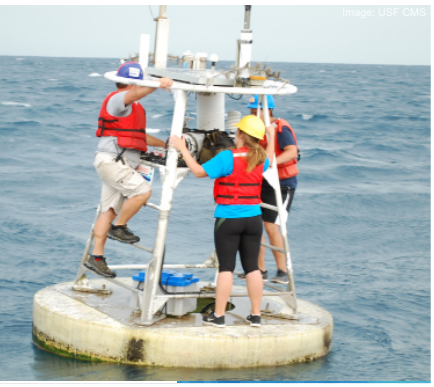

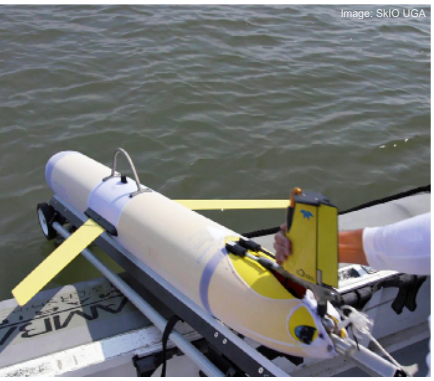

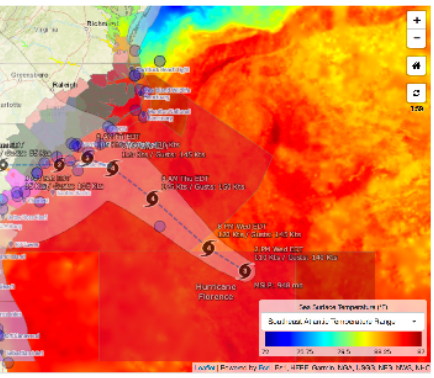

SECOORA
SOUTHEAST
COASTAL OCEAN OBSERVING
REGIONAL ASSOCIATION

Regional Coastal Ocean Observing System Strategic Operational Plan 2026 - 2030

This document presents the Southeast Coastal Ocean Observing Regional Association (SECOORA) priorities for contributing to our improved understanding, management, and stewardship of valued coastal ocean resources. It will serve as a guide for future investments in SECOORA's regional coastal ocean observing system (RCOOS).

U.S. INTEGRATED OCEAN OBSERVING SYSTEM
CERTIFIED
REGIONAL ASSOCIATION

Version Control

Version	Activity	Date
1.00	Published the SECOORA Regional Coastal Ocean Observing System Strategic RCOOS Plan 2020-2025	4/21/2020
1.50	SECOORA Science Committee review of 2020-2025 RCOOS Plan included recommendations to add a summary of accomplishments, reduce redundancy within the document, add a Marine Heat section, and move the Rip Currents sections out of Marine Operations focus area and into Coastal Hazards and Climate Variability focus area were all completed.	10/31/2024
1.70	Subject matter expert section edits were conducted September to November 2024.	11/15/2024
1.70	SECOORA Board of Directors approved the revised 2026-2030 RCOOS Plan, noting that some updates were still underway.	12/10/2024
1.80	New maps were added for each section; new images were included as needed. Updates to Acoustics Monitoring section completed.	1/16/2025
1.90	Final review 2026-2030 RCOOS Plan completed. Final maps added. Based on Executive Order 14172, all references to Gulf of Mexico were removed except when Gulf of Mexico is within the name of organization that has not been revised at the time this document was written.	2/21/2025
2.00	Finalized the SECOORA Regional Coastal Ocean Observing System Strategic RCOOS Plan 2026-2030	2/28/2025

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1. Overview

1.1 Purpose

This document is a revision of the Southeast Coastal Ocean Observing Regional Association (SECOORA) 2020-2025 Regional Coastal Ocean Observing System (RCOOS) Strategic Operational Plan. SECOORA investment opportunities described in the 2020-2025 RCOOS Plan have led to the expansion of the SECOORA observing system, as shown by the following:

- Charleston Harbor, SC wave buoy and meteorological and physical oceanographic buoy (2022), Ponce de Leon, FL wave and meteorological and physical oceanographic buoy (2023), Fort Pierce, FL meteorological and physical oceanographic buoy (2023), and Fripp Island wave buoy, SC (2024).
- Seafloor Ocean Acidification mooring in Looe Key, FL (2024).
- High Frequency Radar deployments in Myrtle Beach State Park, SC (2021), Treasure Shores Park, FL (2022), Cape Canaveral, FL (2022), Hightower Beach Park, FL, (2024), and Kennedy Space Center, FL (2024)
- The purchase of two G3 Slocum Gliders that filled critical gaps in infrastructure required for routine glider monitoring on the South Atlantic Bight.
- 17 web cameras that are operating throughout the Southeast region.
- Over 100 water level sensors operating throughout the Southeast region.
- Establishment of the first sustained Harmful Algal Bloom (HAB) monitoring program in the Skidaway River and maintaining and expanding HAB monitoring in Estero Bay, FL.
- Product development has focused on sharing web camera and water level data in easy to understand formats - https://wl.secoora.org and https://webcoos.org/ and the Text-A-Buoy system, where users can get the latest ocean and weather information from their favorite buoy in the region.
- The Coupled Northwest Atlantic Prediction System (CNAPS) 30-year reanalysis model (1993-2022) data is accessible via THREDDS server for download and use: https://thredds.secoora.org/thredds/catalog/catalog.html

SECOORA plans to continue building upon the successful build out strategies from our 2020-2025 RCOOS Plan. The 2026-2030 RCOOS Plan presents the SECOORA priorities for contributing to our improved understanding and management of valued coastal ocean resources. It will serve as a guide for future investments in SECOORA's regional coastal ocean observing system (RCOOS). SECOORA is organized to provide coastal and ocean data, tools, and services in the following focus areas, which correspond with the U.S. Integrated Ocean Observing System (IOOS®) societal goals and are important to Southeast stakeholders: Coastal Hazards and Climate Variability; Ecosystems, including Water Quality and Living Marine Resources; and Marine Operations. SECOORA revised the 2020-2025 RCOOS plan based on the needs of the region, as identified by our membership and other stakeholders, and the ability to make significant progress in priority areas. This revision covers the 5-year period, 2026 – 2030. This plan will be reviewed annually by the SECOORA Science Committee. A comprehensive review and revision, with input from the Board of Directors, members, and stakeholders, occurs every 5 years.

This 2026-2030 SECOORA RCOOS Plan is intended to inform:

1. SECOORA staff and Board of Directors, to establish priorities for infrastructure investment and funding decisions.
2. The IOOS Program Office, to inform and meet certification requirements.
3. SECOORA members, to articulate priorities and provide guideposts for future activities.

4. Regional stakeholders and potential members, to describe connections to regional needs and priorities and demonstrate capabilities.

There are three main sections of this document.

1. **Overview** provides regional and national context for SECOORA's work.
2. **RCOOS Subcomponents** identifies current SECOORA investments in observing platforms, modeling, data management and communications, products, and outreach and education.
3. **Focus Areas** describes the thematic priorities that guide our work. SECOORA will invest in data collection, product development, and research to better understand the environmental and societal concerns identified within each of the focus areas. Our purpose is to describe SECOORA's role in addressing these challenging issues. We describe briefly the work of key SECOORA partners and stakeholders and concentrate on how SECOORA contributions complement and leverage these ongoing programs and efforts. Additional opportunities for investment are highlighted in each focus area.

The 2026-2030 RCOOS Plan has three companion plans that are either issue or technology specific. These include the:

- SECOORA Modeling Framework - The purpose of this document is to establish a modeling framework for SECOORA that: Characterizes the range of modeling goals SECOORA will pursue; includes a process to assess modeling gaps and identify new opportunities; articulates a model lifecycle evaluation process, including guidelines that cover development to retirement of models; and, outlines SECOORA's engagement with principal investigators (PIs), the broader modeling community, NOAA, and stakeholders.
- SECOORA Harmful Algal Bloom Plan - The document establishes priorities for contributing to our improved understanding, management, and stewardship of valued coastal ocean resources. This document expands upon the Harmful Algal Bloom (HAB) section of this RCOOS plan to provide sub-regional information for algal species negatively impacting the region and serves as a guide for future investments in regional HAB observing and monitoring.
- High Frequency Radar Observing System: Gap Analysis - This document presents a gap analysis for High Frequency Radar (HFR) observations in North Carolina, South Carolina, Georgia, and Florida. It will serve as a guide for future HFR investments in the Southeast Coastal Ocean Observing Regional Association (SECOORA) region.

The 2026-2030 RCOOS Plan and the companion manuals (above) will provide a guide for future SECOORA investments.

1.2 SECOORA's Regional Coastal Ocean Observing System

SECOORA was established as a non-profit 501(c)(3) in the state of South Carolina in 2007. SECOORA has engaged representatives from a diverse set of stakeholders who are directly involved in defining SECOORA regional priorities as part of the U.S. IOOS efforts. Since 2007, SECOORA has received NOAA funds to build the Southeastern U.S. IOOS Regional Association (RA) and its Regional Coastal Ocean Observing System (RCOOS).

SECOORA invests in end-to-end RCOOS activities that are responsive to societal needs. SECOORA transforms data and analyses into value-added products and services. SECOORA also recognizes that meeting stakeholder needs requires a sound scientific approach. We therefore place emphasis on coordinating a multidisciplinary suite of coastal ocean observations with suitably chosen simulation models so that societally important phenomena may be described, understood, and ultimately predicted via models and applications.

The SECOORA RCOOS consists of:

				
Observing platforms and sensors	**Data management and communications**	**Modeling component**	**Products**	**Outreach and education**
Includes fixed stations, such as buoys and coastal stations, mobile platforms such as gliders and ships, and remote sensing instruments and platforms such as High Frequency Radar (HFR).	Supports seamless access to regional data. DMAC ensures that data are quality controlled and made available in standardized formats. Real-time data are provided to stakeholders via the SECOORA data portal.	Supports a numerical modeling framework (regional to sub-regional scale models). Observations from HFR, buoys, coastal stations, and gliders are linked to predictive models and decision-making tools.	Transforms raw and/or processed data into useful and meaningful decision-making information and tools.	Connects stakeholders to SECOORA data, products, and services and provides opportunities for students through awards, mentorship, and networking.

The RCOOS priorities for the 2026 - 2030 period are to sustain critical observing, modeling, product, and service activities while also seeking opportunities to add new multidisciplinary observing assets. SECOORA will incorporate innovative new technologies and continue to improve upon our effectiveness in meeting stakeholders' needs. Specifically, SECOORA seeks to:

- Effectively engage stakeholders to prioritize investments.
- Provide data management and communications (DMAC) infrastructure and expertise that supports the RCOOS enterprise.
- Sustain, expand, and modernize in situ stations and work with stakeholders to leverage opportunities to fill gaps in coastal and ocean stations.
- Sustain, expand, and modernize an autonomous vehicle program specifically targeted to address fisheries research, hurricane intensity forecasting, and characterization of the shelf waters in the Mid-Atlantic Bight (MAB), South Atlantic Bight (SAB), and West Florida Shelf.
- Sustain and expand the HFR network distributed from Cape Hatteras to West Florida and continue to fill priority HFR gaps.
- Collate multiple data streams including animal and ocean observations to address climate related impacts to ecosystems and fisheries.
- Support model products and where possible transition models to NOAA or other agencies to increase the use of models for management and decision-making.
- Continue delivery and refine automated model nowcast/forecast products and other products based on stakeholder needs.

1.3 Drivers in the Southeast

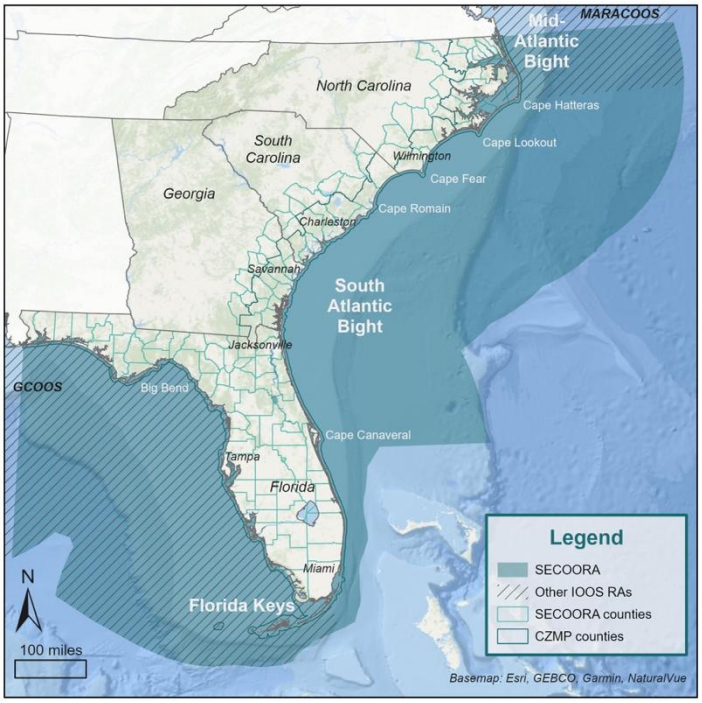
1.3.1 Economic

The ocean and coastal waters of the southeastern United States help drive local weather and regional climate conditions, support ecologically and economically significant ecosystems (which include important fisheries), and provide tourism, boating, fishing, viewing of marine life and marine habitats, and other recreational and commercial opportunities. In 2021, the ocean economy sector contributed $51.7 billion to the southeastern region's gross domestic product and provided over 706,000 jobs with over $25.5 billion in salaries (NOAA 2024a).

The economies and populations of the states in the SECOORA region (Florida, Georgia, North Carolina, and South Carolina) are growing quickly relative to other areas of the United States. According to the United State Census Bureau, the SECOORA states are 4 of the 5 fastest-growing states in the U.S. by raw population numbers, and 4 of the top 10 by percentage, with South Carolina being the fastest growing state in the country by percentage (2023). Many of the coastal counties in these states experienced 1.5% to over 3% this growth during the period July 1, 2022 - July 1, 2024 (United States Census Bureau, 2024). Florida's Gross Domestic Product (GDP) grew by the most of any state in the U.S. in 2023, with South Carolina third and North Carolina tenth (Statista, 2024). As the region becomes more populous and productive, understanding the coastal and oceanic environments to better protect the local people, infrastructure, and ecosystems becomes increasingly important to the economy and health of the country.

1.3.2 Oceanographic

The SECOORA footprint spans the four-state region of North Carolina (NC), South Carolina (SC), Georgia (GA), and Florida (FL) (**Map 1**) and four distinct ocean biogeographic regions, spanning the Gulf, the Florida Keys and Southeast Florida shelf, the South Atlantic Bight, and the southern limit of the Mid-Atlantic Bight. Connecting all four regions is the Loop Current-Florida Current-Gulf Stream continuum. The landward boundaries are also varied and distinct, from the NC Albemarle-Pamlico Sound complex, the extensive salt marshes of SC and GA, the coral ecosystems and coastal mangroves of southern FL, to the seagrass meadows of Florida's Big Bend region. Interspersed within these regions are the major population and port centers of Wilmington, NC, Charleston, SC, Savannah, GA, Jacksonville, FL and the greater Miami region, and Tampa Bay on the FL west coast.



Map 1: The SECOORA footprint covers NC, SC, GA, and FL.

Mid-Atlantic Bight and South Atlantic Bight
The South Atlantic Bight (SAB) extends from Cape Hatteras, NC, to Cape Canaveral, FL and is the transitional zone between the temperate waters of the Mid-Atlantic Bight (MAB) and the subtropical waters of the east Florida shelf. North of Cape Hatteras, the SECOORA region overlaps with the Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS) along the northeastern North Carolina coast. The SAB shelf is wide and shallow, and the physical dynamics are controlled by interactions with the Gulf Stream and the overlying atmosphere. Water movement is dominated by tidal, 2-day to 2-week synoptic scale atmospheric events, and 2- to 12-day Gulf Stream frontal waves. The seabed of the shelf is characterized by extensive, scattered hard bottom outcrops that support a diverse array of sponges, corals, and reef-associated fish.

The SAB supports a range of essential economic activities, including coastal development, shipping and commerce, fishing, boating, and tourism. This area is vulnerable to a variety of hazards, which include severe beach erosion, effects of storms and hurricanes, and high tide “nuisance” flooding. There is a compelling need to understand and predict estuarine and coastal maritime conditions in the region, which requires the establishment of a comprehensive observational network providing real-time and archived information on ocean and weather conditions. This information is needed to develop accurate predictions of shelf circulation in response to wind and Gulf Stream forcing, inform search and rescue, rip current, water level, and marine hazard forecasts, and provide operationally useful information on the status of ecosystem health and living marine resources.

East Florida and Florida Keys
The coastal ocean along the southeast coast of FL is characterized by a very narrow, shallow shelf, which is dominated by Gulf Stream variability and wind forcing. From the Florida Keys to approximately Cape Canaveral, the East-West envelope of Gulf Stream meander is largely confined by the narrowness of the Florida Strait, while from Canaveral northward, the offshore bathymetry constraint eases, and the meander envelope widens significantly. In addition, the slope separating the coastal ocean from the deeper ocean is steep along the East Florida Shelf. This bathymetry, along with the strong horizontal and vertical shears associated with the Florida Current immediately offshore, makes this a difficult region to model accurately. Yet, accurate prediction of shelf circulation response to varying wind and Florida Current forcing is critical to a variety of interests in the coastal ocean here, including search and rescue efforts, planning for mitigation of man-made hazards, and developing an understanding of circulation pathways between vital habitats along the coastline to inform fisheries interests. The East Florida Shelf and coastline encompasses several important ports and supports significant tourism and recreational fishing industries. The Florida Keys is a biologically rich area and the Florida Keys National Marine Sanctuary (FKNMS) protects the nation's only coral barrier reef (NOAA 2024b). FKNMS also serves as a nursery area for fish and invertebrates whose offspring recruit to other areas, supporting recreational and commercial fisheries throughout the Southeast. The Keys are an economic driver for Florida, providing recreation, tourism, and fishing opportunities for visitors from around the world.

West Florida
SECOORA overlaps with the Gulf of America Coastal Ocean Observing System (GCOOS) along the west coast of FL. The Gulf is a semi-closed basin connected to the Caribbean Sea and the Atlantic Ocean. The major current system is the Loop Current, which enters the Gulf through the Yucatán Channel, circulates clockwise in the eastern Gulf, and exits through the Florida Strait to eventually form the Florida Current which then joins the Gulf Stream along the eastern seaboard. Portions of the Loop Current break off forming eddies that affect regional current patterns throughout the Gulf.

The West Florida Shelf is most influenced by the Loop Current and its associated eddies, as well as discharges from major rivers. The Gulf is a suitable habitat for a diversity of harmful algae. The most

notable Harmful Algal Bloom (HAB) species is *Karenia brevis*. Due to coastal currents and winds, this species is found throughout the Gulf at varying concentrations and on occasion is transported to the east coast by the Florida Current. *Karenia brevis* produces a suite of neurotoxins known as brevetoxins which can kill fish, birds, and other marine animals as well as causing health problems in humans (FWC 1999).

The Gulf ecosystems support recreationally and commercially important fish species. Industry drivers in the Gulf include oil and gas, tourism, fishing, and shipping. The impacts of the Deepwater Horizon Oil Spill and frequent HAB events highlight the need to better understand how Gulf ocean circulation patterns disperse HABs and pollutants and affect fish and critical habitats.

1.4 National and Regional Partnerships and Priorities

1.4.1 National

SECOORA is one of eleven Regional Associations (RAs) supported through cooperative agreements from IOOS, the national-regional partnership working to provide new tools and forecasts to improve safety, enhance the economy, protect our environment, and foster environmental stewardship. SECOORA will continue efforts to ensure a strong and sustained IOOS. In partnership with the National Oceanic and Atmospheric Administration (NOAA), the IOOS Program Office, and other federal programs and offices, SECOORA addresses critical national priorities through initiatives that contribute to the Animal Telemetry Network (ATN), Marine Biodiversity Observation Network (MBON), Coastal Ocean and Modeling Testbed (COMT), and Ocean Technology Transition (OTT).

SECOORA is a certified Regional Coastal Observing System (RCOS) operating under a MOA with NOAA IOOS. This certification by NOAA acknowledges SECOORA as meeting federal standards for data gathering and management. In simple terms, this means that ocean and coastal data and information from SECOORA can be used with the same confidence and assurances as other federal data.

SECOORA is a member of the IOOS Association, working with ten other RAs to assure the needs and positions of on-the-ground users in the regions are adequately reflected in national policy and priority setting. SECOORA is actively engaged with other RAs, especially the neighboring RAs in the Gulf, Caribbean, and on the East Coast. These collaborations across regions help ensure efficient pooling of expertise and resources, limit redundancy, and improve effective transfer of knowledge.

There are many national efforts to collect information on U.S. and global observing system capacities. While we will not detail every partner-related technology or effort here, it is recommended that users review the following national plans:

NOAA's National Ocean Service (NOS) and NWS released The National Strategy for a Sustained Network of Coastal Moorings in 2017. At the time of writing, there were 370 existing coastal moorings located within the U.S. Exclusive Economic Zone with 215 operated by federal entities (NOAA and USACE) and 155 by non-federal entities (e.g. IOOS RAs and the National Science Foundation (NSF) Ocean Observatories Initiative). The Strategy evaluates this existing inventory and provides ten recommendations to guide the expansion of the coastal mooring network. The primary recommendation is to identify regional observing gaps best addressed with coastal moorings, using a targeted stakeholder engagement approach to integrate stakeholder input. This effort will be led jointly by NOAA mooring operators and IOOS RAs. This regional stakeholder input will ensure that the network addresses real needs and utilizes available resources efficiently and effectively.

In the report from the National Coastal Ecosystem Mooring Workshop, convened by the Alliance for Coastal Technologies in March 2018, the workshop participants identified the need for a backbone of core biogeochemical and physical measurements that are required to inform societal issues. Impediments to the deployment of these sensors include the cost/price for the sensors and the lack of suitability for deployment on moorings (e.g. wet chemistry sensors, biofouling concerns).

A Plan to Meet the Nation's Needs for Surface Current Mapping presents the uses of HFR, the requirements that drive the measurement of ocean surface currents, and the implementation design for a five-year, national build-out effort. This document was last updated in May of 2015.

NOAA CO-OPS provides accurate, reliable, and timely tides, water levels, currents, and other oceanographic information. CO-OPS operates the National Water Level Observation Network (NWLON) and the PORTS. The data, products and services provided by CO-OPS support safe and efficient navigation, ecosystem stewardship, coastal hazards preparedness and response, and a better understanding of climate change. Unfortunately, there are gaps in CO-OPS NWLON stations that need to be filled. These gaps are identified in A Network Gaps Analysis for the National Water Level Observation Network (NWLON), and gaps and existing stations were recently prioritized in the National Water Level Observation Network Prioritization.

1.4.2 Regional

SECOORA's mission is to observe, understand, and increase awareness of our coastal ocean and to promote knowledge and economic and environmental health through strong regional partnerships. Where possible, SECOORA partners with and supports other regional networks to leverage expertise and expand observing capacity. A few examples follow:

- Southeast Ocean and Coastal Acidification Network (SOCAN): An interdisciplinary network of scientists, resource managers, industry, non-profit, and government representatives dedicated to supporting and encouraging discussions on ocean and coastal acidification.
- Southeast Disaster and Caribbean Recovery Partnership (SCDRP): An affiliation of public, private, and nongovernment organizations (NGO) that provides training, resources, and relationships that coastal communities need to recover after a disaster.
- Southeast Regional Ocean Data Sharing Initiative: SECOORA's regional ocean data sharing (RODS) program is a partnership with coastal zone managers from NC, SC, GA, and FL. The program enhances regional capacity for sharing and integration of data to support coastal and ocean priorities. Funding for this initiative is provided by Congress and is a collaboration between IOOS and NOAA's Office for Coastal Management (OCM).
- NOAA Southeast and Caribbean Regional Collaboration Team (SECART): A means for NOAA and partners to engage at a regional scale (NC, SC, GA, FL, Puerto Rico (PR), and the U.S. Virgin Islands) and invites new approaches to develop products and services that are responsive to the region's changing economy and environment.
- FACT Network: A collaboration of scientists from the Bahamas to the Carolinas using acoustic telemetry and other technologies to better understand and conserve commercially, recreationally, and ecologically important fish and sea turtle species in freshwater, estuarine, and offshore aquatic habitats.
- Renewable Energy: The Atlantic Marine Energy Center, founded in 2022, is a Department of Energy Water Power Technologies Office funded effort to advance marine renewable energy with a wave energy test site off the Outer Banks. BOEM recently leased new blocks in the

SECOORA region to advance the development of offshore wind that will be informed by SECOORA observations in this region.

2. SECOORA Observing Assets

An RCOOS is a comprehensive operation that includes all the components necessary to collect observations and turn them into useful and meaningful information products. They include the following core components that are integrated into a unified system as summarized below:

- **Observing platforms** and sensors including fixed stations, such as buoys and coastal stations, mobile platforms such as gliders and ships, and remote sensing instruments and platforms such as HFR. Emerging technologies (e.g. eDNA) should also be evaluated as these technologies could provide data and information that had previously been unavailable or were not automated.
- **Data management and communications (DMAC)** supports seamless access to regional data. Additionally, DMAC ensures that data are archived, recorded and transmitted in standardized ways that are consistent in content and format with other providers of the same data. Real-time data are provided to stakeholders via the SECOORA data portal. **Artificial Intelligence and Machine Learning** (AI/ML) are helping process large amounts of data to develop new tools and data services. Computers can be trained to accomplish specific tasks by processing these data and recognizing patterns in the data (SAS 2019). Within the ocean observing realm, AI is being used to improve environmental models, quickly analyze seafloor images and create 3-D color reconstructions of the seafloor, and identify specific underwater noises collected by acoustic sensors (Schmidt Ocean Institute 2018).
- **The modeling component** supports a numerical modeling framework (regional to sub-regional scale models) to provide products for managers and other users. Observations from HFR, buoys, coastal stations, and gliders are being linked to predictive models and decision-making tools.
- **Products** transform raw and/or processed data into useful and meaningful decision-making information and tools.
- **Outreach and education** efforts connect stakeholders to SECOORA data, products, and services.

The SECOORA RCOOS provides coastal and ocean data, tools, and services in the following focus areas, which correspond with the U.S. IOOS® societal goals and are important to Southeast stakeholders:

- Coastal Hazards and Climate Variability
- Ecosystems, including Water Quality and Living Marine Resources
- Marine Operations

SECOORA investments in observing, data management, modeling, product, and service activities have been supported through IOOS 5-year cooperative agreements and through funding provided by the Bipartisan Infrastructure Law (BIL), Infrastructure Reinvestment Act (IRA), Ocean Technology Transition (OTT) and other supplemental funding opportunities. SECOORA's goal is to maintain these investments while continuing to grow the SECOORA RCOOS into the future. The following subsections describe current RCOOS investments, provide asset tables to highlight data provided by key observing platforms, and maps that highlight asset locations.

2.1 Current SECOORA RCOOS Investments

The RCOOS priorities for the 2026 - 2030 period are to sustain critical observing, data management and data products, modeling, education and outreach activities. SECOORA is also seeking opportunities to add new observing assets that address societal goals and are important to Southeast stakeholders within the focus areas of Coastal Hazards and Climate Variability; Ecosystems, including Water Quality and Living Marine Resources; and Marine Operations (see Section 3).

Much of the SECOORA RCOOS existing infrastructure has been in place for decades and provides key data for community stakeholders and state and federal partners. Existing RCOOS infrastructure is detailed below. Additionally, see section 2.2 for an Asset Inventory that includes more detailed information.

Observing Assets

- 20 real-time buoys and 4 non real-time moorings offshore of NC, SC, and the east coast of FL and the West Florida Shelf that collect core physical, meteorological, and biogeochemical variables. These data are vital for coastal zone, marine, and hurricane forecasting, rip current forecasting, and tracking pollutants and HABs.
- 22 HFR in NC, SC, GA, and FL provide circulation, wave response and support fisheries management and research.
- 4 real-time coastal stations in Estero Bay, FL that support HAB monitoring.
- 5-8+ glider missions annually that collect surface and subsurface physical and biogeochemical data. Subsurface data are ingested into ocean models to validate and improve model output (e.g. hurricane intensity forecasts). Two gliders are equipped with acoustic receivers to record tagged fish or can be equipped with passive acoustic recorders to “listen” for fish and marine mammal (e.g., right whale) sounds.
- SECOORA and partners operate and maintain 17 active coastal web cameras in NC, SC, and FL. The camera feeds are used to observe shorelines, detect rip currents, validate wave run-up models, document community flooding concerns, view & count wildlife, and improve situational awareness for public safety applications. SECOORA funds data management and detection algorithm integration for camera imagery data.
- 100+ lower cost water level sensors have been deployed by SECOORA and our partners throughout the region to inform communities of flooding and storm surge. Additionally, Flood waters often contain contaminants so alerting communities to flooding is a priority.
- 9 passive acoustic recorders deployed to record biological (e.g., snapping shrimp, fish, and marine mammals) and geophysical sounds as well as anthropogenic noise in the marine environment. These recorders along with temperature and salinity sensors are deployed as fixed moorings in estuarine waters of SC.
- FACT acoustic receivers deployed on 4 SECOORA funded moorings in NC, 3 moorings in south FL, and on 2 SECOORA gliders that operate in the SAB. Receivers record the presence of tagged fish, allowing for detections in areas farther offshore.
- FACT Network partners operate over 800 stations with acoustic receivers in the Southeastern U.S. and over 500 receivers include temperature data which is shared with SECOORA. These temperature data help monitor subsurface temperature around the region and in key geographic areas such as the Florida Keys National Marine Sanctuary and Gray’s Reef National Marine Sanctuary.

- SECOORA is partnering with REEF and the South Atlantic Fishery Management Council to test underwater cameras equipped with measuring tools so that divers can capture fish images to record fish species and length at key reef areas in the Florida Keys.
- SECOORA and partners support ocean acidification monitoring at the Gray's Reef NMS and in the Lower Florida Keys (Looe Key) through the installation and maintenance of climate quality OA monitoring systems.
- SECOORA is working with state and federal agencies to repair and fund the expansion of Surface Elevation Table (SET) monitoring stations in coastal estuaries across the southeast. These passive monitoring stations allow researchers and state agencies to monitor relative elevation change of wetland sediments, informing them on sea level rise and/or anthropogenic impacts to marsh ecosystems.

Data Management

- The SECOORA data portal and data catalog provide access to real-time and non real-time data, models, and satellite data derived from SECOORA funded and non-funded partners and federal and state agencies.
- The SECOORA data management and detection algorithm integration for WebCOOS cameras turns imagery into relevant information about coastal hazards and management, including shoreline change, rip currents, beach usage, and community flooding.
- SECOORA works with the SC Department of Natural Resources (SCDNR) to advance the IOOS Marine Biodiversity Observation Network (MBON) through fisheries data stewardship for the Southeast region. SCDNR is standardizing fisheries data and metadata to be Darwin Core compliant to increase interoperability of data and align with OBIS best practices.
- SECOORA hosts the cloud-based FACT Network database node and provides support for data upload, quality control, processing, sharing, and archival system for acoustic telemetry detection data in the FACT database.

AI/ML

- SECOORA partners at Florida Fish and Wildlife Research Institute (FWRI) are developing machine learning techniques to autonomously detect, classify, and alert to ocean sounds in real-time (e.g. fish, marine mammals, anthropogenic).
- SECOORA and partners are developing and operationalizing machine learning algorithms based on web camera data to identify people, birds, and watercraft from web camera images to link beach activities (i.e., human use) with beach warnings (e.g., rip current and swim advisories).
- Continue to develop and operationalize machine learning algorithms based on real-time measurements from multiparameter sondes to predict microbial water quality.

Modeling

- SECOORA partners operate the Tampa Bay Coastal Ocean Model (TBCOM) and the West Florida Coastal Ocean Model (WFCOM). These models provide four-dimensional marine circulation and storm surge nowcasts/forecasts for the eastern Gulf. These models enable Harmful Algal Bloom (HAB) tracking and forecasts and pollutant/oil spill trajectory modeling.
- Coupled Northwest Atlantic Prediction System (CNAPS) model provides four-dimensional nowcasts and forecasts of the marine environment. Additionally, CNAPS can provide storm characteristics (e.g., wind structure, storm intensity and tracks).

Products

- The Text-A-Buoy system allows users to get the latest ocean and weather information from buoys in the region.

- The Southeast Water Level Network provides access to SECOORA and partner water level data within the Southeast.
- Eyes on the Storm is an interactive SECOORA portal that connects users to live and past hurricanes and tropical storm data. The tool pulls data from within 50 miles of a hurricane's path and showcases the highest wind speeds and wave heights and lowest barometric pressure.
- The FACT Data Visualization Tool (DaViT) is a user-friendly interactive web tool that allows users to visualize movement information of specific fish, invertebrate and aquatic reptile species along with their range and seasonal trends. Data contributors for every visualization are acknowledged with links to project pages allowing fisheries managers to identify and contact persons doing research on species of interest.
- How's the Beach provides daily water quality nowcasts for select recreational waters and swimming beaches based on ensemble modeling and machine learning. Data needs include rainfall, salinity, wind conditions, tide, and water temperature as well as lunar phase and anthropogenic activities and influences.
- The Beach Conditions Reporting System (BCRS) provides condition reports for beaches and coastal recreation areas. This citizen-science program is supported by volunteer Beach Ambassadors that undergo training to make accurate condition reports. There are several sites located along the east and west coasts of Florida, South Carolina, North Carolina, Georgia, and the Gulf coast.
- ShellCast is a precipitation-based water quality forecasting system that alerts shellfish growers and resource managers about predicted lease closures using rainfall predictions from the National Weather Service. Predictions cover shellfish waters along the North Carolina, South Carolina, and Florida coasts.
- The Southeast Marine Mapping Tool provides access to regional ecological data to help inform offshore ocean use decisions.
- The WebCOOS website includes a clickable map of each camera location, a listing of all the WebCOOS cameras, and links to product and documentation pages. Each camera's page shows a livestream video (if applicable), archived imagery, and any annotated imagery products that have been produced at that site.

Education and Outreach

- SECOORA hosts K-12 education materials based on common terminology and concepts for meteorology and physical oceanography. Waves, Build-a-Buoy, and Ocean Observing Technology are featured.
- SECOORA hosts K-12 hurricane education materials that includes a glossary of common terminology and concepts for hurricane meteorology and physical oceanography and lesson plans that address storm surge and barometric pressure.
- Sea Level Rise Curriculum: The K-12 classroom curriculum provides foundational science principles and allows middle school students to use real data to create data visualizations of sea level rise.
- Water Shapes Our Planet: This virtual science unit with a hands-on component provides a unique experience where students explore local weather, discover and craft tools used by scientists to collect weather data, and evaluate long-term trends recorded by climate scientists.
- The SECOORA Hurricane Resources webpage provides a curated list of hurricane data resources for the southeast (updated annually). Additionally, SECOORA supports individual hurricane data pages for storms that could potentially make landfall in the SECOORA region.
- The SECOORA Red Tide Data Resources for Florida page is a curated list of data resources related to the Florida Red Tide, specifically the Harmful Algal Bloom (HAB) species *Karenia brevis*. The website includes current reporting, models, and observing tools.

- The Georgia Harmful Algal Bloom monitoring program incorporates high-resolution, quantitative HAB monitoring in the Skidaway River Estuary to determine environmental conditions conducive to HAB formation in Georgia estuaries. The webpage provides an overview of the project and daily cell counts for the HAB species *Akashiwo sanguinea*.
- The Estuarine Soundscape Observatory Network (ESONS) provides examples of sounds recorded by passive acoustic recorders in four SC estuaries. These recordings provide information on the behavior of snapping shrimp, spawning patterns of fish, foraging patterns and communication of bottlenose dolphins, and noise levels associated with human activity.
- The FACT node includes over 45 partner agencies and institutions using acoustic telemetry to resolve the movements of aquatic species and can summarize and share data with BOEM.
- The Southeast and Caribbean Disaster Resilience Partnership (SCDRP) is a SECOORA network that seeks to strengthen community resilience and support rapid disaster recovery from storms and disasters by serving as the primary network for professionals in emergency management, climate adaptation, and disaster recovery in the U.S. Southeast and Caribbean territories.

2.2 RCOOS Asset Inventory

2.2.1 Buoys and Coastal Ocean Moorings

Background
The National Strategy for a Sustained Network of Coastal Moorings states, “meteorological measurements and in-situ oceanographic observations of physical, chemical, and biological conditions throughout the water column...provide the backbone of coastal intelligence (NOAA 2017).” Moored stations, frequently referred to as buoys, are typically defined as an asset that is anchored to the seabed which provides time-series measurements at the water surface and/or at one or multiple depths within the water column. These are platforms that can be used to deploy sensors which allow scientists and other stakeholders to monitor environmental conditions. A single coastal mooring may be used to support the sensors for multiple scientific studies (NOAA 2017). Additionally, moorings can provide baseline long-term observations to support climate change assessments, including tracking sea surface temperature changes over time (climatology) and ocean acidification.

Current Capacity
SECOORA, with partners at the University of North Carolina Wilmington (UNCW) and the University of South Florida (USF), maintain real-time buoys and non real-time seafloor moorings offshore of NC, SC, and FL. Fixed buoys operated by SECOORA augment the NOAA NDBC mooring array with regional observations for the marine environment. The SECOORA funded data are used by an array of stakeholders, such as NOAA NWS for nowcasts/forecasts of weather and ocean conditions, US Coast Guard (USCG) to initiate their SAROPS (search and rescue) model, and state agencies to assist with HAB tracking. SECOORA has partnered with NOAA Pacific Marine Environmental Laboratory (PMEL) and the University of Georgia (UGA) to support the long-term Ocean Acidification (OA) mooring located in Gray’s Reef National Marine Sanctuary. Through BIL funding, SECOORA worked with Mote Marine Laboratory and Aquarium (MML) to install an OA sensor suite within the Florida Keys National Marine Sanctuary, specifically Looe Key, FL.

Based priorities identified in the 2020-2025 Regional Coastal Ocean Observing System (RCOOS) Strategic Operational Plan, SECOORA was able to expand and buoy and mooring operations as follows:

- Charleston Harbor, SC wave buoy and meteorological and physical oceanographic buoy in 2022.
- Ponce de Leon, FL wave and meteorological and physical oceanographic buoy in 2023.
- Fort Pierce, FL meteorological and physical oceanographic buoy in 2023.
- Fripp Island, SC wave buoy was deployed next to the existing meteorological and physical oceanographic buoy in 2023.
- Ocean Acidification mooring in Looe Key, FL in 2024.

Through initial funding from the National Academies of Sciences, Engineering, and Medicine (NASEM), USF deployed an oceanographic buoy 100 nautical miles southwest of Naples, FL. This buoy, named C22, fills a critical gap in the SECOORA observing footprint on the West Florida Shelf by capturing Loop Current dynamics.

Through funding provided by the Florida Department of Environmental Protection (FDEP), USF developed the Tampa Bay Observing Network (TBON). TBON consists of five real-time stations measuring water quality, meteorology, and currents within Tampa Bay. Real-time water quality and meteorological data are freely accessible to the public via the TBON website, SECOORA, and NDBC.

Core Variables Collected

Real-time data collected by sensors on buoys and non real-time data collected by seafloor moorings address the need to document variability in the nearshore and offshore environments. The SECOORA real-time buoys measure meteorological and ocean surface conditions. There are several non-real-time stations in the SECOORA footprint that measure subsurface conditions. See **Table 1** for a list of SECOORA buoys and moorings and the variables collected. See **Table 2** for the list of OA and biogeochemical data collected from Gray's Reef and Looe Key moorings. **Map 2** identifies the locations for each station.

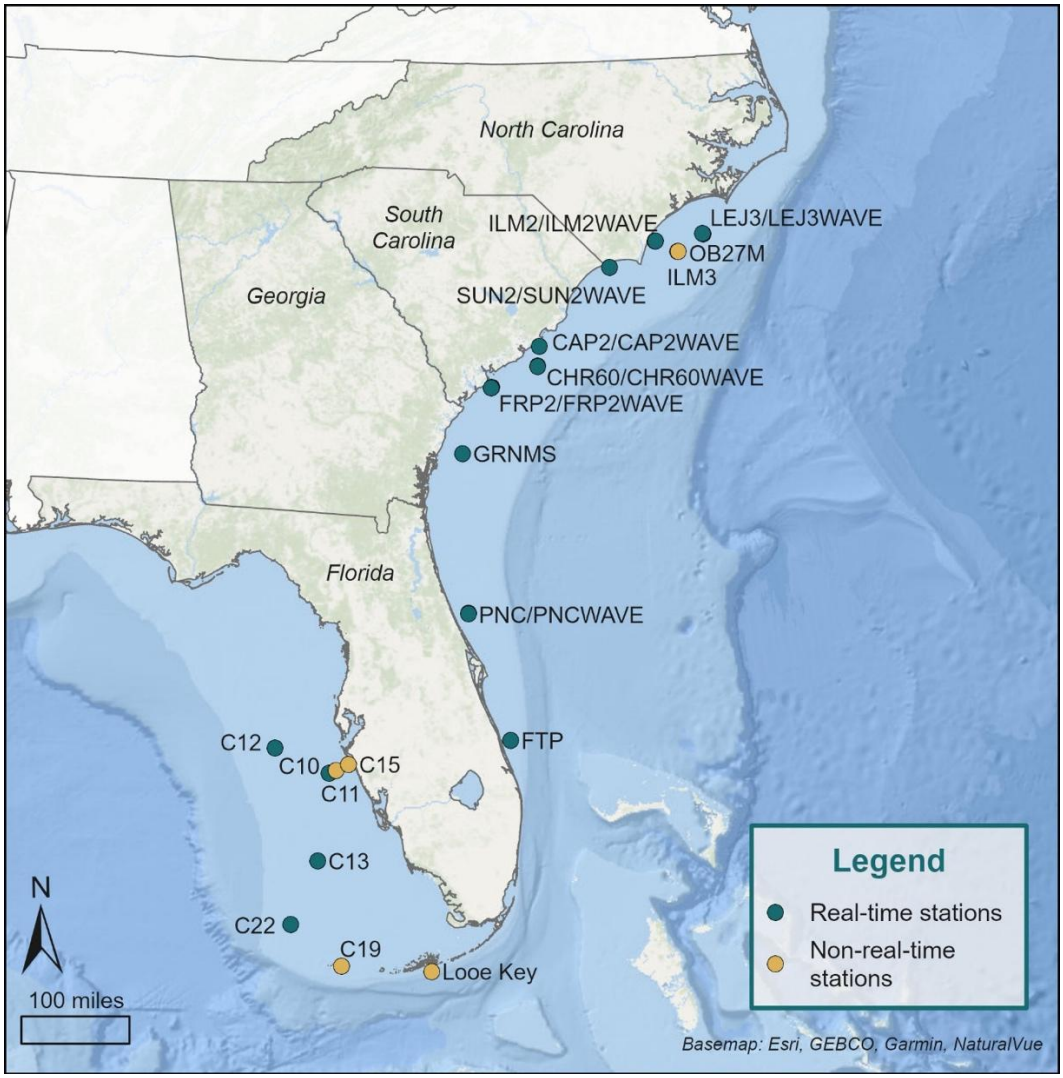
Table 1. SECOORA real-time buoys and non-real time moorings and variables collected

Buoy Name	Wind Speed, Gust, Direction	Air Temp	Barometric Pressure	Relative Humidity	SW/LW Radiation	Water Temp	Currents	Waves	Cond/ Salinity	Acoustic Receivers
UNCW Buoys and non real-time seafloor moorings										
LEJ3 - Outer Onslow Bay	X	X	X	X		X			X	X
LEJ3Wave						X		X		
ILM3 - Outer Onslow Bay	X	X	X	X		X			X	X
ILM2 - Inshore Onslow Bay	X	X	X	X		X			X	
ILM2Wave						X		X		
SUN2 - Northern Long Bay	X	X	X	X		X			X	X
SUN2Wave						X		X		
OB27M - Onslow Bay*						X	X	X	X	
CHR60	X	X	X	X		X			X	X
CHR60Wave						X		X		

Buoy Name	Wind Speed, Gust, Direction	Air Temp	Barometric Pressure	Relative Humidity	SW/LW Radiation	Water Temp	Currents	Waves	Cond/ Salinity	Acoustic Receivers
CAP2 - Inshore Capers Island	X	X	X	X		X			X	
CAP2Wave						X		X		
FRP2 - Inshore Fripp Island	X	X	X	X		X			X	
FRP2Wave						X		X		
PNC - Ponce de Leon	X	X	X	X		X			X	
PNCWave						X		X		
FTP - Fort Pierce	X	X	X	X		X			X	X
USF Buoys and non real-time seafloor moorings										
C10 - WFS Central nearshore	X	X	X	X	X	X	X		X	
C12 - WFS Central offshore	X	X	X	X	X	X	X		X	
C13 - WFS South	X	X	X	X	X	X	X		X	
C11 - WFS Subsurface*						X	X	X		
C15 - WFS Subsurface*						X	X	X		
C19 - WFS Subsurface*						X	X	X		
C22 - WFS South	X	X	X	X		X				
*Non real-time seafloor station										

Table 2. SECOORA OA Moorings

	Water temperature	Salinity	pCO_2 (air)	pCO_2 (seawater)	pH	DO
UGA OA Mooring						
Gray's Reef NMS	X	X	X	X	X	X
Mote Marine Laboratory OA Mooring						
Looe Key, Florida Keys NMS*	X	X			X	X
*Non real-time seafloor station						



Map 2. SECOORA funded real-time buoys and non real-time moorings within the region.

2.2.2 Coastal Stations

Background

Coastal stations are operated by federal, state, local, and academic partners. Coastal stations can be configured with sensor suites to meet a variety of stakeholder needs. Many of the sensors for coastal stations are attached to piers, pilings, or other structures. While more easily accessible than offshore moored stations, coastal stations often require more routine maintenance. SECOORA partners who operate coastal stations include:

- NOAA CO-OPS operates water level stations in NC, SC, GA, and FL. CO-OPS also works with partners to operate PORTS stations at major port locations in the SECOORA region including Charleston, SC, Savannah, GA, Jacksonville, FL, Miami, FL, Port Everglades, FL, and Tampa Bay, FL.
- NOAA's National Estuarine Research Reserve System (NERRS) has seven reserves in the Southeast. As part of the national System-Wide Monitoring Program, they collect estuarine water quality and meteorological data, and other physical and biogeochemical data. SECOORA

has previously funded instrumentation for deployment at the North Inlet - Winyah Bay NERR to expand water quality monitoring.
- Indian River Lagoon Observatory Network of Environmental Sensors (IRLON) operates 14 sites in the Indian River Lagoon and the St. Lucie Estuary on the east coast of FL.

Current Capacity
The SECOORA Water Level Network began in 2021 through IOOS funding with partners from the American Shore and Beach Preservation Association (ASBPA), Hohonu, Georgia Tech, Coastal Carolina University (CCU), Florida Atlantic University (FAU), and Florida International University (FIU). SECOORA and partners operate over 100 water level stations across the 4-state southeast region. Water level data is used to address a range of community needs such as emergency planning, identifying options for ingress/egress during flooding, and monitoring the total number of high tide flood events. CCU and FAU include meteorological sensors at their sites to better correlate weather patterns with changes in water level. FIU hosts citizen science events to build awareness of King Tides and water quality issues related to flooding caused by King Tides. Through 2022 - 2027 BIL funding and 2024 - 2029 IRA Topics 1 and 2 funding, SECOORA has prioritized the installation of water level sensors in flood prone communities.

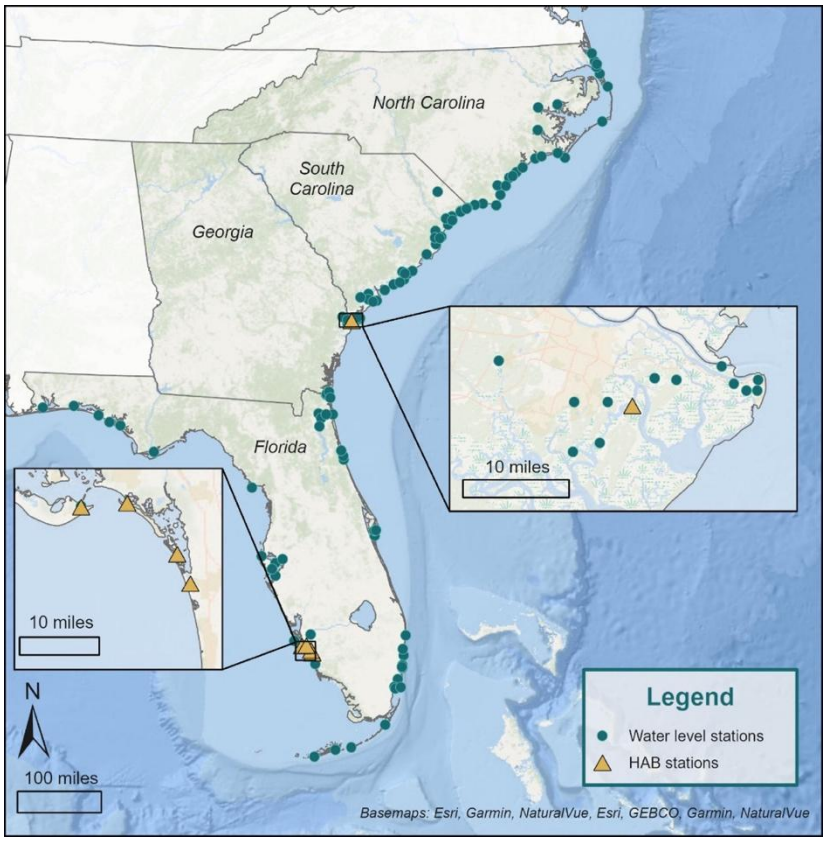
The Southeast Water Level Workshop was hosted in June 2023 by SECOORA and NOAA CO-OPS to address water level needs within the Southeast. The workshop report provides an overview of the current water level operators, sensor technology, data products, station and data management best practices, and key gaps in water level observations. The gap assessment provides critical information for the SECOORA Regional Coastal Ocean Observing System Plan.

Through IOOS supplemental HAB funding provided as part of the SECOORA 2021-2026 IOOS award, SECOORA is working with Florida Gulf Coast University (FGCU) and UGA Skidaway Institute of Oceanography (SkIO) and Marine Extension & Georgia Sea Grant on two HAB monitoring projects. Both projects have established coastal monitoring stations for HAB tracking. FGCU is sharing water quality and meteorological data from four shore-based stations within the southwest Florida watersheds of Estero Bay and San Carlos Bay. FGCU also collects Imaging Flow Cytobots (IFCB) samples from the four live streaming stations. These samples are being used to develop an updated phytoplankton genera classifier to better understand potential HAB bloom dynamics in the coastal zone. The long-term goal of this effort is to refine and update this classifier so it can be compared to other SECOORA and GCOOS partners to develop a consolidated classifier. This classifier will allow for overall regional comparison of phytoplankton community distributions and diversity of potential HAB species. FGCU is also collecting discrete water samples monthly from all four live streaming stations using YSI ProSample Autosamplers. These samples are used to determine estuarine nutrient parameters during chlorophyll a peaks to measure if nutrient concentrations are peaking or being removed during potential bloom events.

SkIO and Marine Extension & Georgia Sea Grant is implementing the first HAB monitoring program for the state of Georgia. The team is documenting the relationship between cell densities of HAB species and water quality parameters in the Skidaway River Estuary. The project goal is to identify environmental conditions that are conducive to HAB formation in Georgia estuaries with a specific focus on the HAB *Akashiwo sanguinea.* The team conducts weekly measurements of water quality, nutrients, and cell densities in non-summer months in the estuary. During summer months and through fall, the sampling frequency increases daily to capture seasonal biological and chemical transitions in the phytoplankton community. Cell counts are obtained via a FlowCAM fluid imaging system.

The water level, water quality, and meteorological data ingested by SECOORA is provided to the public via the SECOORA Data Portal and cell counts for the HAB *Akashiwo sanguinea*, found in the Skidaway

River, GA are found here: https://secoora.org/georgia-harmful-algal-blooms/. The water level data are also provided on the SECOORA developed, mobile friendly website Southeast Water Level Network (https://wl.secoora.org).



Map 3: SECOORA water level stations are depicted as green dots and the HAB monitoring locations are identified in the call out boxes as yellow triangles.

Core Variables Collected

Water level data are provided for real-time stations within the SECOORA region (see map locations in Map 2). Water quality and meteorological data are collected in real-time and delayed mode at HAB stations in Georgia and Florida. The water quality variables collected at each station are found in **Table 3** and the locations are identified in **Map 3**.

Table 3. SECOORA HAB monitoring stations

	Water Temp	Salinity	Chl	FDOM	DO	O_2	pH	Turbidity	Phycoerythrin
FGCU coastal stations in Estero Bay, FL									
Vester Field Station	X	X	X	X	X	X	X	X	X
New Pass Bridge	X	X	X	X	X	X	X	X	X
Gulf Star Marina	X	X	X	X	X	X	X	X	X
Sanibel City Dock	X	X	X	X	X	X	X	X	X
UGA SkIO Marine Extension & GA Sea Grant									
Skidaway River	X	X	X				X	X	

2.2.3 High Frequency Radar

Background
Just as the winds in the atmosphere provide information about where and when weather systems occur, ocean currents determine the movement of oceanic events (NOAA 2015b). High Frequency Radar (HFR) is used to measure the speed and direction of ocean surface currents. HFR can measure currents over a large region of the coastal ocean, from a few kilometers out to ~200 km offshore, and can operate under any weather conditions. They are located near the water's edge and need not be situated atop a high point of land (IOOS website). Monitoring coastal current speed and direction is essential for oil spill and point source pollution tracking and prediction, search and rescue, marine navigation, HAB forecasts, marine protected area and ecosystem management, effects of climate change on coastal ecosystems, and coastal zone management (NOAA 2015b).

Current Capacity
SECOORA's highest priority is to maintain the existing SECOORA HFR assets which provide detailed surface current data (i.e. current speed and direction) from 22 stations throughout the SECOORA region. See Table 4 for a list of HFR locations, operators, the year installed, and frequency for each station.

Based priorities identified in the 2020-2025 Regional Coastal Ocean Observing System (RCOOS) Strategic Operational Plan, SECOORA was able to expand HFR operations as follows:

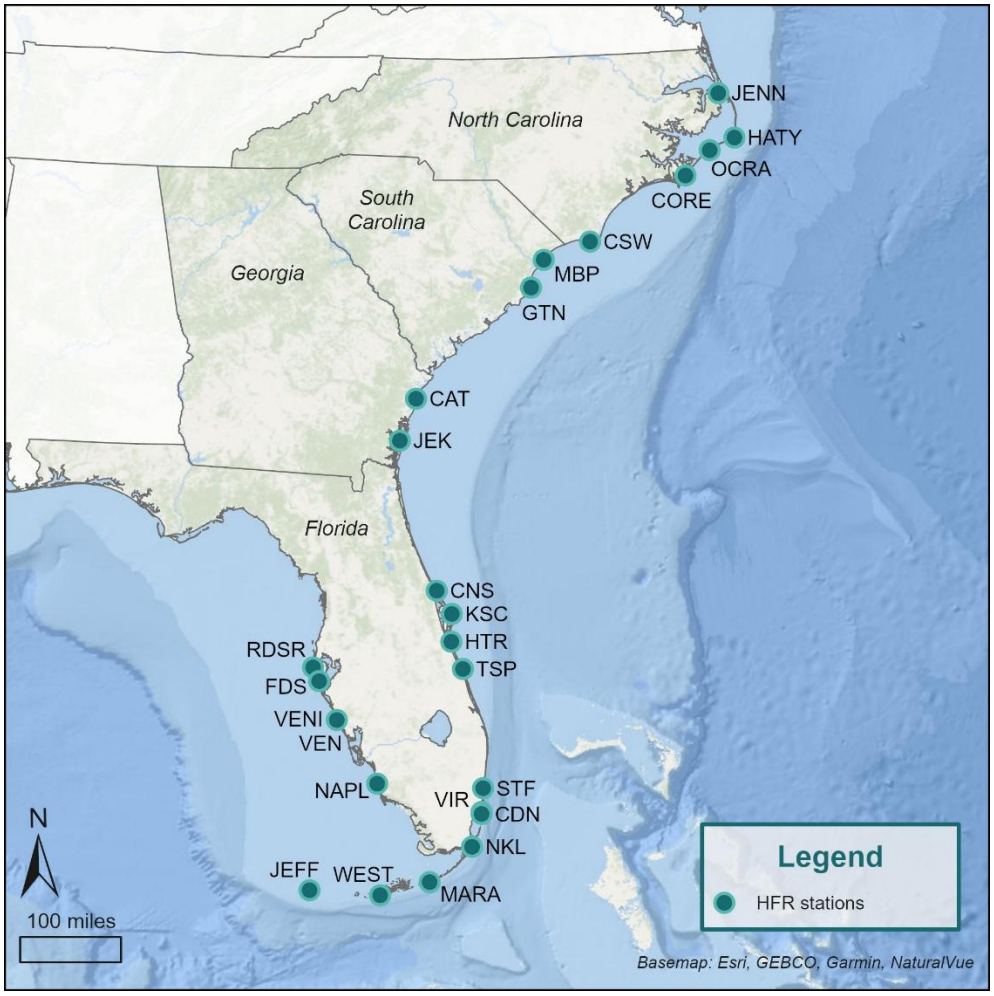
- Myrtle Beach State Park, SC (2021) installed and operated by the University of South Carolina (UofSC)
- Treasure Shores Park, FL (2022) installed and operated by Florida Institute of Technology (FIT)
- Cape Canaveral, FL (2022) installed and operated by the UGA Skidaway Institute of Oceanography (SkIO)
- Hightower Beach Park, FL, (2024) installed and operated by FIT
- Kennedy Space Center, FL (2024) installed and operated by SkIO

Through funding provided by the National Academies of Sciences, Engineering, and Medicine (NASEM), three additional HFR were installed in Florida that fill critical gaps in the SECOORA HFR footprint. These stations require funding for sustained operations and maintenance as outlined in the 2022 SECOORA High Frequency Radar Observing System: Gap Analysis. These stations are identified as MARA, JEFF, and WEST in Table 4. Map 4 provides a map of HFR installations throughout the region.

Table 4. HFR Stations by operator, location, manufacturer and frequency

Operator	Station Name	Year Installed	Location	HFR Type	Frequency (mHz)
ECU Coastal Studies Institute (CSI) & UNC-CH	DUCK/moved to JENN	2003 (DUCK)/2023 moved to JENN	Duck, NC moved to Nags Head in 2023	CODAR	5
ECU CSI & UNC-CH	HATY	2003	Buxton, NC	CODAR	5
ECU CSI & UNC-CH	OCRA	2017	Ocracoke, NC	CODAR	5

Operator	Station Name	Year Installed	Location	HFR Type	Frequency (mHz)
ECU CSI UNC-CH	CORE	2013	Core Banks, NC	CODAR	5
UofSC	CSW	2013	Caswell Beach, NC	WERA	5
UofSC	GTN	2012	Georgetown, SC	WERA	5
UofSC	MBP	2021	Myrtle Beach State Park, SC	WERA	13
SkIO	CAT	2006	St. Catherine's Island, GA	WERA	5
SkIO	JEK	2009	Jekyll Island, GA	WERA	13
SkIO	CNS	2022	Canaveral National Seashore, FL	WERA	13
SkIO	KSC	2024	Kennedy Space Center, FL	WERA	13
FIT	TSP	2022	Treasure Shores Park, FL	WERA	13
FIT	HTR	2024	Hightower Beach Park, FL	WERA	13
UM	STF	2008	Dania Beach, FL	WERA	12
UM	VIR	2008	Virginia Key, FL	WERA	13
UM	CDN	2004	Crandon Park, FL	WERA	13
UM	NKL	2020	North Key Largo, FL	WERA	13
USF	RDSR	2003	Redington Shores, FL	CODAR	5
USF	VENI	2004	Venice, FL	CODAR	5
USF	NAPL	2005	Naples, FL	CODAR	5
USF	FDS	2010	Ft. DeSoto Park, FL	WERA	13
USF	VEN	2010	Venice, FL	WERA	13
USF	MARA*	2019	Marathon, FL	CODAR	5
USF	WEST*	2022	Key West, FL	CODAR	5
USF	JEFF*	2024	Fort Jefferson/Dry Tortugas, FL	CODAR	5
* These sites were funded by NASEM to monitor the currents through the Straits of Florida.					



Map 4. High Frequency Radar (HFR) sites within the SECOORA domain.

2.2.4 Autonomous Vehicle Observatory

Background

Autonomous vehicles such as gliders and surface vehicles collect high spatial density data that augment moored buoy arrays, HFR, and satellite data. Most autonomous vehicles are easy to deploy, and all are flexible in terms of mission objectives and event response **(Image 1)**. Further, they can be deployed for days-to-months collecting environmental data. The use of autonomous vehicles is often more cost effective than ship-based, crewed surveys, especially for long duration missions or repetitive tasks. Gliders are now used by SECOORA and other IOOS RAs to help characterize the vertical and horizontal structure of the water column, providing important observations for assimilation into numerical models, such as hurricane intensity models, operated by the U.S. Navy and NOAA Atlantic Oceanographic and Meteorological Laboratory (AOML).

Image 1: University of South Florida glider, Sam, being deployed from the R/V *Nancy Foster* (credit: Julia Wallace).

Current Capacity

SECOORA invested funds from the 2016-2021 SECOORA IOOS award to establish a glider observatory for monitoring of shelf circulation and water properties in the SAB. Through Fill-the-Gaps funding provided by NOAA during Year 3 of this award (2019), SECOORA was able to purchase the G3 Slocum glider, named Franklin. We have continued these investments into the 2021-2026 SECOORA IOOS award and have successfully completed 4-5 glider missions annually in the SAB and West Florida Shelf. The SECOORA glider operators have added 2 additional hurricane glider missions each year and SECOORA was able purchase an additional G3 Slocum glider, Unit 1091, in 2022 through funding from the Disaster Relief Supplemental Award to Accelerate Improvements in Hurricane Intensity Forecasting Through Underwater Glider Field Campaigns. SECOORA is continuing to prioritize glider funding through our BIL and IRA funding by supporting hurricane glider missions and right whale monitoring missions in the SAB. Mobile platforms, outfitted with passive acoustic receivers, can operate within the right whale winter calving grounds offshore of SC, GA, and northern FL to listen for marine mammals with the express purpose of monitoring right whales.

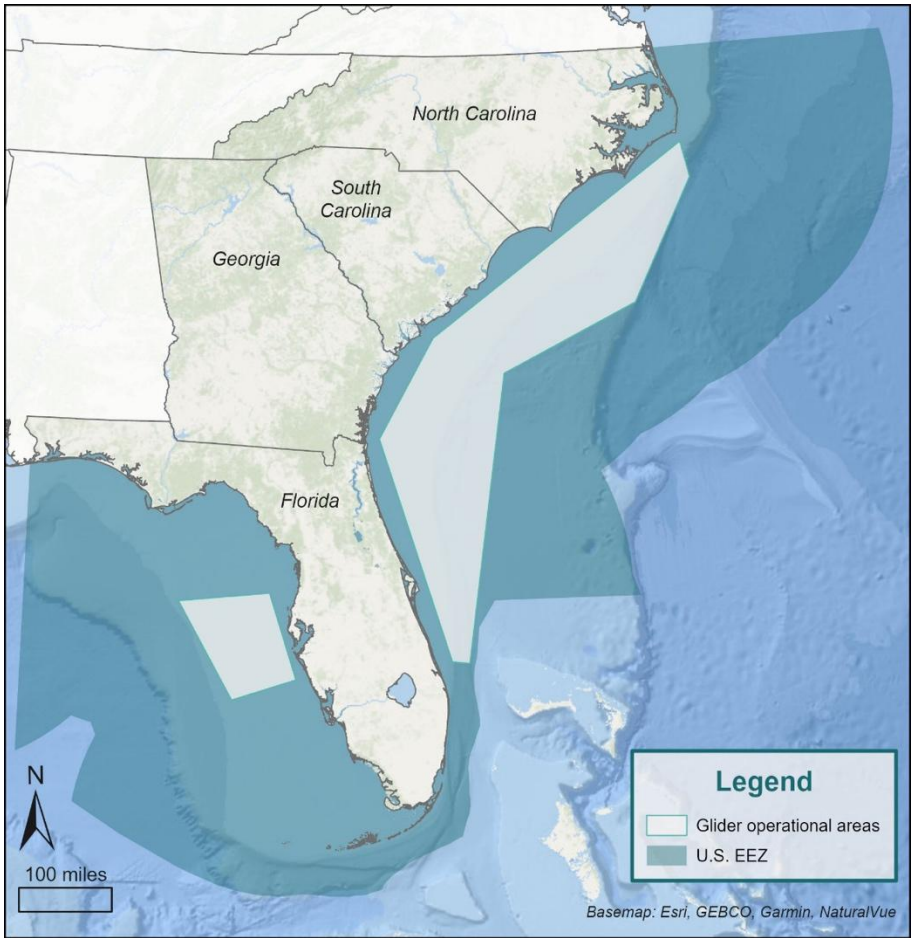
Glider Fleet: Gliders currently being used for the SECOORA Glider Observatory are owned by SECOORA (operated and maintained by SkIO), SkIO, USF, UNCW (operated and maintained by SkIO), and North Carolina State University (NCSU), operated and maintained by SkIO). See Table 5 for a list of gliders operated within the SECOORA footprint. Map 5 highlights the glider operational areas in the SAB and West Florida Shelf.

Core variables collected

Sensors on gliders measure physical variables such as pressure, temperature, salinity, currents, biological variables relevant to the abundance of phytoplankton and zooplankton, and ecologically important chemical variables such as DO and nitrate. A full list of variables that can be collected by each glider is available in **Table 5**.

Table 5. Gliders within the SECOORA observatory and data than can be collected by each. Note that note all sensors are deployed on the glider for every mission.

Glider Name	Owner/ Operator	Year manufac-tured	Conduct-ivity	Temp.	Salinity	DO	Chl-a	CDOM	Back-scatter	Passive acoustic receiver (tags)	Passive acoustic monitoring (soundscape)
Franklin	SECOORA/ SkIO	2019	X	X	X	X	X	X	X	X	X
1091	SECOORA/ SkIO	2023	X	X	X	X	X	X	X	X	X
Angus	SkIO	2018	X	X	X	X	X	X	X	X	X
Pelagia	UNCW/SkIO	2006	X	X	X	X	X	X	X		
Salacia	NCSU/SkIO	2008	X	X	X						
Bass	USF	2008	X	X	X	X	X	X	X	X	X
Sam	USF	2008	X	X	X	X	X	X	X	X	X



Map 5. SECOORA glider missions occur along the South Atlantic Bight and on the West Florida Shelf. The sensors included on each glider are often mission specific and can range from monitoring subsurface conditions to inform HAB tracking or hurricane intensity to monitoring right whale calving grounds.

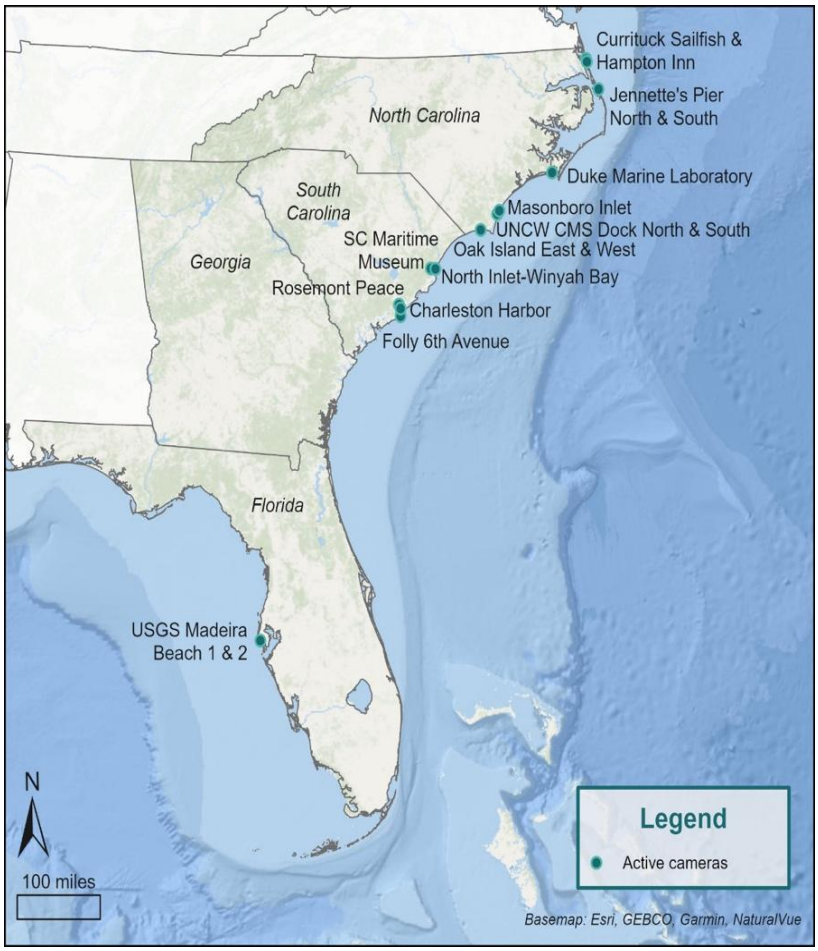
2.2.5 Web Cameras

Background

Shore-based web cameras are becoming more readily available to the science community and are transforming coastal environmental monitoring **(Image 2)**. Improvements in camera technology and image processing capabilities, paired with decreases in cost, enable widespread use of camera systems by researchers and for a growing range of environmental monitoring applications. Dusek et al. (2019) describes how web camera video imagery can help with coastal monitoring, and these uses fall into the following categories: coastal morphological change, hydrodynamics, human impacts on coastal resources, recreation and weather observations, and ecological, environmental, and water quality observations.

The NOAA WebCAT pilot project was launched in 2017 as a public-private partnership between SECOORA, Surfline, Inc., and other collaborators. The goal of WebCAT was to evaluate the application of web camera data to address environmental monitoring needs and to standardize observations made by web cameras. A major outcome of this project was the development of best practices on web camera installation so that future camera installations can meet standards for scientific use. Following the WebCAT project, the Launching WebCOOS project started in 2020 with NOAA OTT funding to develop an operational web camera coastal observing network in the SECOORA region. The WebCOOS network expanded from 7 cameras to over 20 as the team engaged camera operators, partners, and end users and automated processing of information from web camera imagery. AI/ML algorithms for a variety of coastal applications, including shoreline change, beach usage, ecological monitoring (bird and seal detection and counting), and rip currents, were also developed and integrated at scale in the cloud. Cameras in areas subject to flooding document community concerns and provide context and evidence of flood extent.

Image 2: Pictured above is an example of a shore-based web camera. (Credit: Surfline)



Map 6. Locations for the 17 SECOORA Active Webcams.

Current Capacity

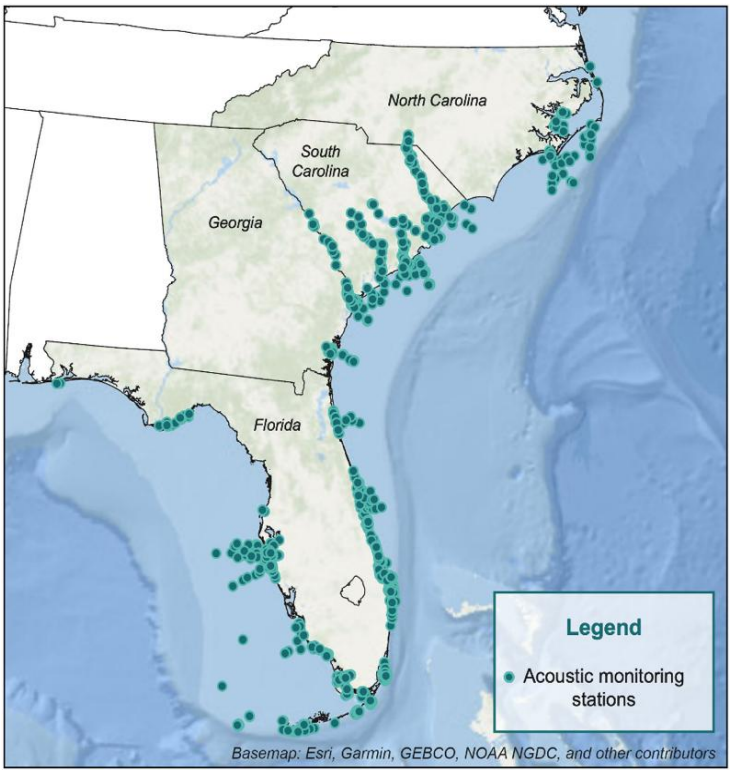
There are currently 23 active cameras in the national network, 17 of which are within the SECOORA region (Map 6). The current cameras are maintained by the WebCOOS team and local partners or camera operators. The AI/ML algorithms mentioned above are running in the cloud at relevant stations, and work continues to refine the accuracy of the models. Funding from a second NOAA OTT grant in FY23 is facilitating the expansion of the network by a planned 60 cameras in partnership with the 10 other IOOS Regional Associations. Surfline\Wavetrax, Inc. has been brought on as a contractor for this project to streamline the installation process, and Axiom Data Science continues to manage the imagery data and product delivery. A workshop held in October 2024 in Charleston facilitated knowledge sharing among the WebCOOS team, Surfline, IOOS RA representatives, and federal and local partners.

2.2.6 Acoustic Monitoring

Background
Acoustic monitoring in the SECOORA region includes acoustic telemetry and soundscape monitoring.

Acoustic Telemetry: SECOORA partners with the FACT Network, a collaboration of scientists and stakeholders leading acoustic telemetry work in the southeast. FACT researchers attach or implant acoustic transmitters (or "tags") to fish or aquatic reptiles as part of independent studies. Each tag emits unique sound pulses that are heard by underwater recording devices (receivers). As animals move through the network of receivers, the unique code and date and time are recorded. Paired with deployment and tag metadata, this creates an animal location observation point. This provides valuable insight into individual and population level migration patterns, the use of specific ecosystems (e.g. estuaries, coral reefs), and seasonal distribution patterns.

Soundscape Monitoring: Passive acoustic recorders, knowns as hydrophones, allow for continuous and long-term sampling of the underwater soundscape. Hydrophones are used to document sounds underwater that can help better understand the behavior of soniferous (i.e., sound emitting) species. The long-term goal is to 'eavesdrop' on key behaviors of marine animals that can change rapidly or gradually in response to environmental changes and human impacts, thus providing a measure of resilience or shifting baselines in a globally changing environment. Soundscape information can be used to understand animal responses or resilience to various stressors including vessels, underwater construction, overfishing, chemical pollution, harmful algal blooms, climate change, and extreme weather events like hurricanes and floods. Many organisms produce and use sound to navigate, communicate, avoid predation, forage, and reproduce. By listening to the soundscape, researchers can gain insight into the acoustic behavior of marine animals at a high temporal resolution over multiple levels of biological complexity. For example, these recordings provide information on the behavior of snapping shrimp, spawning patterns of fish, foraging patterns and communication of bottlenose dolphins, and noise levels associated with human activity. These recordings provide information on the seasonal and annual behavior of marine life and noise levels associated with human activity, such as boat and ship noise.



Map 7. Receiver stations within the FACT Network downloaded between 2022-2024.

Current Capacity
Acoustic Telemetry: SECOORA hosts the FACT data node which is used to aggregate tag metadata, deployment metadata, and detections from contributors. As animals move through the network of over 1,400 receiver stations (**Map 7**), the unique code and date and time are recorded. Tag metadata and detection data are matched within the network as well as

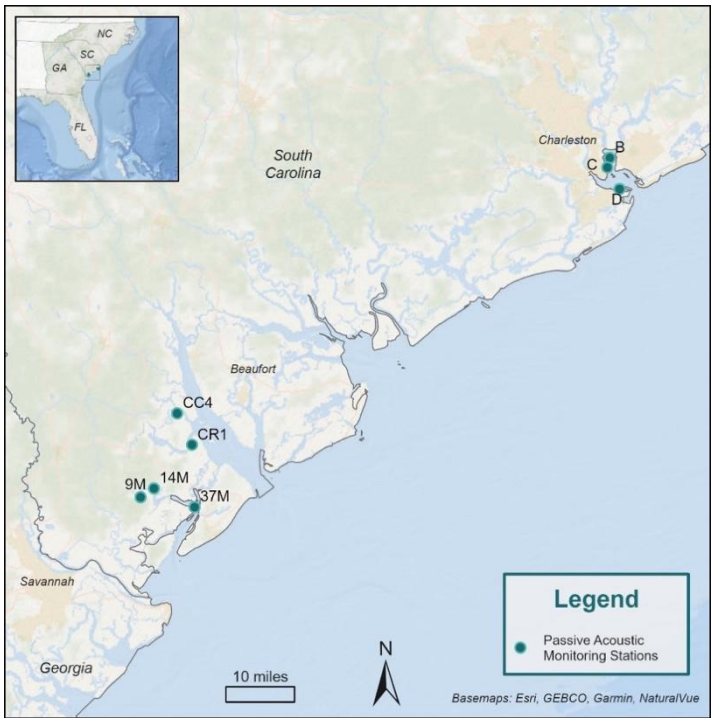
between networks with compatible data systems including but not limited to The Atlantic Coast Telemetry (ACT Network) in the mid-Atlantic, Ocean Tracking Network (OTN) globally, and Pacific Islands Regional Acoustic Telemetry (PIRAT) Network in the Pacific Islands region. x Many of the underwater receivers that record data from a tagged animal also have integrated or co-located temperature sensors. Water temperature data are being submitted to the SECOORA data portal on a quarterly basis where they can be used for fisheries research, marine heat monitoring, and subsurface ocean modeling. The FACT Data Wrangler is the principal liaison with OTN Regional Data Nodes, manages all the data submitted to the FACT node, and conducts outreach to external collaborators to contribute data to FACT. A breakdown of tagged species in the FACT network based on the International Union for Conservation of Nature (IUCN) status for species and the number of tags that have been placed on each species is provided in **Table 6**.

Many of the underwater receivers that record data from a tagged animal also have integrated or co-located temperature sensors. Water temperature data are being submitted to the SECOORA data portal on a quarterly basis where they can be used for fisheries research, marine heat monitoring, and subsurface ocean modeling.

Table 6. International Union for Conservation of Nature (IUCN) status for species registered in the FACT network and the number of tags that have been placed on each species.

IUCN Status	Number of species registered in the FACT Network	Number of tags registered in the FACT Network
Critically Endangered	7	806
Endangered	15	1,200
Near Threatened	10	462
Vulnerable	25	2,886
Least Concern	71	5,637
Data Deficient	3	162

Soundscape Monitoring: SECOORA has invested in the Estuarine Soundscape Observing Network (ESONS) to monitor and better understand fishery dynamics in South Carolina. ESONs operates a network of nine passive acoustic monitoring stations located in the May River, Chechessee Creek and Colleton River; Charleston Harbor, and near Pritchards Island **(Map 8)**. ESONS uses passive acoustic recorders that allow continuous and long-term sampling of the underwater soundscape. These recordings provide information on the behavior of marine life and noise levels associated with human activity. Key species monitored through listening include silver perch, oyster toadfish, black drum, spotted seatrout, red drum, and bottlenose dolphins. At the federal level, ESONS contributed data to The SoundCoop Project (Passive Acoustic Data | National Centers for Environmental Information (NCEI)), which was a three-year effort funded by NOAA IOOS, Bureau for Ocean Energy Management, U.S Navy Living Marine Resources, and the Office of Naval Research. In collaboration with the passive acoustic monitoring (PAM) community, the goal was to develop technology for scalable processing of comparable sound level metrics and to provide open access to centralized data for science and



Map 8: Locations of passive acoustic monitoring stations within South Carolina estuaries.

management applications. Following this paradigm, ESONS sound files and metrics will be archived with NCEI.

2.2.7 Unmanned Aircraft Systems

Background

Unmanned aircraft systems (UAS) are commonly referred to as drones. UAS technology is rapidly advancing and payloads can include red, green, and blue (RGB) cameras and video, lidar, infrared sensors, and multispectral and hyperspectral sensors. In some cases, UAS can collect geospatial data faster, at higher resolution and lower cost than conventional platforms (e.g., aircraft, ships, satellites). UAS may also provide a lower impact alternative to traditional data collection methods, such as marsh transects, which may harm sensitive species and habitats. Operation of UAS and processing of UAS data for scientific data collection is a complex undertaking requiring specific skills, knowledge of best practices, and an understanding of the limitations of UAS platforms, sensors, and data (ACT 2018b). SECOORA supports the use of UAS to help address management needs, including monitoring shoreline change, storm damage assessments, elevation mapping, monitoring HABs in the nearshore, and marine species monitoring/counts.

Current Capacity

SECOORA sponsors the Drones in the Coastal Zone (DITCZ) community of practice as well as scholarship opportunities for drone operators in the southeast to attend the three-part Uncrewed Aircraft Systems Executive Education courses offered by the Duke University Nicholas School of the Environment. To date, 19 people have participated in Executive Education courses.

2.2.8 Surface Elevation Tables (SETs)

Background
Precise measures of sediment elevation in wetlands are necessary to determine rates of elevation change, particularly relative to sea level rise, and to gain an understanding of the processes responsible for elevation change. The SET provides a nondestructive method for making highly accurate and precise measurements of sediment elevation of intertidal and subtidal wetlands over long periods of time relative to a fixed subsurface datum (USGS 2018). SETs are used by federal agencies, state agencies, and academic institutions to monitor coastal estuarine erosion and accretion rates. Many of the SET locations within the southeast region have been operational for decades, providing high resolution marsh surface elevation change data.

Current Capacity
Through 2022 - 2027 BIL funding, SECOORA has established a SET Community of Practice to convene SET practitioners to share SET data, identify gaps in SET locations within each state, and fund the repair of established SETs and install new SETs. The repairs and expansion of the SET monitoring stations will allow researchers and state agencies to monitor relative elevation change of sediments, informing them on sea level rise and/or anthropogenic impacts to marsh ecosystems. SECOORA issued an RFP in late 2024 for proposals to expand the network. These new SETs will be installed in 2025 with updates provided on the SET Community of Practice website.

2.3 Data Management and Communications (DMAC)

Background
A coherent strategy that enables the integration of marine data streams across disciplines, institutions, time scales, and geographic regions is central to the success of IOOS and other regional, national, and international ocean and coastal observing systems. One of the primary goals of DMAC is making discovery, access, and understanding of ocean, coastal, and Great Lakes information easy for the public. To this end, SECOORA has a mandate to collect, organize, and provide access to regional coastal and oceanographic data. These data need to have QA/QC standards and metadata, be electronically accessible and well organized, and understandable to allow researchers, policy makers, industry, and the general public to make well-informed decisions. To satisfy this mandate, SECOORA supports a web-based data portal for the entire region providing ocean, coastal, and relevant land based environmental data and information products.

Current Capacity
SECOORA is a certified regional coastal observing system (RCOS), which recognizes that SECOORA meets federal data management standards and requirements identified by the U.S. IOOS as the Data Management and Cyberinfrastructure core capability requirements for IOOS Regional Associations. This ensures that data collected by SECOORA and member entities and distributed on the SECOORA web portal are managed according to best practices identified by IOOS. This also ensures that appropriate metadata and QA/QC practices are followed and that the data are of a known quality to the end user. SECOORA's data management expertise and capacity provides a solid foundation to support member and stakeholder efforts – private, local, state or federal – to develop products and services for decision makers.

SECOORA has a detailed DMAC Plan for the 5 year period from 2021-2026. This document was last revised in May 2022. A new version will be available by summer 2026 that covers the period 2026-2030. Any data collection or product development supported by SECOORA considers all the

documented requirements outlined in the current DMAC plan. Additionally, each SECOORA funded observing asset has its own data management plan that describes how the data is collected, data QA/QC procedures, and how the data are passed to the SECOORA data management system. These data management plans are updated by the observing asset operators annually.

2.4 Modeling

Background
A central goal of SECOORA is to develop, in partnership with end users, models that will support decision-making. SECOORA is implementing a robust strategy to acquire atmospheric and oceanographic observations from HFR, coastal and oceanographic stations, and autonomous vehicles. Despite SECOORA's robust strategy, coastal and ocean observations cannot be collected everywhere, so SECOORA supports predictive models to fill gaps. The available observations are being linked to predictive models essential to improving ocean circulation modeling and other marine environment conditions. SECOORA supports a numerical modeling framework (regional to sub-regional scale models) to provide validated modeling products for managers and other users.

Current Capacity
SECOORA's 2021 – 2026 IOOS funded proposal includes three separate predictive modeling efforts.

- A Coupled North Atlantic Prediction System (CNAPS) model developed by NCSU: This fully coupled ocean circulation, wave, and atmosphere modeling system predicts conditions over a wide area of the coastal northwest Atlantic Ocean on a daily basis. CNAPS is designed to predict coastal ocean conditions over the entire SECOORA domain with a high degree of scientific accuracy and provide detailed sub-regional information through relocatable grid refinement and nesting technology, and to update and transmit such information to stakeholders in a timely and clear fashion.
- The West Florida Coastal Ocean Model (WFCOM) developed and maintained by the USF College of Marine Science Ocean Circulation Lab: This model focuses on the eastern Gulf and downscales from the deep ocean, across the continental shelf and into the major estuaries by nesting the Finite Volume Coastal Ocean Model (FVCOM) in the HYbrid Coordinate Ocean Model (HYCOM). WFCOM provides daily, automated ocean SECOORA circulation nowcast/forecasts from the Mississippi River Delta to the Florida Keys. The model simulations include real-time river inflows and are quantitatively gauged against in situ observations for the region. By further nesting a higher resolution version of FVCOM in WFCOM, the Tampa Bay Coastal Ocean Model (TBCOM) provides daily automated nowcast/forecasts for Tampa Bay, Sarasota Bay, the Intracoastal Waterway, and all the inlets connecting these with the Gulf. Both WFCOM and TBCOM in collaboration with the Florida Fish and Wildlife Conservation Commission Fish and Wildlife Research Institute provide short-term (3.5-day) harmful algal bloom (HAB) trajectory forecasts for both the surface and the near bottom waters that are used by local, state and other public entities for tracking blooms of the neurotoxic *Karenia brevis*.
- A high-resolution, web-based system to monitor and forecast pelagic *Sargassum* in the coastal zones of the Atlantic Ocean, Caribbean Sea, and Gulf has been developed by modelers at the USF College of Marine Science. The USF team developed algorithms suitable for high-resolution satellite data to map and quantify *Sargassum* distribution and abundance and they are working on a short-term forecasting system to forecast *Sargassum* trajectory. Rafts of *Sargassum* are identified with satellite remote sensing. The latitude and longitude, current speed and direction (integrated daily from HYCOM) are used to predict the movement of the raft and a possible beaching time, in essence, forming an early warning system. The need for this effort has been documented in the SECOORA Harmful Algal Bloom Plan.

SECOORA has developed a strategic and forward-looking approach to identify model needs for the region and implement modeling efforts. This is done by focusing on the goals of the various types of modeling projects that SECOORA may support, describing how SECOORA and modeling teams will engage with partners and users to improve collaboration and service delivery, and outlining the process SECOORA will use to ensure modeling projects are addressing user needs and identified gaps. For more information on SECOORAs approach to modeling, please review the SECOORA Modeling Framework.

2.5 Products

Background
SECOORA strives to create data products that meet a variety of end user needs. Basic products, such as the Text-a-Buoy system, are a low-tech way for individuals to quickly access the most recent data from their favorite ocean or coastal station. More sophisticated data products, such as the SECOORA Data Portal, allow users to access a range of data types to support research and policy-making needs.

Current Capacity
The SECOORA Data Portal is a data exploration tool with a customized public web interface that allows scientists, managers, and the general public to discover and access coastal and ocean data. The Portal assimilates datasets from many different sources. Users can search or browse real-time conditions, operational and research forecasts, satellite observations, and other spatially referenced datasets that describe regional biological, chemical, and physical characteristics. The portal and associated data catalog are the key access points for SECOORA data.

SECOORA directly supports other data products that meet specific stakeholder needs, specifically:

- The Text-A-Buoy system allows users to get the latest ocean and weather information from buoys in the region.
- The Southeast Water Level Network provides access to SECOORA and partner water level data within the Southeast.
- Eyes on the Storm is an interactive SECOORA portal that connects users to live and past hurricanes and tropical storm data. The tool pulls data from within 50 miles of a hurricane's path and showcases the highest wind speeds and wave heights and lowest barometric pressure.
- The FACT Data Visualization Tool (DaViT) is a user-friendly interactive web tool that allows users to visualize movement information of specific fish, invertebrate and aquatic reptile species along with their range and seasonal trends. Data contributors for every visualization are acknowledged with links to project pages allowing fisheries managers to identify and contact persons doing research on species of interest.
- How's the Beach provides daily water quality nowcasts for select recreational waters and swimming beaches based on ensemble modeling and machine learning. Data needs include rainfall, salinity, wind conditions, tide, and water temperature as well as lunar phase and anthropogenic activities and influences.
- The Beach Conditions Reporting System (BCRS) provides condition reports for beaches and coastal recreation areas. This citizen-science program is supported by volunteer Beach Ambassadors that undergo training to make accurate condition reports. There are several sites located along the east and west coasts of Florida, South Carolina, North Carolina, Georgia, and the Gulf coast.

- ShellCast is a precipitation-based water quality forecasting system that alerts shellfish growers and resource managers about predicted lease closures using rainfall predictions from the National Weather Service. Predictions cover shellfish waters along the North Carolina, South Carolina, and Florida coasts.
- The Southeast Marine Mapping Tool provides access to regional ecological data to help inform offshore ocean use decisions.
- The WebCOOS website includes a clickable map of each camera location, a listing of all the WebCOOS cameras, and links to product and documentation pages. Each camera's page shows a livestream video (if applicable), archived imagery, and any annotated imagery products that have been produced at that site.

2.6 Outreach and Education

Current Capacity
SECOORA uses formal and informal communications to engage members, stakeholders, and students. Outreach activities and products include informational one-pagers, presentations at meetings, news stories, e-newsletters, and content for the SECOORA website and social media outlets. SECOORA also spends considerable time meeting with legislators' staff to educate them on the importance of coastal and ocean observing. Public engagement occurs through public forums, generally held twice a year around priority topics; annual member and stakeholder meetings; and regularly scheduled topical webinars. SECOORA also involves the public through campaigns to help fund buoys, fund student internships, or vote to name new assets (e.g., gliders). These efforts increase stakeholder awareness of observing activities and their relevance.

SECOORA sponsors two annual educational award opportunities. The Vembu Subramanian Ocean Scholars Award is a yearly award in remembrance of Vembu Subramanian, a former colleague who lived a life dedicated to uplifting others. The award is provided to one undergraduate student and one graduate student or early career professional to provide travel support to attend and/or present their research at a regional or national meeting or conference. The Data Challenge Award encourages graduate and undergraduate student applicants to use data from SECOORA combined with technologies, tools, videos, and creativity to visualize, analyze, and apply data to tackle real-world questions or problems. SECOORA also supports other educational opportunities that include science festivals, local and regional K-12 science and engineering fairs, funding undergraduate and graduate students through PI awards, undergraduate field excursions, and provision of online educational resources.

Additional Outreach and Education activities are listed below:
- SECOORA hosts K-12 education materials based on common terminology and concepts for meteorology and physical oceanography. Waves, Build-a-Buoy, and Ocean Observing Technology are featured.
- SECOORA hosts K-12 hurricane education materials that includes a glossary of common terminology and concepts for hurricane meteorology and physical oceanography and lesson plans that address storm surge and barometric pressure.
- Sea Level Rise Curriculum: The K-12 classroom curriculum provides foundational science principles and allows middle school students to use real data to create data visualizations of sea level rise.
- Water Shapes Our Planet: This virtual science unit with a hands-on component provides a unique experience where students explore local weather, discover and craft tools used by scientists to collect weather data, and evaluate long-term trends recorded by climate scientists.

- The SECOORA Hurricane Resources webpage provides a curated list of hurricane data resources for the southeast (updated annually). Additionally, SECOORA supports individual hurricane data pages for storms that are predicted to make landfall in the SECOORA region.
- The SECOORA Red Tide Data Resources for Florida page is a curated list of data resources related to the Florida Red Tide, specifically the Harmful Algal Bloom (HAB) species *Karenia brevis*. The website includes current reporting, models, and observing tools.
- The Georgia Harmful Algal Bloom monitoring program incorporates high-resolution, quantitative HAB monitoring in the Skidaway River Estuary to determine environmental conditions conducive to HAB formation in Georgia estuaries. The webpage provides an overview of the project and daily cell counts (weekly during non-summer months) for the HAB species *Akashiwo sanguinea*.
- The Estuarine Soundscape Observatory Network (ESONS) provides examples of sounds recorded by passive acoustic recorders in four SC estuaries. These recordings provide information on the behavior of snapping shrimp, spawning patterns of fish, foraging patterns and communication of bottlenose dolphins, and noise levels associated with human activity.
- The FACT node includes over 100 partner agencies and institutions using acoustic telemetry to resolve the movements of aquatic species and can summarize and share data with BOEM and OBIS.
- The Southeast and Caribbean Disaster Resilience Partnership (SCDRP) is a SECOORA network that seeks to strengthen community resilience and support rapid recovery from storms and disasters by serving as the primary network for professionals in emergency management, climate adaptation, and disaster recovery in the U.S. Southeast and Caribbean territories.

3. SECOORA RCOOS Investment Opportunities based on Focus Areas

SECOORA's primary mission is to provide coastal and ocean data, tools, and services in the following focus areas, which correspond with the U.S. IOOS® societal goals and are important to Southeast stakeholders: Coastal Hazards and Climate Variability; Ecosystems, including Water Quality and Living Marine Resources; and, Marine Operations. For each of these societal goals, SECOORA has identified the currently available RCOOS subcomponents that are in use to meet stakeholder needs for accurate and reliable data and information.

Within each focus area, SECOORA has identified specific issue areas that are of high priority in the Southeast. For each of these issues areas, the following information is provided:

- Challenges: defines key management challenges in the region
- Partner Activities: examples of related efforts by state, federal, and NGO partners
- Priority Geographic Area(s): identifies the most critical geographic areas for expansion of the SECOORA RCOOS
- Future SECOORA Investment Opportunities: needs defined by stakeholder engagement, subject matter expert discussion, and previous observing platform gap analyses that can guide expansion of the SECOORA RCOOS

3.1 Coastal Hazards and Climate Variability

The Southeast experiences severe weather and climate-related events that cause significant hardships for the economic, environmental, health, and social well-being of residents and visitors. Major storm events such as Hurricanes Ian and Nicole (2022), as well as active 2021, 2023, and 2024 hurricane seasons, caused damage across the Southeast from heavy rain, winds and storm surge **(Image 3)**. Additionally, increasing frequency of days with flooding impacts to coastal infrastructure are challenging community response capabilities. The collection of environmental data by in-situ and mobile assets are required to both establish baseline scenarios of coastal system function and to enable effective hazard response. Long-term data are needed to assess changing environmental and ecosystem conditions, regime shifts, and the impacts of severe weather events. These long-term data will enable better understanding of climate variability and improve the ability to forecast, adapt to, and mitigate changes.

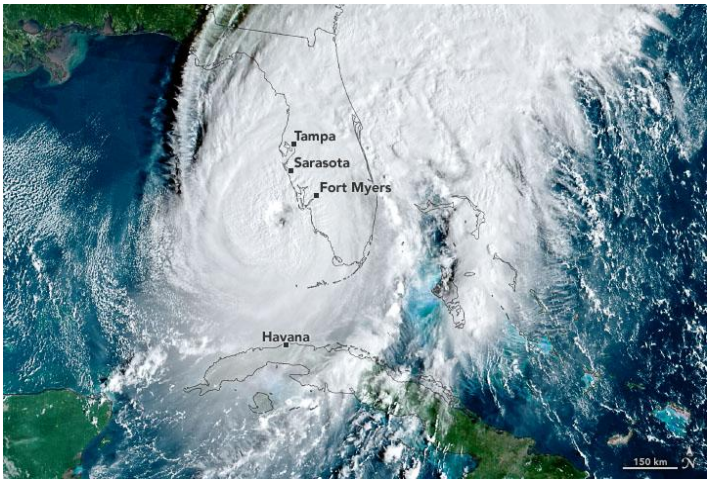


Image 3: Hurricane Ian caused damage across the Southeast from heavy rain, winds, and storm surge. (Credit: NASA)

SECOORA is staged to address the following issues within the Coastal Hazards and Climate Variability focus area:

- Rip Currents

- Storm Tracking and Forecasting
- Coastal Flooding and Sea Level Rise

3.1.1 Rip Currents

A rip current is a narrow, fast-moving channel of water that starts near the beach and extends offshore through the line of breaking waves (NOAA 2019f, Image 4). The United States Lifesaving Association estimates that the annual number of deaths due to rip currents on our nation's beaches exceeds 100. According to the United States Life Saving Association (2024), rip currents account for over 80% of rescues performed by surf beach lifeguards. NWS Weather Forecast Offices (WFOs) issue daily rip current forecasts alerting beachgoers when rip current probabilities are low, medium, or high. These forecasts are often manually generated based on tide cycle and meteorological conditions (Dusek and Seim 2013). WFOs are transitioning to the probabilistic NOAA rip current forecast model, however the transition has slowed in part due to a lack of rip current and nearshore wave observations.

Challenges:

- Beaches without lifeguards do not have a warning mechanism for hazardous rip currents nor do they provide observations to inform WFOs of rip current occurrence.
- Lack of surfzone or nearshore observations. Rip current, bathymetry and shallow water wave observations are needed to identify when conditions are favorable for rip current formation and to validate numerical wave models.
- Operationalizing and validating rip current detection models based on web camera imagery is technologically challenging and resource intensive.

Image 4: Pictured above is an example of a rip current, highlighted in green. (Credit: NOAA)

Partner Activities:

- NOAA CO-OPS sponsored the development of the NOAA statistical rip current forecast model, which is now operational at NWS. The model predicts the likelihood of hazardous rip currents occurring given wave and water level inputs from the numerical wave and water level model Nearshore Wave Prediction System (Dusek et al. 2014 and link).
- The United States Lifesaving Association, in partnership with NWS and National Sea Grant Program, works to raise awareness about the dangers of rip currents. New outreach materials and signage have been developed based on the most recent scientific research.
- The NWS as well as NC Sea Grant, SC Sea Grant, and FL Sea Grant conduct outreach to improve rip current identification and increase swimmer safety.

Priority Geographic Areas(s): Swimming beaches in the southeast

Future SECOORA Investment Opportunities:

Observing Assets

- Invest in additional real-time buoys that collect meteorological and physical oceanographic data as well real-time nearshore wave buoys that provide spectral wave data. Observations can be used by the NWS for rip current nowcast/forecasts.
- Install web cameras at popular recreational beaches for rip current detection.

Data Management and Communications

- Continue sharing data from SECOORA partners with NDBC through standardized ERDDAP data services, allowing meteorological and physical oceanographic data to be ingested into the NWS Advanced Weather Interactive Processing System (AWIPS). Once the data is in AWIPS it is available to NWS offices for use in nowcasts/forecasts and modeling.
- Continue operation of a web camera data assembly center to support continued research on utilizing webcams to detect rip currents and to provide access to rip current detection products.

AI/ML

- Continue to work with WebCOOS partners to standardize and operationalize image storage and processing for rip current detection.
- Continue to evaluate and improve machine learning algorithms to identify rip currents as part of WebCOOS (de Silva et al., 2021; de Silva et al., 2023).

Products

- Expand beach notification data products regionally to meet stakeholder needs (e.g. beachgoers, coastal tourism).

3.1.2 Storm Tracking and Forecasting

The Southeast, Gulf, and Caribbean regions are highly impacted by tropical cyclones. Based on NOAA Atlantic Oceanographic and Meteorological Laboratory (AOML) data, there have been 24 named storms impacting the southeast region between 2020 - 2024 (NOAA 2024c). Tropical cyclones pose a variety of threats to people and property due to wind, heavy rainfall, and storm surge (NOAA 2019b). According to the 2023 National Climate Assessment, there has been an increase in Atlantic hurricane activity since the 1960's. Tracking storms and forecasting impacts is vital for the protection of life and property; however, understanding how storms impact coastal and ocean ecosystems is also needed to develop effective mitigation strategies. Animal tracking, such as conducted by FACT partners, is one way to help understand ecosystem impacts from storms.

Challenges:

- Lack of funding to expand buoy and coastal station networks to fill priority gap locations.
- Limited number of glider observations necessary to enhance hurricane models.
- Difficulty coupling hydrologic, hydrodynamic, wave, and atmospheric models to improve predictions of storm surge and inundation.
- Limited understanding of the long-term impacts of storm surge/inundation on coastal ecosystems and the built environment.
- Limited observations to evaluate the ecological impacts of storms.

Partner Activities:

- NOAA's National Hurricane Center (NHC) provides storm tracking, forecasts, and hazard alerts for tropical cyclones. Data from SECOORA buoys are used by NHC for storm tracking and forecasting purposes.
- NOAA AOML is working with the U.S. Navy, IOOS, RAs, and Saildrone to improve global ocean forecasts with observations from surface vehicles and underwater profiling gliders.
- USACE's Wave Information Study collects directional wave data to drive nearshore wave transformation models, perform research and development on existing wave modeling technologies, perform climate trend analyses, monitor coastal projects, and evaluate satellite based remote sensing systems.

- USGS has a suite of sensors and online tools to evaluate water level nationally. For example, the USGS Surge, Wave, and Tide Hydrodynamics (SWaTH) Network covers NC to Maine and monitors and documents the height, extent, and timing of storm surge with the deployment of short term sensors within the storm path. Data are available for viewing on the USGS Flood Event Viewer.
- University of Miami Rosenstiel School of Marine and Atmospheric Science (RSMAS) is working with the NOAA NHC and NOAA Hurricane Hunters to deploy drop sondes and other instrumentation to collect core physical and meteorological variables within the hurricane. The data is incorporated into NOAA NHC models. RSMAS also produces an ocean heat content model daily.
- Coastal Emergency Risks Management Project uses storm surge models to provide visualizations to emergency managers, weather forecasters, and geographic information system specialists to help evaluate the impact of storms.

Priority Geographic Areas(s): Entire SECOORA domain

Future SECOORA Investment Opportunities:

Observing Assets

- Invest in additional real-time buoys that collect meteorological and physical oceanographic data as well real-time nearshore wave buoys that provide spectral wave data. Observations can be used by the NHC, NWS, and SECOORA partners to validate hurricane tracks and model performance.
- Invest in existing buoys to expand subsurface temperature monitoring with real-time data transmission to evaluate subsurface ocean heat content.
- Invest in coastal stations that collect meteorological data as well as water level data to monitor storm surge.
- Invest in web cameras in flood-prone areas to capture flood and storm surge extent and provide context for water level sensor recordings.
- Increase the number of standard and event driven glider missions annually during hurricane season within the SAB and Gulf.
- Expand animal tracking and underwater soundscape monitoring to better understand fishery and ecosystem response to storm events.
- Expand the HFR network to track ocean circulation to enable faster post-hurricane search and rescue activities for stranded boaters, damaged vessels, etc.
- Add wave buoys within the HFR footprint to validate HFR derived waves.
- Use drones at regular intervals to monitor shoreline change.
- Expand and monitor SETs to evaluate changes in marsh habitat due to storm impacts.

Modeling

- Incorporate coastal ecosystem data into models to address impacts of storm surge and sea level rise on natural environments (e.g., marsh, mangroves) and built environment.

AI/ML

- Train models in image segmentation and analysis technologies to enable and operationalize extraction of water levels directly from image data.

Education and Outreach

- Create one-pagers and on-line post storm event summaries to highlight data collected by SECOORA assets.

- Create videos on the SECOORA website that describe the benefit of RCOOS assets to storm tracking and forecasting.

3.1.3 Coastal Flooding and Sea Level Rise

According to NOAA (2022), as sea levels continue to rise, our coastal communities will experience more frequent high tide flooding - a National average of 45 to 85 days per year by 2050. High tide flooding and storm surge related coastal flooding leads to hazards such as road closures, residential flooding, beach and marsh erosion, and risks to public health **(Image 5)**. SECOORA can help address localized flooding and longer-term issues related to sea level rise based on our experience in operating observing platforms that provide community-level data necessary to improve the accuracy of inundation forecasts and models.

Challenges:

- Meeting demand for water level data with the current limited spatial coverage.
- Installation and maintenance of water level sensors and webcams to accurately determine water level and flood extent.
- Fully coupling terrestrial water inputs and coastal ocean dynamics to understand storm surge and water quality impacts.

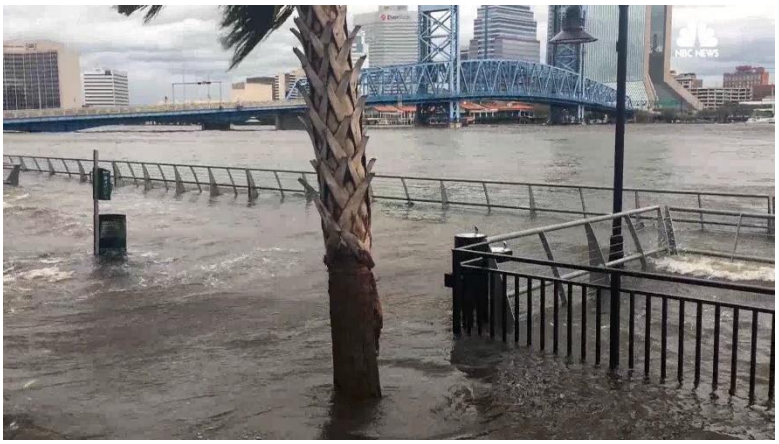


Image 5: Pictured above is a major flood event in Jacksonville, Florida (Credit: NBC News).

Partner Activities:

- NOAA Center for Operational Oceanographic Products and Services (CO-OPS) has released an annual outlook on coastal high tide flooding every year since 2014 and provides a monthly high tide flooding outlook to inform of the days and locations high tide flooding is most likely over the next year.
- NOAA CO-OPS operates water level stations along the east coast and Gulf which provide shore based water level and meteorological data collection to support sea level and inundation monitoring.
- NOAA CO-OPS developed the Coastal Inundation Dashboard to provide localized flooding reports for locations where water level stations are available.
- NOAA Water Initiative is working to couple land surface and coastal estuary models to improve the prediction of total water level in the coastal zone (NOAA 2016).
- The NWS and the USGS update forecasts for some areas several times a day using real-time water levels from the NWS Nearshore Wave Prediction System. The team's Total Water Level and Coastal Change Forecast Viewer displays results from a new model that currently covers about 1,865 miles of coastline in select areas from Florida through Maine.
- The Flood Inundation Mapping and Alert Network, or FIMAN, is operated by the North Carolina Department of Public Safety. FIMAN is the primary resource for North Carolina state-wide flood awareness and forecasting.

Priority Geographic Areas(s): Entire SECOORA domain

Additional SECOORA Investment Opportunities:

Observing Assets

- Invest in additional real-time buoys that collect meteorological and physical oceanographic data as well real-time nearshore wave buoys that provide spectral wave data. Observations can be used by the NWS, state and local emergency managers, and SECOORA partners to monitor potential storm surge.
- Continue partnering with communities and organizations to install water level sensors to help inform understanding and response to chronic and storm surge related flooding. See 2023 Water Level Workshop Report for more detail on water level needs within the southeast.
- Invest in CPIES deployed on the seafloor, under the Gulf Stream. These stations should also be within the HFR coverage areas to validate Gulf Stream dynamics and help track Gulf Stream changes related to climate change.
- Expand the webcam network to observe real-time water level changes.
- Use drones to capture images/video footage at regular intervals to monitor shoreline change and flooding hotspots. This imagery can be used to correlate in situ observed water level with inundation impacts and the development of localized flood thresholds.
- Expand and monitor SETS to evaluate changes in marsh habitat due to changes in sea level.

Modeling

- Improve coastal ocean circulation model for coastal inundation and flooding forecasts (e.g., by expanding model grid coverage towards land).
- Integrate water level data into models to improve accuracy of storm surge forecast guidance products.
- Incorporate coastal ecosystem data into models to address impacts of storm surge and sea level rise on natural (e.g., marsh, mangroves) and built environments.

AI/ML:

- Train models in image segmentation and analysis technologies to enable and operationalize extraction of water levels directly from image data.

Data Management and Communications

- Partner with NOAA CO-OPS to display SECOORA water level data and relevant links to webcams on the Coastal Inundation Dashboard.
- Partner with USGS to share water level and wave data during and post-storm events. USGS data could provide additional data for SECOORA modeling groups to validate their model output (skill assessment).
- Continue to work with partners to standardize and operationalize coastal web camera image processing for coastal flooding and shoreline change detection.

Outreach and Education

- Partner with NOAA CO-OPS and NGS to offer training related to water level sensor installation, vertical elevation surveys, use of OPUS to process survey data, and metadata creation. These needs are outlined in the 2023 Water Level Workshop Report.
- Partner with NOAA and USGS to offer on-line training opportunities about existing water level resources (e.g. websites, online tools) to expand awareness of existing tools with communities, local and state government officials, and K-12 and University educators. These needs are outlined in the 2023 Water Level Workshop Report.

3.2 Ecosystems: Living Marine Resources and Water Quality

Marine ecosystems are dynamic and function through complex physical, chemical, geological, and biological interactions that change over time and space. Coastal ocean ecosystems in the Southeast region are dominated by the Loop Current, Florida Current, and Gulf Stream. Our estuaries, coral reefs, and coastal ocean support numerous important fisheries by providing habitat for all life stages from larval to adult. Many of these species, including shrimp, shellfish, crabs, and fin fish are managed under state and federal fishery management plans. These areas are influenced by coastal development and tourism, both of which contribute anthropogenic impacts (e.g. run-off, chemical and noise pollution) to tidal rivers, estuaries, and beaches. Nutrients in runoff can cause eutrophic conditions which can lead to HABs and cyanobacteria blooms, resulting in significant fish kills and negative impacts to human health. Additionally, coastal areas often see elevated fecal bacteria concentration occur following rainfall, which prompt swimming advisories and temporary or permanent shellfish harvest area closures.

SECOORA is staged to address the following issues in the Ecosystems focus area:

- Marine Heat
- Fisheries
- Estuarine and Coastal Ocean Soundscapes
- Public Health
- Harmful Algal Blooms
- Coral Health
- Coastal and Ocean Acidification

3.2.1 Marine Heat

Marine heatwaves (MHW) are prolonged extreme oceanic warm water events that can have devastating impacts on marine ecosystems. MHWs occur when ocean water temperatures are much warmer than normal (usually above the 90th percentile of their climatological distribution) for at least five consecutive days (Climate Central 2004). Marine heatwaves have become more frequent, severe, and long-lasting over the last 30+ years, impacting ecosystems and fisheries (Oliver 2019).

Marine heatwaves may vary in physical characteristics as well as their impacts on marine biota and ecosystems such as corals, seagrasses (Smale 2019), harmful algal blooms (Smith et al. 2021), and range expansion of pathogenic species such as non-Cholera Vibrio bacteria (Vezzulli 2016). They have been shown to be statistically correlated to higher temperatures and humidity in nearby coastal cities (Hu 2021). In the Florida Keys, the 2023 extreme marine heatwave caused massive coral bleaching and die off of natural and restored coral reefs (NOAA 2024d). Marine heatwaves can also lead to harmful algal blooms and individual events have caused over $800 million in direct costs and $3.1 in indirect losses (Smith et al. 2021).

Challenges:

- Limited number of moorings offshore - most are in the nearshore coastal zone.
- Limited number of spatially distributed acoustic doppler current profilers (ADCPs) for water column current measurements and limited geographic coverage of surface current monitoring.
- Few bottom water temperature sensors in the coastal ocean. Most are primarily in estuarine and riverine locations.
- Need to identify, standardize, collate, and share multiple datasets currently stored in disparate locations with different standards.

- Understanding causes of temperature anomalies: surface heating vs. advection of warmer waters vs. lack of cool-water upwelling.
- Understanding how organisms and ecosystems will respond to changes in ocean temperature over short (acute, heatwaves) and long (chronic, climate) timescales.

Priority Geographic Area(s): FL Keys including the Florida Keys National Marine Sanctuary; Gray's Reef National Marine Sanctuary; shellfish aquaculture and shellfish harvest areas.

Partner Activities:

- NOAA Physical Sciences Laboratory provides high resolution gridded sea surface temperature and ice data using multi-satellite sensor (AVHRR+VIIRS) data (https://psl.noaa.gov/data/gridded/data.noaa.oisst.v2.highres.html)
- NOAA Office of Satellite and Product Operations provides several Sea Surface Temperature maps and products: https://www.ospo.noaa.gov/products/ocean/sst.html
- AOML conducts studies related to coral bleaching, sea level rise impacts to coral reefs, and supports the Coral Health and Monitoring Program.
- The Florida Keys NMS conducts research and monitoring to study the effectiveness of its marine zones and the health of its marine resources.
- Mote Marine Laboratory is implementing the Florida Keys strategic coral disease response and restoration initiative. This 10-year plan will be implemented through a consortium of coral research and restoration institutions.
- The University of North Carolina Wilmington Reproduction and Evolutionary Ecology Fogarty Lab (REEF Lab) works to better understand the stressors driving coral mortality and how to optimize coral husbandry for restoration. The REEF lab includes a state-of-the-art spawning facility that mimics conditions in the wild for ex-situ spawning but also allows for experimental manipulations of environmental conditions.
- Biscayne Bay National Park Service leads efforts to collect real-time and non real-time physical oceanographic data within Biscayne Bay, Dry Tortugas, and Everglades National Park. Real-time data from Biscayne Bay and the Everglades are being shared with SECOORA.
- SECOORA, GCOOS, CARICOOS and their partners are currently co-developing pan regional tools to forecast marine heat waves across the three regions to be more responsive to stakeholder needs. An initial approach is to evaluate temperature and current datasets, identify gaps in data, and standardize and synthesize the data so that it can be used for forecast products.
- RSMAS Ocean Heat Content (OHC) datasets: https://isotherm.rsmas.miami.edu/heat/weba/atlantic.php. Includes ocean heat content, geostrophic currents, SST, mixed layer depth, sea surface height anomaly, depths of 20°C and 26°C isotherms, Hovmöller diagrams, and equivalent OHC.
- 352 FACT sites include water temperature data within the SECOORA domain. These data are shared with SECOORA and available on the data portal.

Additional SECOORA Investment Opportunities:

Observing Assets

- Invest in additional real-time buoys that collect meteorological, physical, and biogeochemical variables in priority geographic areas.
- Invest in existing buoys to expand subsurface temperature monitoring sensors with real-time data transmission to evaluate subsurface ocean heat content.
- Invest in additional coastal and estuarine stations that collect meteorological, physical, and biogeochemical variables to identify water quality impacts related to marine heatwaves.

- Invest in low-cost water temperature sensors to collect bottom, mid-water, and surface water temperatures to evaluate marine heatwave impacts through the water column.
- Increase glider missions in critical habitats that are vulnerable to marine heatwaves.

Emerging Technologies
- Evaluate developments in low-cost autonomous vehicles (e.g. JaiaBots) for subsurface temperature monitoring.

Data Management
- Standardize and synthesize temperature data from disparate in situ and satellite data sources to analyze surface and subsurface temperature for the SECOORA region.
- Continue partnering with researchers and state and federal agencies to share real-time and non real-time temperature data.

Modeling
- Models that predict surface and subsurface temperature in critical locations at relevant, actionable timescales.

Products
- Forecasts of marine heatwaves for key, critical locations such as aquaculture operations, Gray's Reef National Marine Sanctuary, and the Florida coral reef ecosystems, including the Florida Keys National Marine Sanctuary.
- Cross-RA marine heat products to track and forecast marine heatwaves across the GCOOS, SECOORA, and CARICOOS domains.

Education & Outreach
- Engage with regional stakeholders to determine how best to produce marine heatwave products that will inform decision making (e.g., timing for coral propagation in nursery areas).

3.2.2 Fisheries

Fish, fishing, and fisheries are major components of the ecology, heritage, and economy that support and sustain the unique culture of the southeastern states.

Recruitment, population density, and movement of fish are driven in part by ocean circulation, climate, and weather. However, the integration of these drivers in population models and the management process is lacking. SECOORA is qualified to provide, organize, and supplement real-time and historic ocean data to help inform fisheries management decisions for federal and state agencies as well as inform how animal distributions may shift due to a changing climate. (Also, see the section on Marine Heat.)

Image 6: A SCUBA diver services an acoustic receiver in the Florida Keys. (Credit: FACT Network)

Challenges:

- Limited publicly accessible telemetry datasets (e.g., not all detection data are aggregated in a centralized location, many tag detections are embargoed for extended periods of time, datasets are difficult to find and understand) for visualization or broader research.
- Limited characterization and evaluation of fish movement, habitat use, site fidelity, life history, and stock structure for many species due to lack of research and or dissemination of research results beyond an academic audience and organizational reporting (i.e. peer-reviewed publications and unpublished data).
- Limited multi-species synthesis.
- Limited spatial and temporal data on spawning of ecologically and economically important fish species within the region.
- Changes to critical habitat essential to managed species are not well researched.
- Limited integration of marine environmental variability (including climate change) impacts on stock abundance, migration, and species richness.
- Insufficient data management and modeling capabilities to link biological, oceanographic, and meteorological processes.

Priority Geographic Area(s): Ocean waters with a primary focus on the managed areas as defined by South Atlantic Fishery Management Council (SAFMC), Gulf of Mexico Fisheries Management Council (GOM FMC), Atlantic States Fisheries Commission (ASFMC), and individual states. Major fisheries areas within the Gulf that need ecosystem monitoring include Pensacola Bay, FL, the Florida Middle Grounds, and north of Key West at the 10 m isobath.

Partner Activities:

- The SAFMC and GOM FMC are charged with conservation of fish stocks and fish habitat and management of recreational and commercial fisheries dependent on those resources in the U.S. Exclusive Economic Zone (3-200 nautical miles) off NC, SC, GA, and FL.
- State fishery management agencies, often in collaboration with federal, regional, and academic partners conduct assessments for key fisheries in state waters. They also manage fish species in state waters (inshore to 3 nautical miles).
- The National Marine Fisheries Service (NMFS) Southeast Fisheries Science Center (SEFSC) conducts multi-disciplinary research programs to provide management information to support national and regional programs.
- The Southeast Reef Fish Survey is a partnership between the Southeast Fishery Independent Survey (SEFIS), South Carolina Department of Natural Resources (SCDNR) Marine Resources Monitoring, Assessment, and Prediction (MARMAP), and Southeast Area Monitoring and Assessment Program South Atlantic (SEAMAP-SA). These groups work together to determine distribution, relative abundance, and essential habitat of economically and ecologically important fishes in Atlantic waters off the Southeastern coast.
- NOAA's MBON manages biological data and shares the data through the MBON Portal. MBON supports groups to develop and document best practices associated with marine biodiversity observations, including methods for data collection and data management. MBON plans to integrate biodiversity data with physical and biogeochemical observations as the network matures.
- The FACT Network, covering the southeast Atlantic coast, and the Integrated Tracking of Aquatic Animals in the Gulf of Mexico (iTAG) are collaborative organizations whose partner agencies and institutions use acoustic telemetry to resolve the movements of aquatic species **(Image 6)**.

- SAFMC is working with the Florida Fish and Wildlife Research Institute (FWRI) and regional partners, to develop ecosystem models for the South Atlantic which require integration of oceanographic and remotely sensed data to fully characterize variability in the natural system.

Additional SECOORA Investment Opportunities:

Observing Assets

- Invest in ecosystem moorings in priority geographic locations or add additional biogeochemical and biological sensors to existing moorings.
- Work with partners to deploy profiling gliders to collect physical oceanographic and biogeochemical data, and record ambient noise (using hydrophones or passive acoustic recorders), and fish tags. Key locations for glider transects include the Florida Middle Grounds, Gray's Reef NMS, and natural and artificial reef habitats in the Atlantic and Gulf.
- Expand HFR coverage for surface current mapping which is valuable for larval transport models.
- Expand real-time and non real-time bottom temperature data collection throughout the SECOORA domain.
- Support continued acoustic tagging and tracking of key and data-poor species (e.g., Atlantic Sturgeon, Tripletail, Red Drum, Cobia, and various shark species) to increase data exchange from fish tagging efforts for research, management, and conservation efforts.
- Increase hydrophones in estuarine and nearshore waters to record sound in the marine environment to better understand how recreational vessels and large container ships affect fish movement, foraging, courtship behavior, and spawning.
- Continue to facilitate collaboration between the FACT Network and asset operators in the southeast to place acoustic receivers on/near ocean observing infrastructure (Moorings of Opportunity program).

Emerging Technologies

- Work with partners to conduct eDNA sampling and analysis to inform species presence/absence and overall biodiversity in priority geographic areas.
- Evaluate acoustic sensors that can be incorporated onto Spotter Wave buoys for fish detections and soundscape monitoring.

Data Management and Communications

- Develop data analysis tools and visualizations that incorporate oceanographic and biogeochemical data such as that available from the CNAPS 30-year Reanalysis product, with fish tag detections.

Modeling

- Incorporate coastal ecosystem data into models to address impacts of storm surge and sea level on natural environments (e.g., marsh, mangroves).
- Develop high-resolution coupled physical-biogeochemical models to link oceanographic processes with recruitment success for commercially important offshore reef fish.
- Incorporate HFR data into water quality models.
- Develop high-resolution coupled physical-biogeochemical models to link marine carbonate ecosystem information with oceanographic processes.

Products

- Support the development of products derived from animal tracking data, such as outputs from the BioTrack Initiative, which generate stakeholder-defined maps for informing conservation management of marine biodiversity hotspots under present and future environmental change.

- Expand the development of data visualization tools derived from underwater passive acoustic monitoring, such as the BioSound data explorer, that visualize trends in acoustic-based biodiversity indices over space, time, and seascape conditions.

AI/ML

- Expand and refine machine learning techniques to identify and quantify sources of ocean sounds (e.g., fish, marine mammals, anthropogenic noise).
- Evaluate emerging technologies that identify and quantify ocean pollutants and pathogens.

Education and Outreach

- Support training for fisheries managers in using SECOORA supported data visualization, models, and model products.
- Collaborate with partners to implement a citizen science project to report shifting marine species.

3.2.3 Estuarine and Coastal Ocean Soundscapes

Many marine animals depend on sound for their most basic needs—foraging, communication, protection, reproduction, and navigation (NOAA 2015a). Soundscape ecology is an emerging field which studies biological, geophysical, and anthropogenic sounds that are produced in a landscape (Pijanowski et al. 2011). Hydrophone recordings are used to document sounds that can help us better understand the behavior of snapping shrimp, fish, and marine mammals **(Image 7)**. Soundscape networks can 'eavesdrop' on key behaviors of marine animals that can change rapidly or gradually in response to environmental changes and human impacts, thus providing a measure of resilience or shifting baselines in a globally changing environment. Anthropogenic sounds that may impact our marine environment include noise from recreational vessels, global shipping, oil and gas exploration, dredging, construction activity, and naval exercises. Thus, there is a need to better understand the potential impacts of human-based noise on ocean fauna.

Image 7: Researchers at the University of South Carolina Beaufort deploy passive acoustic monitoring sensors in Chechessee Creek. (Credit: Alyssa Marian)

Challenges:

- There are few established, long-term passive acoustic networks that have recorded baseline soundscape data of various ecosystems.
- Scientists need to understand how yearly patterns of fish calling and chorusing associated with courtship relates to year class strength. Answering this type of question will inform stakeholders on the utility of passive acoustics in helping manage fisheries.
- Limited data on how soundscapes near ports compare to more pristine areas.
- Limited information on how climate variability, changes in salinity, dissolved oxygen, and pH affect soundscapes.
- Limited data on how anthropogenic noise from recreational vessels and global shipping affects fish courtship behavior and spawning.

- Researchers need machine learning approaches to identify and quantify fish sounds, marine mammal vocalizations, and anthropogenic noise that can be applied easily to thousands of sound files.

Priority Geographic Area(s): Ports, estuaries, natural and artificial reef habitats, offshore energy lease blocks, sand borrow areas, Essential Fish Habitat-Habitat Areas of Particular Concern and other managed areas.

Partner Activities:

- NOAA NMFS has developed an Ocean Noise Strategy, and is working toward implementation. They have deployed two hydrophones in the SECOORA region as part of their ocean noise reference stations, one near the FL panhandle and one off the east coast of FL.
- BOEM funds studies on impacts of human-generated noise on marine life through its Environmental Studies Program.
- The US Department of Transportation, Maritime Administration (MARAD) Maritime Environmental and Technical Assistance (META) program funds studies related to measurement, detection, and modeling of vessel generated underwater radiated noise.

Additional SECOORA Investment Opportunities:

Observing Assets

- Increase passive acoustic recorders in estuarine and nearshore waters, especially near ports and shipping channels as well as more pristine ecosystems.
- Increase the number of profiling glider missions to collect physical oceanographic and biogeochemical data, and record ambient noise (hydrophones), and fish tags.
- Conduct glider missions that support whale detections, specifically right whales, in the SAB during calving season. Data can inform management strategies to protect whales near busy shipping lanes.

Emerging Technologies

- Work with partners to conduct eDNA sampling near hydrophones. Validate eDNA sampling based on analyzed hydrophone data to inform species presence/absence as well as overall biodiversity in a particular location.

AI/ML

- Expand and refine machine learning techniques to identify and quantify sources of ocean sounds (e.g., fish, marine mammals, anthropogenic noise).

Products

- Expand the Estuarine Soundscape Observatory Southeast (ESONS) products to include a larger geographic footprint and additional species.
- Develop machine learning tools to identify key species and vessel types.

3.2.4 Public Health

According to the U.S. Census Bureau, coastal counties in NC, SC, GA, and FL are seeing high rates of population growth and urbanization (2024). At the same time, these coastal areas are also visited by millions of tourists annually. Coastal managers and public health officials within the SECOORA region are concerned about health risks associated with pathogens, microplastics, and contaminants of emerging concern (CEC), as they affect recreational beach and swimming water quality and shellfish water quality **(Image 8)**. In relation to shellfish, harvest restrictions are instituted and managed by state fisheries and public health offices to ensure products are only harvested when water quality is acceptable, and disruptions from temporary or permanent harvest closures pose economic constraints on the growth of commercial fisheries and mariculture industries. SECOORA and its partners are working with federal and state agencies as well as municipal governments to address public health concerns in the region.

Image 8: The growing oyster aquaculture industry in the southeast U.S. requires access to unimpaired coastal and estuarine waters. (Credit: Jamie Moncrief)

Challenges:

- Impaired coastal and estuarine water quality can threaten human health, local economies and ecosystems.
- High numbers of people are at risk of contact with *Vibrio* spp., *E. coli,* and other bacteria and pathogens in recreational swimming waters and shellfish harvesting waters. Risk of exposure to antimicrobial resistant organisms in swimming and shellfish harvesting waters is a growing concern.

Priority Geographic Area(s): Beaches and estuarine waters within the SECOORA domain.

Partner Activities:

- The United States Environmental Protection Agency (U.S. EPA) Virtual Beach is a software package designed for developing site-specific statistical models for the prediction of pathogen indicator levels at recreational beaches (EPA 2024).
- The Arnold School of Public Health at the University of South Carolina (USC) houses the Consortium for Oceans and Human Health (COHH; formerly known as the Center of Excellence for Oceans and Human Health and Climate Change Interactions) that is looking at microplastics, HABs, bacteria, and increased virulence of *Vibrios* as well as their associated impacts on public health.

Additional SECOORA Investment Opportunities:

Observing Assets

- Invest in additional nearshore real-time buoys and coastal stations that collect meteorological and physical oceanographic core variables to inform forecast and model product development.
- Invest in ecosystem moorings in priority geographic areas or add additional biogeochemical and biological sensors to existing moorings.
- Install water quality sensors at inshore locations and at major river entrances, such as the Cape Fear River, NC, Savannah River, GA, and St. John's River, FL. These could be piling stations or

SECOORA could work with the USCG to instrument aids to navigation. Stations should measure water quality parameters: water temperature, salinity, DO, pH, turbidity, chlorophyll fluorescence and fluorescence of dissolved organic matter (FDOM, a proxy for total dissolved organic carbon).
- Add meteorological and water quality stations to commercial ocean fishing piers.
- Install web cameras at popular recreational beaches to identify the number of beachgoers that may be impacted when water quality indicators do not meet state standards.
- Use drones to capture images/video footage at regular intervals for detection and tracking of pollutants and water quality monitoring.

Emerging Technologies
- Evaluate emerging technologies that identify and quantify ocean pollutants (microplastics) and pathogens.

Modeling
- Develop tracer model rapid response tools for pollutant tracking based on existing circulation nowcast/forecast models.

Products
- Expand water quality and beach notification data products regionally to meet stakeholder needs (e.g., beachgoers, fishermen, aquaculture, public safety, public health, and coastal tourism).

Education and Outreach
- Collaborate with partners to implement citizen science projects related to beach and estuarine water quality.

3.2.5 Harmful Algal Blooms

HABs occur when algae — single-cell photosynthetic organisms that live in marine and freshwater environments — experience increased growth while producing toxic or harmful effects to people, fish, shellfish, marine mammals, and birds. The HABs in fresh and marine waters are usually very different, but they overlap in low salinity estuaries (NOAA 2019c). One of the most well-known HABs in the southeastern region is the Florida red tide caused by *Karenia brevis*, a type of dinoflagellate that produces potent neurotoxins. The toxins can become aerosolized near beaches and cause human respiratory illness. They can also accumulate in shellfish and cause Neurotoxic Shellfish Poisoning in humans (WHOI 2018).

SECOORA developed a HAB Plan to address regional HAB issues **(Image 9)**. This document is an addendum to the SECOORA RCOOS Plan and serves as a guide for future investments in regional HAB observing and monitoring. It should be referenced to identify SECOORA partner activities, current investments, and priority research locations.

Image 9: SECOORA developed a HAB Plan to address regional issues.

Additional SECOORA Investment Opportunities:

The following are the current regional priorities as identified in the HAB Plan.

Observing Assets

- Add additional biogeochemical and biological sensors to existing SECOORA moorings.
- Increase the number of onshore or nearshore coastal stations that collect meteorological and physical oceanographic core variables.
- Expand the use of Imaging FlowCytobot (IFCB), Environmental Sample Processor (ESP), and SPATT Bags for HAB detection and analysis.
- Use drones to capture images/video footage at regular intervals for detection and tracking of HABs.
- Increase the number of standard and event driven SECOORA glider missions annually in the SAB and Gulf. Work with partners to deploy autonomous surface vehicles (ASVs) or profiling gliders to collect physical oceanographic and biogeochemical measurements for HABs in ocean waters.
- Add meteorological and water quality stations at beaches and shellfish harvest areas.

Modeling

- Sustain existing SECOORA-funded coastal ocean circulation models to provide key information of physical oceanographic processes for HAB observing, short-term tracking, and integrated analysis.
- Develop high-resolution ecological or coupled physical-biological HAB models based on existing SECOORA-funded coastal ocean circulation models, specifically the West Florida Shelf Ocean Model and the Tampa Bay Circulation Model, both operated by USF.

Data Management and Communications

- Support the analysis of satellite data for HABs detection and tracking.
- Coordinate data and communications with our neighboring regional associations.

Products

- Expand water quality and HAB data products regionally to meet stakeholder needs (e.g., state agencies, beachgoers, fishermen, aquaculture, and coastal tourism).

Emerging Technologies

- Support development and implementation of emerging technologies to detect HAB species and their toxins.

SECOORA's priority will be to initiate, and then sustain, HAB observing, monitoring, and modeling in regional hotspots identified in Section 3 of this HAB plan.

3.2.6 Coral Health

Florida's Coral Reef is the third largest living reef on the planet and the only barrier reef system in the continental U.S. **(Image 10)**. The entire system is situated in the SECOORA domain. It underpins the state's marine ecosystems and protects our coastlines from major storms. Worldwide, coral species are facing severe threats from warming ocean waters, ocean acidification, and disease. For example, corals in FL and the Caribbean are experiencing a multi-year outbreak of stony coral tissue loss disease (NOAA 2021). Additionally, deep water corals are found throughout the southeast Atlantic with the Gray's Reef National Marine Sanctuary being a hotspot for *Oculina* corals.

Challenges:

- Climate change impacts to corals (e.g., water temperature warming and ocean acidification) are difficult to mitigate and cause coral bleaching, reduced growth, and lack of recruitment.
- Possible damage or destruction to reefs due to commercial and recreational fishing within reef ecosystems.
- Increase in population, coastal development, and recreational use of coral reef ecosystems are contributing to an increase in pollutants (e.g. run-off, oil/fuel from boats).
- New diseases are occurring and spreading.
- Loss of grazers throughout Florida's coral reef ecosystems.

Image 10: Coral reef in Florida Keys National Marine Sanctuary. Photo Credit: Bill Goodwin, NOAA

Priority Geographic Areas(s): Oculina Bank, southeast Florida and Florida Keys

Partner Activities:

- AOML conducts studies related to coral bleaching, sea level rise impacts to coral reefs, and supports the Coral Health and Monitoring Program.
- The Florida Keys NMS conducts research and monitoring to study the effectiveness of its marine zones and the health of its marine resources.
- Mote Marine Laboratory is implementing the Florida Keys strategic coral disease response and restoration initiative. This 10-year plan will be implemented through a consortium of coral research and restoration institutions.
- Aquarius Reef Base, operated by Florida International University, is located in Key Largo, FL and supports a variety of coral reef ecosystem science missions annually.
- The University of Miami Benthic Ecology and Coral Restoration Lab works to protect and recover depleted coral populations through coral propagation, active restoration, and citizen science.
- The University of North Carolina Wilmington Reproduction and Evolutionary Ecology Fogarty Lab (REEF Lab) works to better understand the stressors driving coral mortality and how to optimize coral husbandry for restoration. The REEF lab includes a state-of-the-art spawning facility that mimics conditions in the wild for ex-situ spawning but also allows for experimental manipulations of environmental conditions.

Additional SECOORA Investment Opportunities:

Observing Assets

- Invest in ecosystem moorings in priority geographic areas to monitor meteorological, physical, and biogeochemical parameters that are key for understanding coral reef health and response to environmental stressors.
- Expand bottom temperature data collection in priority geographic areas to monitor monthly and seasonal water temperature trends.
- Expand HFR coverage for surface current mapping in the Florida Keys and Georgia to identify how currents may carry estuarine and riverine discharge and disease-causing pathogens into coral reefs.
- Work with partners to deploy profiling gliders at deep water coral reefs such as Oculina Bank to collect physical oceanographic and biogeochemical measurements.

- Use drones to capture images/video footage at regular intervals for coral reef habitat mapping, detection of coral bleaching, and marine debris detection in coral reef ecosystems.
- Expand use of passive acoustic recorders to listen to healthy and degraded coral reefs, which can provide information on snapping shrimp acoustic behavior and fish sounds in these different environments.
- Expand ocean acidification monitoring throughout Florida's coral reef ecosystems and Gray's Reef National Marine Sanctuary.

Emerging Technologies

- Work with partners to conduct eDNA sampling and analysis to inform species presence/absence in a particular location and overall biodiversity.
- Evaluate emerging technologies that identify and quantify ocean pollutants and pathogens.

Modeling

- Develop high-resolution coupled physical-biogeochemical models to link marine carbonate ecosystem information with oceanographic processes.

3.2.7 Coastal and Ocean Acidification

Ocean acidification (OA) occurs when the ocean absorbs carbon dioxide from the atmosphere which causes a change in the chemistry of the ocean, making it more acidic (NOAA 2024e). In addition, coastal acidification can occur due to excess nutrient inputs from land, ocean warming, and coastal upwelling events. These changes can reduce the buffering capacity of coastal waters and enhance respiration-driven acidification through organic carbon and nutrient loading (NOAA 2024e). These changes in ocean and coastal water chemistry can have significant impacts on marine calcifiers, including coral and shellfish, early life-stages of fin and shellfish, and the economic and ecosystem services they provide. It is necessary to establish baselines of carbonate chemistry, monitor and identify sources of acidification and characterize its broader impacts in the southeast so we can adapt to these changes and better understand their potential effects on marine ecosystems **(Image 11)**. Scientists, resource managers, and industry experts are beginning to untangle the sources of changing chemistry and evaluate the consequences of extreme events superimposed on long-term trends (Wickes 2016).

Image 11: SCUBA divers service the SeapHOx OA sensor located at Looe Key, Florida. (Credit: Mote Marine Laboratory)

Challenges:

- Current monitoring and research for acidification in the southeast is limited, particularly in coastal areas.
- There are few monitoring stations directly associated with industry (e.g., shellfish farms and hatcheries).

- Extreme events have both immediate and lasting impacts on carbonate chemistry that are difficult to quantify given limited monitoring.

Priority Geographic Areas(s):

- Estuarine waters in the SECOORA domain that support the shellfish aquaculture industry and that may be susceptible to HABs.
- Additional priority locations for acidification monitoring in the southeast identified through SOCAN stakeholder workshop (SOCAN 2017) and include: 1) offshore of Sapelo Island, GA; 2) Gulf Stream, east of Gray's Reef, GA; and, 3) Biscayne Bay National Park, FL.
- Coral reef ecosystems in the southeast including the Florida Reef Tract and deepwater corals from NC to FL.

Partner Activities:

- NOAA's Ocean Acidification Program (OAP) funds research nationally to monitor acidification and understand its impact on marine ecosystems, societies, and economies.
- RSMAS at the University of Miami has a Coral Reef Futures Laboratory and an Ocean Acidification Coral Laboratory both focused on understanding the impacts of climate change on corals.
- NOAA's AOML Ocean Carbon Cycle Group operates ships of opportunity and conducts repeat hydrographic surveys to track ocean carbon.
- The Ocean Acidification Program at Mote studies the responses of ecologically important species — like corals — to projected levels of OA.
- USGS National Water Dashboard provides daily streamflow conditions, river discharge, and weather data for the U.S.

Additional SECOORA Investment Opportunities:

Observing Assets

- Equip NDBC stations 41013 (Frying Pan Shoals, NC) and 41010 (Canaveral East, FL) with OA sensor suite.
- Invest in ecosystem moorings and coastal stations in priority geographic areas. These stations should collect climate quality OA data, specifically pH, pCO_2, Total alkalinity, and Dissolved Inorganic Carbon (DIC), for use by state and federal resource managers.
- Equip a subset of the existing SECOORA moorings operated by UNCW and USF with additional sensors to monitor OA conditions. These include pH and pCO_2, chlorophyll, CTDs throughout the water column, and water column currents.

Emerging Technologies

- Evaluate emerging technologies that may be useful in studying coral reefs and coastal ecosystems. Examples include dissolved inorganic carbon and alkalinity sensors, which will provide better measures of OA (ACT 2018a).

Modeling

- Develop high-resolution coupled physical-biogeochemical models to link marine carbonate ecosystem information with oceanographic processes to enable predictive capability of OA assessment.

Products

- Annual OA monitoring products that can be used to inform state agencies and shellfish farmers of OA projections.

3.3 Marine Operations

Meteorological and in-situ physical oceanographic observations collected in real-time are critical to a wide user community including federal, state, and local governments, academic and industry partners, commercial and recreational boaters and fishermen, and beachgoers. These observations allow users to: monitor, prepare for, and respond to weather events threatening coastal communities; support efficient and safe marine transportation; provide information for search and rescue response; and inform offshore resource use and siting.

SECOORA is staged to address the following Marine Operations focus areas:

- Marine Safety
- Offshore Resources

3.3.1 Marine Safety

Data obtained from buoys and HFR are accessed daily by stakeholders across the southeast. These real-time observations support safe boating, shipping and commerce, mitigation of man-made (e.g., oil spill) and natural (e.g., HABs) hazards. Marine safety at sea is dependent on marine weather and oceanographic conditions. SECOORA contributes data from real-time moorings and HFR that assist the U.S. Coast Guard (USCG) with search and rescue efforts and NOAA's NWS with marine and coastal zone forecasts.

Image 12: Real-time data plays a crucial role in ensuring port safety by helping port authorities, ship operators, and port pilots make informed decisions based on weather and sea conditions. (Credit: Port of Miami)

Challenges:

- Lack of funding to expand mooring and HFR coverage to priority gap locations.
- Vessel strikes cause damage to real-time buoys annually.
- Tropical cyclones cause damage to real-time buoys, water level sensors, and HFR annually.

Priority Geographic Areas(s):
VA/NC border to Cape Hatteras; Long Bay, SC (between Myrtle Beach and Georgetown); the entire Georgia coastline; east coast of FL, specifically Sebastian Inlet, Jacksonville, Delray Beach; Biscayne Bay, Miami; key locations on the West Florida Shelf, specifically, Northwest of the Pulaski Shoals Light, offshore of Tampa Bay, DeSoto Canyon, along shelf break south of Destin, Tallahassee (and northeast of NDBC mooring 42036), Florida Bay, 20 m isobath west of Naples.

Partner Activities:

- NOAA nowCOAST maintains both land-based and marine based observations and forecast data.
- NOAA NWS maintains land-based weather stations and a marine weather forecast website with access to many resources.

- NOAA National Data Buoy Center (NDBC) operates oceanographic buoys for use in operational forecasting, warnings, and models.
- NOAA Physical Oceanographic Real-time System (PORTS) has been deployed to support port activities in Charleston, SC, Savannah, GA, Jacksonville, FL, Miami, FL, Port Everglades, FL, and Tampa Bay, FL. The PORTS support safe and cost-efficient navigation by providing ship masters and pilots with data required to avoid groundings and collisions.
- USACE and the Coastal Data Information Program (CDIP) operate wave buoys deployed in coastal and offshore waters in NC and FL. These buoys primarily measure waves and sea surface temperature.
- USCG leads ocean search and rescue operations nationwide. They depend on data from buoys and HFR for the Search and Rescue Optimal Planning System (SAROPS) which helps to better delineate the search area. Additionally, water temperature data is used for hypothermia modeling.
- NOAA's Office of Response and Restoration (ORR) Emergency Response Division provides 24-hour, 7 day a week response to spill events.
- NSF supports the Ocean Observatories Initiative Pioneer Array which has moved to the southern Mid-Atlantic Bight (MAB), offshore of Nags Head, NC. The array comprises buoys, autonomous underwater vehicles (gliders and Remus), subsurface and seafloor platforms. The Pioneer Array will remain on the MAB from 2024 until at least 2030.

Additional SECOORA Investment Opportunities:

Observing Assets

- Invest in additional buoys that collect meteorological and physical oceanographic core variables in priority geographic areas.
- Install physical oceanographic and water quality sensors at major river entrances and ports, such as the Cape Fear River, NC, Savannah River, GA, St. Johns River, FL, Miami, FL, and Charlotte Harbor, FL.
- Expand HFR coverage for surface current mapping and potentially ship tracking based on SECOORA's High Frequency Radar Observing System: Gap Analysis.
- Add wave buoys to expand wave data availability, and when possible, to validate HFR derived waves.
- Add visibility sensors at port entrances.

Education and Outreach

- Develop better connections with USCG and USACE for use of HFR data to include provision of training opportunities as needed.
- Advance outreach and education materials on ocean observing systems, such as buoys, to help reduce ship strikes.

3.3.2 Offshore Resources

Marine offshore areas are becoming more active each year with increased shipping, military use, and offshore energy and mineral exploration. There are many active offshore initiatives in the southeast including mining sand resources for beach nourishment, offshore wind lease development, marine renewable energy testing and development, and the potential drilling for hydrocarbons. In the southeast, offshore wind energy development is underway in North Carolina with other states exploring the potential as well. Marine renewable energy, an energy source harnessed from the natural movement of water, including waves, tides, and river and ocean currents, is being explored in NC and FL. Through active partnerships with US Department of Energy (DOE), BOEM, state regulatory

agencies, state and local permitting authorities, port operators, industry, and other stakeholders, SECOORA can provide observations to inform investigation, installation, and monitoring of offshore resource-based projects.

Challenges:

- It is often difficult to find or access data from federal agencies, state agencies, and academic institutions.
- There are dwindling sand resources available for use in long-term shore preservation efforts.

Priority Geographic Areas(s):

- Offshore areas identified in the National Outer Continental Shelf (OCS) Renewable Energy Leases mapbook, specifically off northeastern and southeastern NC.
- Sand resources and borrow areas throughout the southeast.
- Areas with high potential for offshore aquaculture activities such as the West Florida Shelf.

Partner Activities:

- BOEM is the lead federal agency for siting related to oil and gas, renewable energy, and marine minerals, but partners with other federal (e.g., NASA, NOAA) and state agencies and academic partners to conduct environmental studies. BOEM convenes partners to coordinate offshore wind activities through intergovernmental task forces in NC and SC. There is one renewable energy project underway offshore of northeastern North Carolina and another area under consideration in southeastern North Carolina.
- The Regional Wildlife Science Collaborative for Offshore Wind (RWSC) is coordinating with federal agencies, states' natural resources management programs, tribal communities, and offshore wind developers to assure they are collaborating on wildlife data collection, research, and information/data sharing in U.S. Atlantic waters.
- USACE and BOEM coordinate on the identification and use of offshore sand, gravel, and shelf resources under the Marine Minerals Program. They also partner with various state and local agencies through regional sand management working groups.
- The ECU Coastal Studies Institute (CSI) receives state and DOE funding for marine renewable ocean energy development. CSI is also a founding partner of the Atlantic Marine Energy Center (AMEC).
- At FAU/Harbor Branch the Southeast National Marine Renewable Energy Center is exploring ocean current energy solutions with funding from DOE.
- NSF supports the Ocean Observatories Initiative Pioneer Array which moved to the southern Mid-Atlantic Bight (MAB), offshore of Nags Head, NC. The array comprises buoys, autonomous underwater vehicles (gliders and Remus), subsurface and seafloor platforms. The Pioneer Array will remain on the MAB from 2024 until at least 2030.
- The Nature Conservancy (TNC) with support from SECOORA has developed the Southeast Marine Mapping Tool to help evaluate proposed locations for offshore projects such as dredging and wind energy sites (**Image 13**). The tool provides access to synthesized regional ocean features, marine species data, management data – all required to make informed decisions related to permitting and resource management.

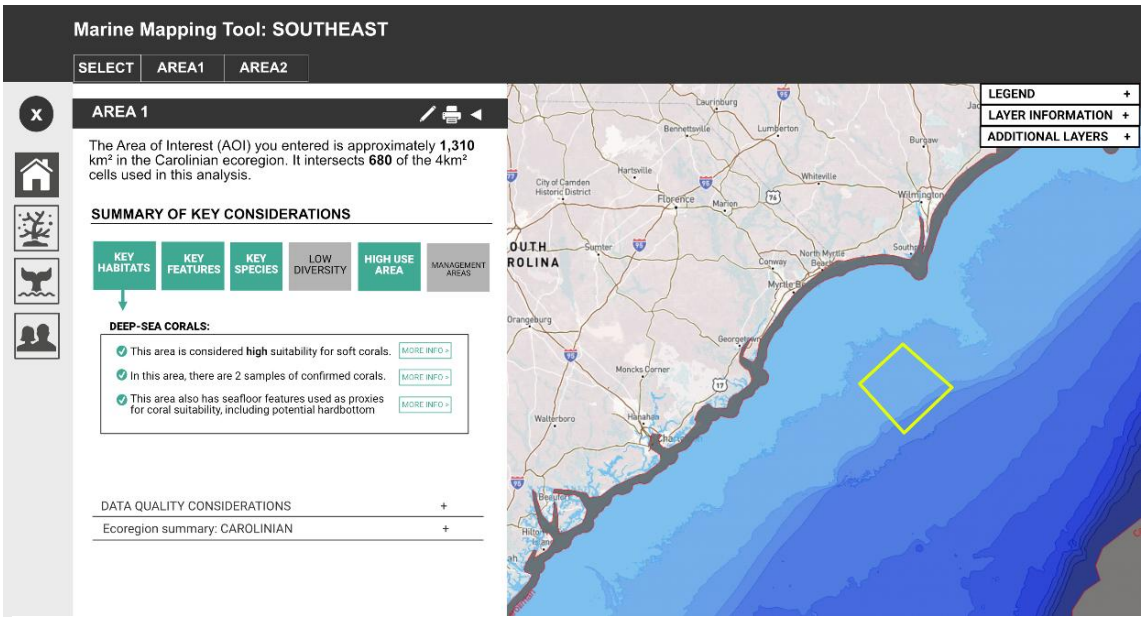


Image 13: The Southeast Marine Mapping Tool provides access to regional ecological data to help inform offshore ocean use decisions. Credit: Mary Conley, The Nature Conservancy

Additional SECOORA Investment Opportunities:

Observing Assets

- Leverage CSI investments supporting ocean renewable energy to expand observations off the NC Outer Banks.
- Work with partners to increase the number of glider deployments to collect physical oceanographic, biological (fisheries and marine mammal), and biogeochemical measurements to inform BOEM and other federal partners on habitat use and migratory patterns.
- Use coastal webcams or drones to capture images/video footage at regular intervals for shoreline assessments.

Citations

ACT 2018a. Alliance for Coastal Technologies (ACT) Workshop Proceedings: National Coastal Ecosystem Moorings Workshop. University of Washington, 20-21 March 2018, http://www.act-us.info/Download/Workshops/2018/Ecosystem_Mooring_Workshop_Report.pdf.

ACT 2018b. Practical Uses for Drone to Address Management Problems in Coastal Zones. The Alliance for Coastal Technologies. Workshop Proceedings Alliance for Coastal Technologies, Wells, Maine, 25-27 September 2018. http://www.act-us.info/Download/Workshops/2018/Drone.pdf.

Climate Central. 2024. Ocean Heatwaves. https://medialibrary.climatecentral.org/climate-matters/2020-ocean-heat-waves

de Silva, Akila, Issei Mari, Greg Dusek, James Davis, Alex Pang. 2021. Automated rip current detection with region based convolutional neural networks. Coastal Engineering, vol. 166, June 2021, doi: https://doi.org/10.1016/j.coastaleng.2021.103859.

de Silva, Akila, Mona Zhao, Donald Stewart, Fahim Hasan Khan, Greg Dusek, James Davis, Alex Pang. 2023. RipViz: Finding Rip Currents by Learning Pathline Behavior, in *IEEE Transactions on Visualization and Computer Graphics*, vol. 30, no. 7, pp. 3930-3944, Feb 2023. doi: 10.1109/TVCG.2023.3243834.

Dusek, Greg and Harvey Seim. 2013. A Probabilistic Rip Current Forecast Model. Journal of Coastal Research, Vol. 29, No. 4 (July 2013), pp. 909-925, URL: https://www.jstor.org/stable/23486560.

Dusek, G., Debra Hernandez, Mark Willis, Jenna A. Brown, Joseph W. Long, Dwayne E. Porter, and Tiffany C. Vance. 2019. WebCAT: Piloting the Development of a Web Camera Coastal Observing Network for Diverse Applications. Frontiers in Marine Science. 25 June 2019. 6:353. doi: 10.3389/fmars.2019.00353, https://www.frontiersin.org/articles/10.3389/fmars.2019.00353/full.

Dusek, G., Andre van der Westhuysen, Alex Gibbs, Donnie King, Scott Kennedy, Roberto Padilla-Hernandez, Harvey Seim and David Elder, (2014), Coupling a rip current forecast model to the nearshore wave prediction system. Proceedings 94th AMS Annual Meeting, Atlanta, Ga. 02-06 February 2014. Full manuscript available here: https://ams.confex.com/ams/94Annual/webprogram/Paper238859.html.

EPA 2024. Environmental Modeling Community of Practice. Virtual Beach. United States Environmental Protection Agency, January 2024, https://www.epa.gov/ceam/virtual-beach-vb.

FWC 1999. About Red Tides in Florida. Florida Fish and Wildlife Conservation Commission, 1999. https://myfwc.com/research/redtide/general/about/.

Hu, L. (2021). A global assessment of coastal marine heatwaves and their relation with coastal urban thermal changes. Geophysical Research Letters, 48, e2021GL093260. https://doi.org/10.1029/2021GL093260.

NOAA 2015a. Sound Check: New NOAA Effort Underway to Monitor Underwater Sound. NOAA Office of Science and Technology, National Marine Fisheries Service, 24 August 2015. https://www.st.nmfs.noaa.gov/feature-news/acoustics.

NOAA 2015b. A Plan to Meet the Nation's Needs for Surface Current Mapping. NOAA Integrated Ocean Observing System. May 2015. https://cdn.ioos.noaa.gov/media/2017/12/national_surface_current_plan.pdf.

NOAA 2016. NOAA Water Initiative: Vision and Five-Year Plan. December 2016. https://www.noaa.gov/water/explainers/noaa-water-initiative-vision-and-five-year-plan.

NOAA 2017. National Strategy for a Sustained Network of Coastal Moorings. NOAA Integrated Ocean Observing System. January 2017. https://cdn.ioos.noaa.gov/media/2017/12/NationalStrategyforSustainedNetworkofCoastalMoorings_FINAL.pdf.

NOAA 2019b. Hurricanes. NOAA Education, May 2019, https://www.noaa.gov/education/resource-collections/weather-atmosphere-education-resources/hurricanes.

NOAA 2019c. Harmful Algal Blooms. NOAA National Ocean Service, 02 October 2019, https://oceanservice.noaa.gov/hazards/hab/.

NOAA 2019f. Rip Current Survival Guide. NOAA Ocean Today interview with Greg Dusek, https://oceantoday.noaa.gov/ripcurrentfeature/.

NOAA 2021. Florida Reef Tract Coral Disease Outbreak. Florida Keys National Marine Sanctuary, National Ocean Service. https://floridakeys.noaa.gov/coral-disease/.

NOAA 2022. Annual High Tide Flooding Outlook: 2023. Center for Operational Oceanographic Products and Services. https://tidesandcurrents.noaa.gov/publications/2023_Annual_High_Tide_Flooding_Outlook.pdf

NOAA 2024a. Office for Coastal Management, 2024: Time-Series Data on the Ocean and Great Lakes Economy for Counties, States, and the Nation between 2005 and 2019 (Sector Level), https://www.fisheries.noaa.gov/inport/item/48033.

NOAA 2024b.Florida Keys National Marine Sanctuary. https://floridakeys.noaa.gov/corals/coralreefs.html

NOAA 2024c. Hurricane Impacts and Landfalls. NOAA AOML. https://www.aoml.noaa.gov/hrd/hurdat/All_U.S._Hurricanes.html

NOAA 2024d. NOAA Climate.gov. The future of coral restoration in the Florida Keys after unprecedented marine heat wave of 2023. https://www.climate.gov/news-features/event-tracker/future-coral-restoration-florida-keys-after-unprecedented-marine-heat#:~:text=In%20the%20summer%20of%202023,An%20error%20occurred.

NOAA 2024e. NOAA Ocean Acidification Program, https://oceanacidification.noaa.gov/OurChangingOcean.aspx.

Oliver, Eric, C. J., Burrows Michael T. , Donat Markus G. , Sen Gupta Alex , Alexander Lisa V. , Perkins-Kirkpatrick Sarah E. , Benthuysen Jessica A. , Hobday Alistair J. , Holbrook Neil J. , Moore Pippa J. , Thomsen Mads S. , Wernberg Thomas , Smale Dan A. 2019. Projected Marine Heatwaves in the 21st Century and the Potential for Ecological Impact. Frontiers in Marine Science. Vol. 6. doi: https://doi.org/10.3389/fmars.2019.00734

Pijanowski, B.C., Farina, A., Gage, S.H., Dumyahn, S.L., Krause, B. What is soundscape ecology? An introduction and overview of emerging new science. (2011). Landscape Ecology. Vol. 26, Issue 9, pp 1213-1232.

SAS. 2019. Artificial Intelligence. SAS Institute Inc. https://www.sas.com/en_us/insights/analytics/what-is-artificial-intelligence.html.

Schmidt Ocean Institute. Artificial intelligence guides rapid data-driven exploration of underwater habitats. Science Daily, 11 September 2018. https://www.sciencedaily.com/releases/2018/08/180830095358.htm.

Smale, D.A., Wernberg, T., Oliver, E.C.J., Thomsen M., Harvey B.P., Straub S.C., Burrows M.T., Alexander L.V., Benthuysen J.A., Donat M.G., Feng M., Hobday A.J., Holbrook N.J., Perkins-Kirkpatrick S.E., Scannell H.A., Sen Gupta A., Payne B.L., Moore P.J. (2019). Marine heatwaves threaten global biodiversity and the provision of ecosystem services. Nature Climate Change 9, 306–312. https://doi.org/10.1038/s41558-019-0412-1.

Smith K.E., Burrows M.T., Hobday A.J., Sen Gupta A., Moore P.J., Thomsen M., Wernberg T., Smale D.A. (2021). Socioeconomic impacts of marine heatwaves: Global issues and opportunities. Science 374: 6566. DOI: 10.1126/science.abj3593.

SOCAN 2017. SOCAN Monitoring Workshop, Workshop Report. Southeast Ocean and Coastal Acidification Network. 28 February 2017. https://docs.wixstatic.com/ugd/17544c_7b10c400708f4d1d8f4c545c326d251d.pdf.

Statista 2024. https://www.statista.com/statistics/248028/percent-change-in-us-gross-domestic-product-gdp-by-state/

United States Census Bureau 2023. https://www.census.gov/newsroom/press-releases/2023/population-trends-return-to-pre-pandemic-norms.html

United States Census Bureau 2024. https://www.census.gov/library/visualizations/2024/comm/percent-change-county-population.html

USGS 2018. Surface Elevation Table https://www.usgs.gov/centers/eesc/science/surface-elevation-table#:~:text=The%20Surface%20Elevation%20Table%20(SET,elevation%20change%20of%20wetland%20sediments

United States Lifesaving Association 2024. https://www.usla.org/page/ripcurrents.

Vezzulli, L., C. Grande, P. C. Reid, P. Hélaouët, M. Edwards, M.G. Höfled, I. Brettard, R.R. Colwelle, and C. Pruzzoa. 2016. Climate influence on Vibrio and associated human diseases during the past half century in the coastal North Atlantic. PNAS 113, E5062–E5071.

WebCAT 2019. Live Cameras and Historic Feeds. Southeast Coastal and Ocean Observing Regional Association. https://secoora.org/webcat/.

WHOI 2018. Harmful Algae, Neurotoxic Shellfish Poisoning, 12 October 2018. https://www.whoi.edu/website/redtide/human-health/neurotoxic-shellfish-poisoning/

Wickes, Leslie. 2016 State of the Science Workshop Report. Southeast Ocean and Coastal Acidification Network (SOCAN), https://18e20ebe-fff6-4462-adb0-48dbe8aacf5d.filesusr.com/ugd/17544c_5cb6913266dc4930897b196b9ba9e576.pdf.