquatic vegetation growth model in the Coupled Ocean-Atmosphere-Wave-Sediment Transport (COAWST v3.4) model: Geoscientific Model Development, v. 13, no. 11, p. 5211–5228, https://doi.org/10.5194/gmd-13-5211-2020.

Lang, G., ten Brink, U.S., Hutchinson, D.R., Mountain, G.S., and Schattner, U., 2020, The role of pre-magmatic rifting in shaping a volcanic continental margin—An example from the Eastern North American Margin: Journal of Geophysical Research: Solid Earth, v. 125, no. 11, [article e2020JB019576], https://doi.org/10.1029/2020JB019576.

Lentz, E.E., Zeigler, S.L., Thieler, E.R., and Plant, N.G., 2021, Probabilistic patterns of inundation and biogeomorphic changes due to sea-level rise along the northeastern U.S. Atlantic coast: Landscape Ecology, v. 36, p. 223–241, https://doi.org/10.1007/s10980-020-01136-z.

Luk, S.Y., Todd-Brown, K., Eagle, M., McNichol, A.P., Sanderman, J., Gosselin, K., and Spivak, A.C., 2021, Soil organic carbon development and turnover in natural and disturbed salt marsh environments: Geophysical Research Letters,v. 48, no. 2, [article e2020GL090287], https://doi.org/10.1029/2020GL090287.

Miller, N.C., Lizarralde, D., Collins, J.A., Holbrook, W.S., and Van Avendonk, H.J.A., 2021, Limited mantle hydration by bending faults at the Middle America Trench: Journal of Geophysical Research: Solid Earth, v. 126, no. 1, [article e2020JB020982], https://doi.org/10.1029/2020JB020982.

Molino, G.D., Defne, Z., Aretxabaleta, A.L., Ganju, N.K., and Carr, J.A., 2021, Quantifying slopes as a driver of forest to marsh conversion using geospatial techniques—Application to Chesapeake Bay coastal-plain, United States: Frontiers in Environmental Science, v. 9, [article 616319], https://doi.org/10.3389/fenvs.2021.616319.

Moore, M.T., Phillips, S.C., Cook, A.E., and Darrah, T.H., 2021, Integrated geochemical approach to determine the source of methane in gas hydrate from Green Canyon Block 955 in the Gulf of Mexico: AAPG Bulletin, preliminary version ahead of print posted May 27, 2021, https://doi.org/10.1306/05272120087.

Over, J.R., Brown, J.A., Sherwood, C.R., Hegermiller, C., Wernette, P.A., Ritchie, A.C., and Warrick, J.A., 2021, A survey of storm-induced seaward-transport features observed during the 2019 and 2020 hurricane seasons: Shore and Beach, v. 89, no. 2, p. 31–40, https://doi.org/10.34237/1008924.

Phillips, S.C., Flemings, P.B., You, K., and Waite, W.F., 2021, Thermodynamic insights into the production of methane hydrate reservoirs from depressurization of pressure cores: AAPG Bulletin, preliminary version ahead of print posted October 1, 2021, https://doi.org/10.1306/08182120216.

Pohlman, J.M., Casso, M., Magen, C., and Bergeron, E., 2021, Discrete sample introduction module for quantitative and isotopic analysis of methane and other gases by cavity ring-down spectroscopy: Environmental Science & Technology, v. 55, no. 17, p. 12066–12074, https://doi.org/10.1021/acs.est.1c01386.

Porchetta, S., Temel, O., Warner, J.C., Muñoz-Esparza, D., Monbaliu, J., van Beeck, J., and van Lipzig, N., 2021, Evaluation of a roughness length parameterization accounting for wind-wave alignment in a coupled atmosphere-wave model: Quarterly Journal of the Royal Meteorological Society, v. 147, no. 735, p. 825–846, https://doi.org/10.1002/qj.3948.

Sherwood, C.R., van Dongeren, A., Doyle, J., Hegermiller, C.A., Hsu, T.J., Kalra, T.S., Olabarrieta, M., Penko, A.M., Rafati, Y., Roelvink, D., van der Lugt, M., Veeramony, J., and Warner, J.C., 2021, Modeling the morphodynamics of coastal response to extreme events—What shape are we in?: Annual Review of Marine Science, Review in Advance posted July 27, 2021, https://doi.org/10.1146/annurev-marine-032221-090215.

Tamborski, J.J., Eagle, M., Kurylyk, B.L., Kroeger, K.D, Wang, Z.A., Henderson, P., and Charette, M.A, 2021, Porewater exchange-driven inorganic carbon export from intertidal salt marshes: Limnology and Oceanography, v. 66, no. 5, p. 1774–1792, https://doi.org/10.1002/lno.11721.

ten Brink, U.S., Vanacore, L., Fielding, E.J., Chaytor, J.D., Lopez-Venegas, A.M., Baldwin, W.E., Foster, D., and Andrews, B.D., 2021, Mature diffuse tectonic block boundary revealed by the 2020 southwestern Puerto Rico seismic sequence: Tectonics, preliminary version posted October 12, 2021, https://doi.org/10.1002/essoar.10507060.1.

Wehmiller, J.F., Brothers, L.L., Ramsey, K.W., Foster, D.S., Mattheus, C.R., Hein, C.J., and Shawler, J.L., 2021, Molluscan aminostratigraphy of the US Mid-Atlantic Quaternary coastal system—Implications for onshore-offshore correlation, paleochannel and barrier island evolution, and local late Quaternary sea-level history: Quaternary Geochronology, v. 66, [article 101177], https://doi.org/10.1016/j.quageo.2021.101177.

Wigand, C., Eagle, M., Branoff, B.L., Balogh, S., Miller, K.M., Martin, R.M., Hanson, A., Oczkowski, A.J., Huertas, E., Loffredo, J., and Watson, E.B., 2021, Recent carbon storage and burial exceed historic rates in the San Juan Bay Estuary Peri-urban mangrove forests (Puerto Rico, United States): Frontiers in Forests and Global Change, v. 4, [article 676691], https://doi.org/10.3389/ffgc.2021.676691.

Wilson, S.T., Al-Haj, A.N., Bourbonnais, A., Frey, C., Fulweiler, R.W., Kessler, J.D., Marchant, H.K., Milucka, J., Ray, N.E., Suntharalingham, P., Thornton, B.F., Upstill-Goddard, R.C., Weber, T.S., Arévalo-Martínez, D.L., Bange, H.W., Benway, H.M., Bianchi, D., Borges, A.V., Chang, B.X., Crill, P.M., del Valle, D.A., Farías, L., Joye, S.B., Kock, A., Labidi, J., Manning, C.C., Pohlman, J.W., Rehder, G., Sparrow, K.J., Tortell, P.D., Treude, T., Valentine, D.L., Ward, B.B., Yang, S., and Yurganov, L.N. 2020, Ideas and perspectives—A strategic assessment of methane and nitrous oxide measurements in the marine environment: Biogeosciences, v. 17, no. 22, p. 5809–5828, https://doi.org/10.5194/bg-17-5809-2020.

Yoneda, J., Jin, Y., Muraoka, M., Oshima, M., Suzuki, K., Waite, W.F., and Flemings, P.B., 2021, Comprehensive pressure core analysis for hydrate-bearing sediments from Gulf of Mexico Green Canyon Block 955, including assessments of geomechanical viscous behavior and NMR permeability: AAPG Bulletin, preliminary version ahead of print posted July 7, 2021, https://doi.org/10.1306/04272120204.

Zambon, J.B., He, R., Warner, J.C., and Hegermiller, C.A., 2021, Impact of SST and surface waves on Hurricane Florence (2018)—A coupled modeling investigation: Weather and Forecasting, v. 36, no. 5, p. 1713–1734, https://doi.org/10.1175/WAF-D-20-0171.1.

U.S. Geological Survey Series Publications (3)

Ernst, S., 2021, Woods Hole Coastal and Marine Science Center—2020 annual report: U.S. Geological Survey Circular 1487, 36 p., https://doi.org/10.3133/cir1487.

Himmelstoss, E.A., Henderson, R.E., Kratzmann, M.G., and Farris, A.S., 2021, Digital Shoreline Analysis System (DSAS) version 5.1 user guide: U.S. Geological Survey Open-File Report 2021–1091, 104 p., https://doi.org/10.3133/ofr20211091.

Over, J.R., Ritchie, A.C., Kranenburg, C.J., Brown, J.A., Buscombe, D., Noble, T., Sherwood, C.R., Warrick, J.A., and Wernette, P.A., 2021, Processing coastal imagery with Agisoft Metashape Professional Edition, version 1.6—Structure from motion workflow documentation: U.S. Geological Survey Open-File Report 2021–1039, 46 p, https://doi.org/10.3133/ofr20211039.

Data Releases (38)

Ackerman, K.V., Defne, Z., and Ganju, N.K., 2021, Coastal wetlands of the Blackwater region, Chesapeake Bay, Maryland: U.S. Geological Survey data release, https://doi.org/10.5066/P9M7H6XG.

Ackerman, K.V., Defne, Z., and Ganju, N.K., 2021, Geospatial characterization of salt marshes for Massachusetts: U.S. Geological Survey data release, https://doi.org/10.5066/P97E086F.

Ackerman, S.D., Barnhardt, W.A., Worley, C.R., Nichols, A.R., Baldwin, W.E., and Evert, S., 2021, High-resolution geophysical and geological data collected in Little Egg Inlet and offshore the southern end of Long Beach Island, NJ, during USGS Field Activities 2018-001-FA and 2018-049-FA: U.S. Geological Survey data release, https://doi.org/10.5066/P9C3J33K.

Aretxabaleta, A.L., Defne, Z., and Ganju, N.K., 2021, Wave thrust values at point locations along the shorelines of Chesapeake Bay, Maryland and Virginia: U.S. Geological Survey data release, https://doi.org/10.5066/P9SLXS0G.

Aretxabaleta, A.L., Defne, Z., and Ganju, N.K., 2021, Wave thrust values at point locations along the shorelines of Massachusetts and Rhode Island: U.S. Geological Survey data release, https://doi.org/10.5066/P9LFGKFW.

Aretxabaleta, A.L., Defne, Z., Kalra, T.S., Blanton B.O., and Ganju, N.K., 2021, Tidal datums, tidal range, and nuisance flooding levels for Chesapeake Bay and Delaware Bay: U.S. Geological Survey data release, https://doi.org/10.5066/P9G7KGBF.

Baldwin, W.E., Bergeron, E.M., Foster, D.S., Moore, E.M., Nichols, A.R., O'Brien, T.F., Miller, N.C., and Ruppel, C.D., 2021, Split-beam echo sounder and navigation data collected using a Simrad EK80 wide band transceiver and ES38–10 transducer during the Mid-Atlantic Resource Imaging Experiment (MATRIX), USGS field activity 2018–002–FA: U.S. Geological Survey data release, https://doi.org/10.5066/P948VJ4X.

Baldwin, W.E., Chaytor, J.D., Foster, D.S., Moore, E.M., Nichols, A.R, and ten Brink, U.S., 2021, Multichannel seismic-reflection and navigation data collected using SIG ELC1200 and Applied Acoustics Delta Sparkers and Geometrics GeoEel digital streamers during USGS field activity 2020-014-FA, southwest of Puerto Rico, March 2020: U.S. Geological Survey data release, https://doi.org/10.5066/P96GY6TQ.

Baldwin, W.E., Foster, D.S., Bergeron, E.M., Dal Ferro, P., McKee, J.A., Moore, E.M., Nichols, A.R., O'Brien, T.F., Powers, D., Miller, N.C., and Ruppel, C.R., 2021, Sonobuoy seismic and navigation data collected using Sercel GI guns and Ultra Electronics seismic sonobuoys during the Mid-Atlantic Resource Imaging Experiment (MATRIX), USGS Field Activity 2018–002–FA: U.S. Geological Survey data release, https://doi.org/10.5066/P97LBUSP.

Bartlett, M.K., Farris, A.S., Weber, K.M., and Himmelstoss, E.A., 2021, Massachusetts shoreline change project—A GIS compilation of vector shorelines (1844–2018): U.S. Geological Survey data release, https://doi.org/10.5066/P9O8QA8N.

Bartlett, M.K, Henderson, R.E., Farris, A.S., and Himmelstoss, E.A., 2021, Massachusetts shoreline change project, 2021 update—A GIS compilation of shoreline change rates calculated using Digital Shoreline Analysis System version 5.1, with supplementary intersects and baselines for Massachusetts: U.S. Geological Survey data release, https://doi.org/10.5066/P9YGIYFX.

Boggess, A.A., Buczkowski, B.J., and Chaytor, J.D., 2021, Sedimentological and geotechnical analyses of marine sediment cores from the New England Mud Patch: U.S. Geological Survey data release, https://doi.org/10.5066/P9ZYK3PX.

Bracero-Marrero, L., J.L., Barreto-Orta, M., Hernández-Montcourt, N., Maldonado-Gonzalez, R., Himmelstoss, E.A., and Heslin, J.L., 2021, A GIS compilation of vector shorelines and shoreline classification for Puerto Rico from 1970 and 2010: U.S. Geological Survey data release, https://doi.org/10.5066/P9SEUAHC.

Brooks, T.W., Eagle, M.J., Kroeger, K.D., Mann, A.G., Wang, Z.A., Ganju, N.K., O'Keefe-Suttles, J.A., Brosnahan, S.M., Chu, S.N., Song, S., Pohlman, J.W., Casso, M., Tamborski, J.J., Morkeski, K., Carey, J.C., Ganguil, P.M., Williams, O.L., and Kurtz, A.C., 2021, Geochemical data supporting investigation of solute and particle cycling and fluxes from two tidal wetlands on the south shore of Cape Cod, Massachusetts, 2012–19: U.S. Geological Survey data release, https://doi.org/10.5066/P9MXLUZ1.

Brooks, T.W., Kroeger, K.D., Michael, H.A., Szymczycha, B., Eagle, M.J., and York, J.K., 2021, Nearshore groundwater seepage and geochemical data measured in 2015 at Guinea Creek, Rehoboth Bay, Delaware: U.S. Geological Survey data release, https://doi.org/10.5066/P94NBY3Z.

Brown, J.A., Sherwood, C.R., Martini, M., Kranenburg, C.J., and Over, J.R., 2021, Ground control point data from the Outer Banks, North Carolina, post-Hurricane Dorian, September 2019: U.S. Geological Survey data release, https://doi.org/10.5066/P9DVZC23.

Butman, B., Montgomery, E.T., Martini, M.M., Borde, J., Pettigrew, N.R., and Wallinga, J.P., 2018, Near-bottom temperature, conductivity, and light transmission observations in the western Gulf of Maine, 2013–2017 (ver. 1.1, November 2021): U.S. Geological Survey data release, https://doi.org/10.5066/P99U02UT.

Cramer, J.M., Brosnahan, S.M., Ackerman, S.D., Pendleton, E.A., Sturdivant, E.J., and Borden, J., 2021, Aerial Imagery collected during unoccupied aircraft systems (UAS) operations in Massachusetts and Maine between March 2018–September 2018: U.S. Geological Survey data release, https://doi.org/10.5066/P9VIUXWE.

Eagle, M.J., Wigand, C., Branoff, B., Balogh, S., Miller, K.M., Martin, R.M., Hanson, A., Oczkowski, A.J., Huertas, E., Loffredo, J., Watson, E.B., and O'Keefe Suttles, J.A., 2021, Collection, analysis, and age-dating of sediment cores from mangrove wetlands, San Juan Bay estuary Puerto Rico, 2016: U.S. Geological Survey data release, https://doi.org/10.5066/P97CAF30.

Henderson, R.E., Heslin, J.L., and Himmelstoss, E.A., 2021, Puerto Rico shoreline change—A GIS compilation of shorelines, baselines, intersects, and change rates calculated using the Digital Shoreline Analysis System (DSAS) version 5.1.: U.S. Geological Survey data release, https://doi.org/10.5066/P9FNRRN0.

Heslin, J.L, Henderson, R.E., and Himmelstoss, E.A., 2021, A GIS compilation of vector shorelines for Puerto Rico from 2015 to 2018: U.S. Geological Survey data release, https://doi.org/10.5066/P9AZYW74.

Heslin, J.L., Henderson, R.E., and Himmelstoss, E.A., 2021, Historical shorelines for Puerto Rico from 1901–1987: U.S. Geological Survey data release, https://doi.org/10.5066/P9CLXCEG.

Kalra, T.S, Ganju, N.K., and Aretxabaleta, A.L., 2021, Idealized COAWST numerical model for testing marsh wave thrust and lateral retreat dynamics routines: U.S. Geological Survey data release, https://doi.org/10.5066/P94HYOGQ.

Kalra, T.S., Ganju, N.K., Defne, Z.D, and Aretxabaleta, A.L., 2021, COAWST model of Barnegat Bay creeks to demonstrate marsh dynamics: U.S. Geological Survey data release, https://doi.org/10.5066/P9QO091Z.

Kratzmann, M.G., Farris, A.S., Henderson, R.E., and Himmelstoss, E., 2021, Preliminary estimates of forecasted shoreline positions and associated uncertainties for Florida and Georgia: U.S. Geological Survey data release, https://doi.org/10.5066/P9OWFEUH.

Kratzmann, M.G, Farris, A.S., Weber, K.M, Henderson, R.E., and Himmelstoss, E.A., 2021, USGS national shoreline change—A GIS compilation of updated vector shorelines (1800s–2010s) and associated shoreline change data for the Georgia and Florida Coasts.: U.S. Geological Survey data release, https://doi.org/10.5066/P9J3CVN4.

O'Keefe-Suttles, J.A., Eagle, M.J., Mann, A.G., Moseman-Valtierra, S., Pratt, S.E., and Kroeger, K.D., 2021, Collection, Analysis, and Age-Dating of Sediment Cores from Salt Marshes, Rhode Island, 2016: U.S. Geological Survey data release, https://doi.org/10.5066/P94HIDVU.

O'Keefe-Suttles, J.A., Eagle, M.J., Mann, A.G., Smith, C.G., and Kroeger, K.D., 2021, Collection, analysis, and age-dating of sediment cores from mangrove and salt marsh ecosystems in Tampa Bay, Florida, 2015: U.S. Geological Survey data release, https://doi.org/10.5066/P9QB17H2.

O'Keefe-Suttles, J.A., Eagle, M.J., Mann, A.G., Spivak, A., Sanks, K., Roberts, D., and Kroeger, K.D., 2021, Collection, analysis, and age-dating of sediment cores from natural and restored salt marshes on Cape Cod, Massachusetts, 2015–16: U.S. Geological Survey data release, https://doi.org/10.5066/P9R154DY.

O'Keefe-Suttles, J.A., Eagle, M.J., Mann, A.G., Wang, F., Tang, J., Roberts, D., Sanks, K., Smith, T.P., and Kroeger, K.D., 2021, Collection, analysis, and age-dating of sediment cores from Herring River wetlands and other nearby wetlands in Wellfleet, Massachusetts, 2015–17: U.S. Geological Survey data release, https://doi.org/10.5066/P95RXPHB.

Over, J.R., Sherwood, C.R., Traykovski, P.A., Brosnahan, S.M., Martini, M.A., Marsjanik, E., and Borden, J.S., 2021, Topographic and bathymetric data, sediment samples, and imagery collected at Head of the Meadow Beach in March 2020, U.S Geological Survey Field Activity 2020–015–FA.: U.S. Geological Survey data release, https://doi.org/10.5066/P9KSG1RQ.

Over, J.R., Sherwood, C.R., Traykovski, P.A., and Marsjanik, E., 2021, Topographic and bathymetric data, sediment samples, structure from motion imagery, and reference mark data collected at Marconi Beach, Wellfleet in winter 2021, U.S Geological Survey Field Activity 2021–022–FA.: U.S. Geological Survey data release, https://doi.org/10.5066/P9POZ9VH.

Pohlman, J.W., and Casso, M., 2021, Comparison of methane concentration and stable carbon isotope data for natural samples analyzed by discrete sample introduction module–cavity ring down spectroscopy (DSIM–CRDS) and traditional methods: U.S. Geological Survey data release, https://doi.org/10.5066/P99B34V1.

Ritchie, A.C., Over, J.R., Kranenburg, C.J., Brown, J.A., Buscombe, D., Sherwood, C.R., Warrick, J.A., and Wernette, P.A., 2021, Aerial photogrammetry data and products of the North Carolina Coast—2018–10–06 to 2018–10–08, post-Hurricane Florence: U.S. Geological Survey data release, https://doi.org/10.5066/P9CA3D8P.

Sherwood, C.R., Over, J.R, and Soenen, K., 2021, Structure from motion products associated with UAS flights in Sandwich, Massachusetts between January 2016 – September 2017: U.S. Geological Survey data release, https://doi.org/10.5066/P9BFD3YH.

Suttles, S.E., De Meo, O.A., Martini, M.A., and Warner, J.C., 2021, Grain-size analysis data from sediment samples in support of oceanographic and water-quality measurements in the nearshore zone of Matanzas Inlet, Florida, 2018: U.S. Geological Survey data release, https://doi.org/10.5066/P9FKARIZ.

Valentine, P.C., and Cross, V.A., 2021, Station information, seabed imagery, and CTD instrument data collected on Stellwagen Bank in December, 2015, U.S. Geological Survey Field Activity 2015–074–FA: U.S. Geological Survey data release, https://doi.org/10.5066/P9XPFQ63.

Valentine, P.C., and Cross, V.A., 2021, Station information, seabed imagery, and CTD instrument data collected on Stellwagen Bank in January 2016, U.S. Geological Survey Field Activity 2016–004–FA: U.S. Geological Survey data release, https://doi.org/10.5066/P934L7PN.

Geonarratives and Other Web Pages (5)

Defne, Z., 2021, U.S. coastal wetland synthesis: U.S. Geological Survey web page, https://wim.usgs.gov/geonarrative/uscoastalwetlandsynthesis/.

Ernst, S., 2021, Woods Hole Coastal and Marine Science Center—Fiscal year 2020 annual report: U.S. Geological Survey web page, https://wim.usgs.gov/geonarrative/woodshole-2020/.

Over, J.C.R., and Hegermiller, C.A., 2021, USGS DUNEX Operations on the Outer Banks: U.S. Geological Survey web page, https://www.usgs.gov/centers/woods-hole-coastal-and-marine-science-center/science/usgs-dunex-operations-outer-banks.

Ruppel, C.D., 2021, Gas hydrate in nature—A geonarrative based on USGS Fact Sheet 3080: U.S. Geological Survey web page, https://wim.usgs.gov/geonarrative/hydrateinnature/.

Ruppel, C.D., 2021, USGS Gas Hydrates Project—A geonarrative based on USGS Fact Sheet 3079: U.S. Geological Survey web page, https://storymaps.arcgis.com/stories/bd008c99e6e14a679ac3759114c512e7.

All photographs by the U.S. Geological Survey unless otherwise indicated.

Page number	Photograph credit	Photograph caption
4 bottom, small	Stephen M. Young	*Amaranthus pumilus* (seabeach amaranth)
8 top	Mike Thompson, National Oceanic and Atmospheric Administration (NOAA)	Celebrating the collection of U.S. Geological Survey Research Geologist Page Valentine's 5000th sample on the National Oceanic and Atmospheric Administration Stellwagen Bank National Marine Sanctuary.
9	Amy Meloski, NOAA	Page Valentine collects his 5000th sample within the Stellwagen Bank National Marine Sanctuary alongside Seth Ackerman and Brian Andrews.
10	Patrick Kelley, U.S. Coast Guard	U.S. Coast Guard cutter *Healy* breaks ice ahead of the Canadian Coast Guard ship *Louis S. St-Laurent* on September 1, 2009. The two ships were part of a multiyear, multiagency Arctic survey to help define the North American continental shelf.
12 top	Lamont-Doherty Earth Observatory	Research vessel *Marcus G. Langseth* entering New York Harbor.
13 top	NOAA	Remotely operated vehicle *Deep Discoverer* surveys a large boulder covered in bamboo corals during the 2021 North Atlantic Stepping Stones expedition. Bamboo corals were locally abundant on these large boulders and more spread out throughout different hard-bottom habitats.
13 large	NOAA	A *Parapagurus* sp. crab with a coral in the genus *Epizoanthus* on its back makes its way across a spectacular and unexpectedly densely packed field of ferromanganese nodules blanketing the sea floor of Gosnold Seamount, explored during dive 16 of the 2021 North Atlantic Stepping Stones expedition.
18 bottom, small	Ray Paterra, U.S. Fish and Wildlife Service	Sunset over Blackwater River photographed from the wildlife drive at Blackwater National Wildlife Refuge (NWR). Blackwater NWR is one of 560 refuges in the refuge system administered by the U.S. Fish and Wildlife Service.
22 large	Sheron Luk, Woods Hole Oceanographic Institution/ Massachusetts Institute of Technology	Adrian Mann, lab manager, analyzes pore water samples on an ion chromatograph.

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