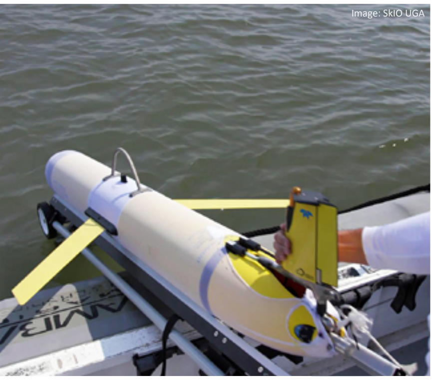
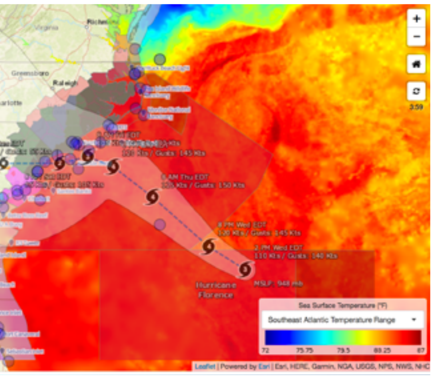




SECOORA

Southeast Coastal Ocean Observing Regional Association

Regional Coastal Ocean Observing System Strategic Operational Plan 2021 - 2026

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

Contents

1. Overview

1.1 Purpose

This document presents the Southeast Coastal Ocean Observing Regional Association (SECOORA) priorities for contributing to our improved understanding, management, conservation, 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). SECOORA is organized to provide ocean data, tools, and services in the following focus areas, which correspond with U.S. Integrated Ocean Observing System (IOOS®) societal goals and are important to southeast stakeholders: Ecosystems, including Water Quality and Living Marine Resources; Marine Operations; Coastal Hazards and Climate Variability. SECOORA has developed this 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 *Regional Coastal Ocean Observing System - Strategic Operational Plan* is intended to inform:

1. SECOORA staff and Board of Directors, to establish priorities for 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 demonstrate capabilities and describe connections to regional needs and priorities.

There are three main sections of this document.

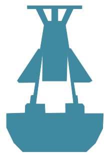
1. **Overview** provides regional and national context for SECOORA's work.
2. **Focus Areas** describes the focus areas that guide our work. SECOORA will invest in data collection, product development, and research to better understand the environmental and societal concerns identified within each of 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.
3. **RCOOS Subcomponents** identifies current investments and previously identified stakeholder needs for observing platforms, modeling, data management and communications, products, and outreach and education efforts.

The combination of the additional investment opportunities to support the focus areas (section 2) and the previously identified gaps and build out needs (section 3) provide a guide for future SECOORA investments.

1.2 SECOORA's Regional Coastal Ocean Observing System

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 or 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 transmitted 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.

The RCOOS priorities for the 2021-2026 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 and expand the HFR network distributed from Cape Hatteras to West Florida and continue to fill priority HFR gaps.
- Sustain, expand, and modernize in situ stations and work with stakeholders to leverage opportunities to fill gaps in coastal and ocean stations.
- Sustain and expand modeling efforts and engage with stakeholders to increase the use of models for management and decision-making.
- 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 South Atlantic Bight (SAB) and West Florida Shelf.
- Continue delivery and refine automated model nowcast/forecast products and other products based on stakeholder needs and utilization of data collected through the observation network.

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, and other recreational opportunities. In 2016 the ocean economy sectors contributed $48.2 billion to the southeastern region's gross domestic product, provided over 805,000 jobs, and over $21.7 billion in salaries (NOAA 2019a).

1.3.2 Oceanographic

The SECOORA footprint spans the four-state region of North Carolina (NC), South Carolina (SC), Georgia (GA), and Florida (FL). Our ocean and coastal waters reach from the eastern side of the Gulf of Mexico (GOM) to the SAB and are connected by the Loop Current-Florida Current-Gulf Stream continuum.

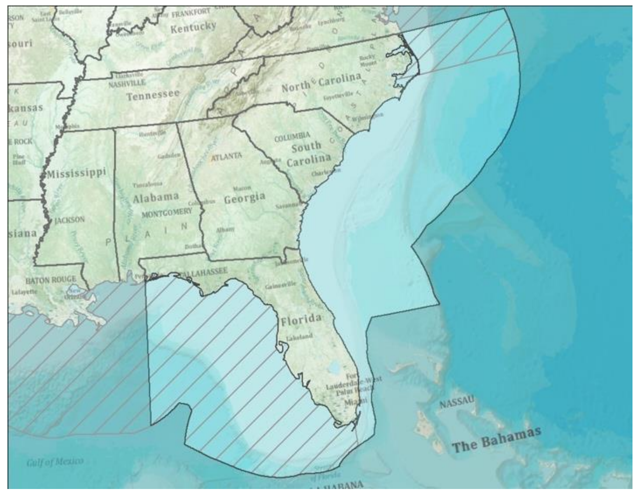


Figure 1 The SECOORA region. The hatched areas represent overlapping boundaries with neighboring IOOS regional associations in the Mid-Atlantic and the Gulf of Mexico.

South Atlantic Bight

The NC, SC, and GA region extends from estuaries to the coast, across the continental margin to the Gulf Stream, and from the GA/FL border to the NC/Virginia border. Here the confluence of the tropical and sub-tropical oceanic, atmospheric, and ecosystem domains, stretching from the Mid-Atlantic Bight through the Georgia Bight, influence a range of sub-to super-regional physical and biogeochemical phenomena. Despite its broad geographic extent, the dynamics of this region exhibit unifying aspects. The shelf is wide and shallow, and the physical dynamics are dominated 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. Within Long Bay, situated in NC and SC, buoyancy also plays an important role in the inner shelf. In these areas, river plumes not only deliver sediment, nutrients, and pollutants to coastal waters but may also provide chemical cues that affect recruitment of estuarine-dependent fishery species. River plumes, especially those comprised of waters from black-water streams, may also influence rates of coastal acidification in nearshore waters.

The NC, SC, and GA coastal zone 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 east coast of FL is characterized by a very narrow, shallow shelf, which is dominated by Gulf Stream variability and wind forcing. The southernmost stretch varies from 5 to 25 km width, from 25° to 27° N latitude, widening northward to ~130 km width off the FL/GA border. 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, anticipation of rip current hazards, 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 (NMS) protects the nation's only coral barrier reef (NOAA Corals and Coral Reefs). 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 Mexico Ocean Observing System (GCOOS) along the west coast of FL. The GOM 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 (NOAA 2016a).

The West Florida Shelf is most influenced by the Loop Current and its associated eddies, and major river discharges. The Gulf is suitable habitat for a diversity of harmful algae. The most notable Harmful Algal Bloom (HAB) species in the Gulf of Mexico is *Karenia brevis*, also known as Florida Red Tide. This species, because of coastal currents and winds, is found throughout the Gulf at varying concentrations and on occasion is transported to the east coast by the Florida Current. *K. brevis* produces brevetoxins which are capable of killing fish, birds, and other marine animals as well as causing health problems in humans (FWC 1999).

The GOM 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 GOM 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, and protect our environment. 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 such as the

Animal Telemetry Network (ATN), Marine Biodiversity Observation Network (MBON), Coastal Ocean and Modeling Testbed (COMT), and Ocean Technology Transition (OTT) projects.

As of May 2017, SECOORA is a certified Regional Information Coordination Entity (RICE). 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 now be used with the same confidence and assurances as 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 GOM, 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.

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): 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): affiliation of public, private, and nongovernment organizations (NGO) that provides training, resources, and relationships that coastal communities need to recover after a disaster.
- Regional Ocean Planning efforts: SECOORA supports efforts aimed at meeting the Administration's Ocean Policy. It also engages in regional discussions about sand management with the U.S. Army Corps of Engineers (USACE) and the Bureau of Ocean Energy Management (BOEM) state task forces regarding needs for offshore energy planning.
- 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 grassroots collaboration of marine scientists from the Bahamas to the Carolinas using acoustic telemetry and other technologies to better understand and conserve our region's important fish and sea turtle species.

2. Focus Areas

SECOORA focus areas broadly follow the IOOS societal benefits of safety, economy, and environment. SECOORA focus areas for 2021-2026 include: Coastal Hazards and Climate Variability; Ecosystems: Living Marine Resources and Water Quality; and, Marine Operations. Sub-topics for each focus area in Section 2 were identified by evaluating stakeholder priority concerns for the SECOORA region.

For each sub-topic listed within the focus area, the following information is provided:

- Challenges: defines key management challenges in the region
- Priority Geographic Area(s): identifies the most critical geographic areas
- Partner Activities: examples of related efforts by state, federal, and NGO partners
- Core Variables Required: core variables as defined by IOOS with other data identified as needed
- Current SECOORA Investments: funded RCOOS components
- Additional SECOORA Investment Opportunities: needs defined by stakeholder engagement, subject matter expert discussion, and previous observing platform gap analyses

2.1 Coastal Hazards and Climate Variability

The southeast experiences severe weather- and climate-related events that cause significant hardships for the economic, environmental, and social well-being of residents and visitors. Major storm events such as Hurricanes Irma, Florence, and Michael caused damage across the southeast from heavy rain and winds. The collection of environmental data by in-situ and mobile assets are required to establish baseline scenarios of coastal system function. Long-term data are needed to assess changing environment or 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.

Figure 2 Hurricane Matthew in 2016 cost an estimated $10.0 ($10.8) Billion and caused 49 deaths (data).

2.1.1 Storm Tracking and Forecasting

The southeast and Caribbean regions are the most highly impacted by hurricanes, tropical storms, and tropical depressions. These storms pose a variety of threats to people and property due to wind, heavy rainfall, and storm surge (NOAA 2019b). According to the 2014 National climate Assessment, there has been an increase in Atlantic hurricane activity since the 1980's. Tracking these storms and forecasting impacts are vital for the protection of life and property.

Challenges:

- Lack of funding to expand buoy and coastal station networks to fill priority gap locations.

- Limited number of 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.

Priority Geographic Areas(s): Entire domain

Partner Activities:

- NOAA's National Hurricane Center (NHC) and National Weather Service (NWS) provide the storm tracking, forecasts, and hazard alerts for tropical storm systems. Data from SECOORA buoys are used by the NWS for storm tracking and forecasting purposes.
- NOAA's Atlantic Oceanographic and Meteorological Laboratory (AOML) is working with the U.S. Navy, IOOS, and RAs to improve global ocean forecasts with observations from 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 Surge, Wave, and Tide Hydrodynamics (SWaTH) Network covers NC to Maine and monitors and documents the height, extent, and timing of storm surge.
- 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 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.

Core Variables Required:

- Physics: wind speed and direction, air temperature, water temperature, salinity, surface waves, currents, sea level, heat flux, bathymetry
- Biogeochemistry: optical properties, ocean color
- Biology and Ecosystems: biological vital rates (including, but not limited to, production, recruitment, mortality, fecundity, growth, and feeding rates)

Other Data:

- satellite sea surface temperature
- barometric pressure
- ocean heat content
- chlorophyll
- land cover (built and natural)
- coastal topography

Current SECOORA Investments:

Observing Assets

- 12 buoys and 4 non real-time moorings offshore of NC, SC, and the West Florida Shelf to that collect core physical and biogeochemical variables.
- 6 coastal stations (5 in FL and 1 in SC) that monitor physical and biogeochemical variables.

- 3-5 glider missions annually that collect core physical variables. The data are disseminated to the international scientific community via the National Glider Data Assembly Center (DAC) where they are further made available to the oceanographic modeling community.

Data Management and Communications

- SECOORA Hurricane Tool provides data assimilation capabilities that link observations with regional-scale forecasts and models before, during, and after storm events.

Modeling

- Tampa Bay Coastal Ocean Model (TBCOM) and the West Florida Coastal Ocean Model (WFCOM) provide marine circulation for the eastern Gulf of Mexico.
- Coupled Northwest Atlantic Prediction System (CNAPS) model provides four-dimensional nowcasts and forecasts of storm characteristics (e.g., wind structure, storm intensity and tracks) and their impact on and interaction with the marine environment.
- 2019 COMT project links the NOAA National Water Center (NOAA NWC) National Water Model to coastal ocean models run by North Carolina State University (NCSU) and Fathom Science to accurately quantify terrestrial hydrology (water run-off and riverine input) and the coastal ocean to understand compound flooding and ecological impacts in two locations, Albemarle-Pamlico Sound, NC and St. John's River, FL for storm events.

Products

- Forecast and hindcast products from the 2019 COMT project tailored to stakeholder needs.
- Marine Weather Portal (MWP) which meets the marine weather nowcast and forecast needs (including tropical forecasts) of boaters, mariners, and beachgoers in the southeast and Gulf of Mexico.
- 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.

Education and Outreach

- SECOORA hosts hurricane education materials based on common terminology and concepts for hurricane meteorology and physical oceanography.

Additional SECOORA Investment Opportunities:

Observing Assets

- Invest in additional buoys that collect meteorological and physical oceanographic core variables. Priority locations for moorings are listed in section 3.2.1.
- Invest in additional coastal stations that collect meteorological and physical oceanographic core variables. Priority locations for coastal stations are listed in section 3.2.2.
- Use drones at regular intervals to monitor shoreline change.
- Increase number of standard and event driven glider missions annually (minimum of 6) to include the SAB and GOM.
- Add wave buoys within HFR footprint to validate HFR derived waves.

Data Management and Communications

- Ingest and share data from Hurricane Hunter missions in the SECOORA data management system.
- Partner with USGS Surge, Wave, and Tide Hydrodynamics (SWaTH) network to share water level and wave data, post-storm event. SWaTH data could provide additional data for SECOORA modeling groups to validate their model output (skill assessment).

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.

Products

- Implement a Text-A-Buoy system, where users can get the latest ocean and weather information from their favorite buoy in the region.

Education and Outreach

- Advance outreach and education materials on hazard related ocean observing technologies and associated public benefit through the use of videos on the SECOORA website.

2.1.2 Coastal Flooding and Sea Level Rise

High tide flooding, sometimes referred to as nuisance flooding, is coastal flooding that leads to public inconveniences such as road closures. It is becoming increasingly common as sea levels rise (Sweet et al. 2019). 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, maintenance, and calibration of 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.

Figure 3 Coastal Flooding in Jacksonville, Florida. Photo Credit: NBC News

Priority Geographic Areas(s): Region-wide

Partner Activities:

- NOAA Center for Operational Oceanographic Products and Services (CO-OPS) has released an outlook on coastal high tide flooding with NOAA National Centers for Environmental Information (NCEI) every year since 2014 and provides seasonal bulletins to inform of the days and locations high tide flooding is most likely.
- NOAA CO-OPS operates water level stations along the east coast and GOM which provide shore based water level and meteorological data collection to support sea level and inundation monitoring.
- NOAA CO-OPS developed the 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 2016b).
- USACE Field Research Facility in Duck, NC has instrumented an 560m long pier and nearby coastal ocean waters to constantly record changing waves, winds, tides, and currents to understand coastal processes.
- 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 FL through Maine.

Core Variables Required:

- Physics: wind speed and direction, currents, sea level, water temperature, salinity, bathymetry
- Biogeochemistry: none
- Biology and Ecosystems: none

Other Data:

- barometric pressure
- shoreline mapping
- camera imagery
- river and inlet discharge rates
- land cover (built and natural)
- coastal topography

Current SECOORA Investments:

Observing Assets

- 12 buoys and 4 non real-time moorings offshore of NC, SC, and the West Florida Shelf to that collect core physical and biogeochemical variables.
- 6 coastal stations (5 in FL and 1 in SC) that monitor physical and biogeochemical variables.
- SECOORA and partners operate and maintain 7 beach web cameras in NC, SC, and FL.

Modeling

- 2019 COMT project links the NOAA NWC National Water Model to coastal ocean models run by NCSU and Fathom Science to accurately quantify interactions between terrestrial hydrology (water run-off and riverine input) and the coastal ocean to understand compound flooding for two locations, Albemarle-Pamlico Sound, NC and St. John's River, FL.

Products

- Forecast and hindcast products from the 2019 COMT project tailored to stakeholder needs.

Education and Outreach

- Partner with Georgia Tech University to host middle-grade educational materials on how to use sea level data in the classroom.
- Support regional partnerships based on national and regional concerns (e.g. SOCAN, FACT, SCDRP).

Additional SECOORA Investment Opportunities:

Observing Assets

- Invest in additional buoys that collect meteorological and physical oceanographic core variables. Priority locations for moorings are listed in section 3.2.1.
- Invest in additional coastal stations that collect meteorological and physical oceanographic core variables. Priority locations for coastal stations are listed in section 3.2.2.
- Install webcam 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.
- Partner with organizations and communities to install low cost water level sensors (e.g. Smart Sea Level Sensors project in GA) to help address information gaps related to chronic flooding and storm surge related flooding.

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.

Data Management and Communications

- Partner with SWaTH network to share water level and wave data, post-storm event. SWaTH data could provide additional data for SECOORA modeling groups to validate their model output (skill assessment).
- Work with partners to standardize beach camera image processing for coastal flooding and shoreline change detection.

2.2 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 larval habitat for shrimp, shellfish, crabs, and many species of fin fish which are managed under state and federal fishery management plans. These areas are influenced by coastal development and tourism, both of which contribute to anthropogenic impacts (e.g. run-off, pollution), and tidal rivers, which export nutrients into estuarine and coastal ocean environments. Eutrophic conditions, resulting from anthropogenic impacts and nutrient overload, can lead to HABs and cyanobacteria blooms. These blooms can cause significant fish kills and negative effects on human health which detrimentally impact local economies.

2.2.1 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.

Figure 4 Diver servicing an acoustic receiver in the Florida Keys. Photo Credit: FACT Network

Challenges:

- Limited availability of fish acoustic tag detections (i.e. not all detection data are aggregated in a centralized location, many tag detections are embargoed for extended periods of time) for visualization or broader research.
- Limited characterization and evaluation of fish movement, habitat use, site fidelity, life history, and stock structure for many species.
- Limited integration of marine environmental variability (including climate change) impacts on stock abundance, migration, and species richness.

- Changes to critical habitat essential to managed species are not well researched.
- 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), and individual states.

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

Core Variables Required:

- Physics: wind speed and direction, air temperature, water temperature, salinity, surface waves, currents
- Biogeochemistry: acidity, dissolved oxygen (DO), optical properties (chlorophyll), total suspended matter
- Biology and Ecosystems: biological vital rates (including, but not limited to, production, recruitment, mortality, fecundity, growth, and feeding rates), invertebrate species and abundance, fish species and abundance

Other Variables Required:

- barometric pressure
- fish movement information (e.g. site fidelity, spawning migration timing, habitat use)
- bottom habitat topography and substrate characterizations

Current SECOORA Investments:

Observing Assets

- 12 buoys and 4 non real-time moorings offshore of NC, SC, and the West Florida Shelf to that collect core physical and biogeochemical variables.
- 6 coastal stations (5 in FL and 1 in SC) that monitor physical and biogeochemical variables.
- 20 HFRs that collect surface current data to support fisheries management and research.
- 3-5 SAB glider missions annually to collect surface and subsurface physical and biogeochemical core variables. Two gliders are equipped with acoustic receivers to record tagged fish.
- Acoustic receivers are deployed on four SECOORA funded moorings in NC, three locations in south FL, and on two SECOORA gliders that operate in the SAB. Receivers record the presence of tagged fish.
- Hydrophones are deployed in estuarine waters of SC, on both coasts of FL, and on two gliders in order to record sound in the marine environment to better understand how sounds affect fish movement patterns, foraging, and courtship.
- SECOORA and FACT Network partners operate and maintain 30 temperature sensors at acoustic receiver locations in south FL.

Data Management and Communications

- Work with the SCDNR to advance the IOOS MBON through fisheries data stewardship for the southeast region.
- Host the FACT node (data upload, sharing, and archival system for tag data).

Modeling

- TBCOM and the WFCOM provide marine circulation allowing for HAB tracking and forecasts and oil spill trajectory modeling for the eastern GOM.
- CNAPS model provides four-dimensional marine environment nowcasts and forecasts.

Products

- Pilot visualization tool in development with GA Department of Natural Resources to better understand fish movement patterns based on acoustic tag detections coupled with physical and ecosystem data.

Emerging Technologies

- SECOORA partners at Mote Marine Lab are developing machine learning techniques to identify sources of ocean sounds (e.g. fish, marine mammal, anthropogenic).

Education and Outreach

- Support regional partnerships based on national and regional concerns (e.g. SOCAN, FACT, SCDRP).
- SECOORA also actively participates in FACT meetings and hosts the FACT website.

Additional SECOORA Investment Opportunities:

Observing Assets

- Invest in ecosystem moorings in key locations or add additional biogeochemical and biological sensors to existing moorings. See section 3.2.1.
- Increase number of standard and event driven glider missions annually (minimum of 6) to include the SAB and GOM. Key locations include Florida Middle Grounds, Florida Keys NMS, Gray's Reef NMS, and natural and artificial reef habitats in the Atlantic and GOM. For variables collected by gliders, see Table 3 in section 3.2.3.
- Expand HFR coverage for surface current mapping.
- Expand non real-time bottom temperature data collection throughout SECOORA domain.
- Support continued acoustic tagging and tracking of key species (e.g. Atlantic Sturgeon, Tripletail, Red Drum, Cobia, shark species) to increase data exchange from fish tagging efforts for research, management, and conservation efforts.

- Leverage Fishery Independent Research Program capabilities in the South Atlantic region (MARMAP and SEAMAP) to deploy hydrophones in areas where offshore surveys occur.
- Work with partners to deploy Wave Gliders or profiling gliders to collect physical oceanographic and biogeochemical data, and record ambient noise (hydrophones), and fish tags.

Data Management and Communications

- Develop data analysis tools and visualizations that incorporate oceanographic and biogeochemical data 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) and built environment.
- Develop model prediction and data analysis tools to quantify seasonal variation of surface and subsurface temperature, salinity, circulation, chlorophyll a, NO_3, DO, and other marine environmental variables.
- Incorporate HFR data into water quality models.
- Develop high-resolution coupled physical-biogeochemical models to link marine carbonate ecosystem information with oceanographic processes.

Products

- Create fisheries products (e.g. habitat use by species, seasonal habitat use) based on soundscape data for stakeholders.

Emerging Technologies

- 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.

2.2.2 Ocean Sound

Many marine animals depend on sound for their most basic needs—food, 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 in order to better understand the coupled nature-human system (Pijanowski et al. 2011). Hydrophone recordings are used to document sounds that can help us better understand behavior in fish and marine mammals. Anthropogenic sounds that impact our marine environment include noise from global shipping, oil and gas exploration, construction activity, and naval exercises. There is a need to better understand the breadth of the impacts humans are having on ocean fauna.

Challenges:

- There are few established long-term passive acoustic stations for developing baseline soundscapes.
- Researchers need to better understand human-based sound impacts on biodiversity from “natural” dynamics of ecosystems (Montie pers comm 2019).

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.
- Academic partners conduct research to assess the spatial and temporal patterns of fish in rivers, estuaries, reefs, and the coastal zone.

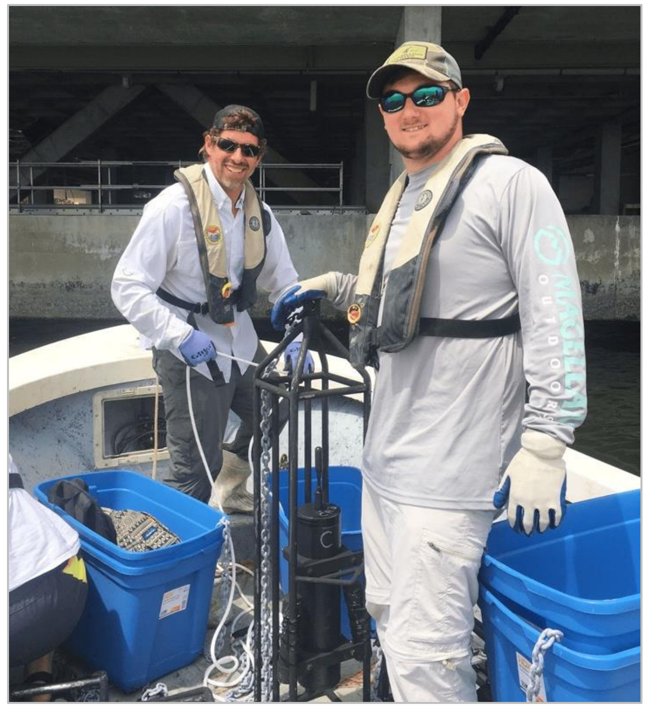


Figure 5 Eric Montie (left) and field manager Bradshaw McKinney deploying an acoustic recorder in the Charleston Harbor. Photo Credit: Eric Montie.

Core Variables Required:

- Physics: wind speed and direction, air temperature, water temperature, salinity, currents
- Biogeochemistry: None
- Biology and Ecosystems: sound

Other Variables Required:

- underwater video
- fish movement patterns identified through telemetry data from tagged fish
- barometric pressure

Current SECOORA Investments:

Observing Assets

- Hydrophones record sound in the marine environment to better understand how sounds affect fish movement patterns, foraging, and courtship. Hydrophones are deployed as fixed moorings in estuarine waters of SC, on both coasts of FL. Hydrophones are also deployed on two gliders.

Emerging Technologies

- SECOORA partners at Mote Marine Lab are developing machine learning techniques to identify sources of ocean sounds (e.g. fish, marine mammal, anthropogenic).

Additional SECOORA Investment Opportunities:

Observing Assets

- Leverage Fishery Independent Research Program capabilities in the South Atlantic region (MARMAP and SEAMAP) to deploy hydrophones in areas where offshore surveys occur.
- Increase number of standard and event driven SECOORA glider missions annually to include the SAB and GOM.
- Work with partners to deploy Wave Gliders or profiling gliders to collect physical oceanographic and biogeochemical data, and record ambient noise (hydrophones), and fish tags.

Products

- Create products based on soundscape data for stakeholders.

2.2.3 Public Health

According to the U.S. Census Bureau, "America's coastline counties - those directly adjacent to the Atlantic, Ocean, Pacific Ocean, or Gulf of Mexico - were home to about 94 million people in 2016, or about 29% of the total U.S. population (Cohen 2018)." Coastal areas of NC, SC, GA, and FL are seeing high rates of population growth and urbanization. At the same time, these coastal areas are also visited by millions of tourists annually. Coastal managers within the SECOORA region are concerned about public 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. SECOORA and its partners are working with federal and state agencies as well as municipal governments to address public health concerns in the region.

Figure 6 Tracking near real time water quality is critical in protecting public health at recreational swimming beaches. Photo Credit: Jamie Moncrief, UNCW

Challenges:

- Impaired coastal and estuarine water quality can threaten 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.

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 2019).
- Arnold School of Public Health at the University of South Carolina (USC) has a National Institute of Environmental Health Sciences-funded center on oceans and human health that is looking at microplastics, HABs, bacteria, and increased virulence of Vibrios as well as their associated impacts on public health.

Core Variables Required:

- Physics: wind speed and direction, air temperature, water temperature, salinity, surface waves, currents
- Biogeochemistry: colored dissolved organic matter, acidity, DO, optical properties (chlorophyll), total suspended matter, dissolved nutrients, pathogens, contaminants
- Biology and Ecosystems: microbial species/abundance/activity

Other Variables Required

- barometric pressure
- precipitation
- airborne particulate matter
- microplastics

Current SECOORA Investments:

Observing Assets

- 12 buoys offshore of NC, SC, and the West Florida Shelf to that collect core physical and biogeochemical variables.
- 6 coastal stations (5 in FL and 1 in SC) that monitor physical and biogeochemical variables.
- SECOORA and partners operate and maintain 7 beach web cameras in NC, SC, and FL.

Products

- Support "How's the Beach," which provides water quality nowcasts 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.

Emerging Technologies

- Develop machine learning algorithms 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).

Education and Outreach

- Partner with University of South Florida (USF) and YSI Xylem to host undergraduate student water quality field trips at the Clam Bayou, FL coastal station.

Additional SECOORA Investment Opportunities:

Observing Assets

- Invest in additional buoys that collect meteorological and physical oceanographic core variables. Priority locations for moorings are listed in section 3.2.1.
- Invest in ecosystem moorings in key locations or add additional biogeochemical and biological sensors to existing moorings. See section 3.2.1.
- Increase number of coastal stations that collect meteorological and physical oceanographic core variables. See section 3.2.2.
- Install physical oceanographic and water quality sensors at major river entrances and ports, such as the Savannah River, GA, Cape Fear River, NC, Tampa Bay, FL, and Charlotte Harbor, FL.
- Install web cameras at popular recreational beaches.
- Use drones to capture images/video footage at regular intervals for detection and tracking of pollutants and water quality monitoring.

Modeling

- Incorporate HFR data into water quality models.

Products

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

Emerging Technologies

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

Education and Outreach

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

2.2.4 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).

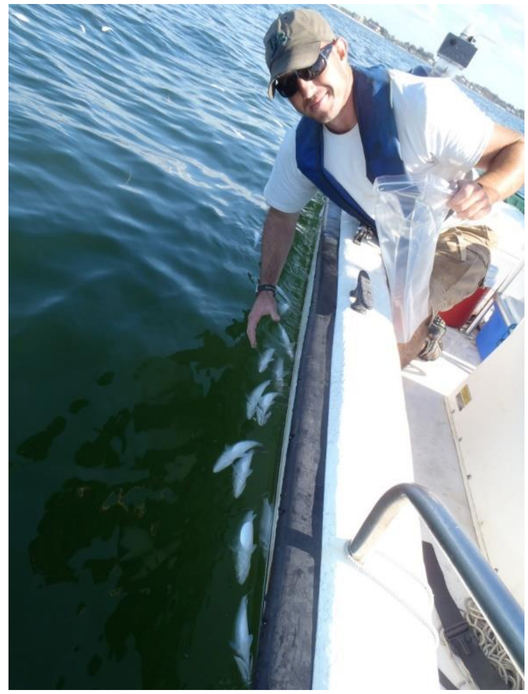


Figure 7 FWC Fish and Wildlife Research Institute staff collect dead fish from the field to be brought back to the FWRI laboratory for analysis. Photo Credit: FWC Fish and Wildlife Research Institute

Studies have shown that some harmful cyanobacteria (CyanoHABs) can be salt-tolerant and able to live in estuarine environments. Eutrophication of fresh and brackish waters, largely due to nutrient run-off from anthropogenic sources (e.g. development, agriculture), has increased the number of CyanoHAB events in coastal areas of the southeast U.S. (Paerl and Huisman 2009). Non-toxic HABs may also cause damage to ecosystems, fisheries resources, and recreational facilities, often due to the sheer biomass of the accumulated algae. When this biomass decays as the bloom terminates, oxygen is consumed, leading to widespread mortalities of plants and animals in the affected area due to depressed levels of dissolved oxygen (Anderson 2009).

Challenges:

- Increasing HABs (including freshwater cyanobacteria blooms) and hypoxic events threaten human health, local economies, and ecosystems.
- Tracking HABs requires assets, multi-agency coordination and investment in development and implementation of hands-on, and autonomous data collection methods.
- Prevention, control, and mitigation of HABs is critical for management and requires multi-institutional efforts and coordinated investment in research to develop viable strategies and technologies as well as cooperation among agencies for implementation.

Priority Geographic Area(s): All areas within the SECOORA domain are impacted by HABS, including cyanobacteria, in coastal, estuarine, and freshwater ecosystems.

Partner Activities:

- NOAA National Centers for Coastal and Ocean Science (NCCOS) advances the scientific understanding and ability to detect, monitor, assess, and predict HAB and hypoxia events. They also provide satellite imagery and analyses for HABS and cyanobacteria blooms.
- NOAACO-OPS provides a GOM HAB Forecast.
- Mote Marine Laboratory has designed a user-friendly app that provides beach condition reports that alert you when dead fish are present, whether there is respiratory irritation among beachgoers, provide water color, the wind direction, and what flags are currently flying at lifeguard-monitored beaches.
- Arnold School of Public Health at the USC has a National Institute of Environmental Health Sciences-funded center on oceans and human health that is looking at HABs, bacteria, and their impact on public health.
- FL Fish and Wildlife Conservation Commission (FL FWC) reports on the current status of *K. brevis* blooms using tables, static maps, and interactive Google Earth maps. FWC provides a statewide *K. brevis* map that breaks down coastal areas to highlight when concentrations are not present, very low, low, medium, and high.
- USF, in coordination with FL FWC, provides seasonal HAB outlooks and short-term (4.5 day) trajectory forecasts for the GOM and Tampa Bay.

Core Variables Required:

- Physics: wind speed and direction, air temperature, water temperature, salinity, surface waves, currents
- Biogeochemistry: colored dissolved organic matter, acidity, DO, optical properties (ocean color, chlorophyll), total suspended matter, dissolved nutrients, pathogens, contaminants
- Biology and Ecosystems: phytoplankton species and abundance

Other Variables Required

- barometric pressure
- precipitation
- airborne particulate matter
- hydrography
- baseline ecosystem data
- tracking of target HAB species (cells and/or toxins)

Current SECOORA Investments:

Observing Assets

- 12 buoys and 4 non real-time moorings offshore of NC, SC, and the West Florida Shelf to that collect core physical and biogeochemical variables.
- 6 coastal stations (5 in FL and 1 in SC) that monitor physical and biogeochemical variables.
- 20 HFRs that collect surface current data to support HAB tracking.
- 3-5 SAB glider missions annually to collect surface and subsurface physical and biogeochemical core variables.
- SECOORA and partners at FWRI, USF, and Mote Marine Lab, are working together to enhance in situ offshore monitoring of HABs using gliders, conducting ship-based field surveys targeting key bloom dynamics, using satellite remote sensing to observe surface optical properties, and evaluating bloom dynamics using physical and ecological modeling.

Modeling

- TBCOM and the WFCOM provide short-term (4.5 day) HAB trajectory forecasts used by FL FWC for HAB bulletins.
- CNAPS model provides four-dimensional marine environment nowcasts and forecasts which can be used for HAB tracking and forecasting.
- 2019 COMT project links the NOAA NWC National Water Model to coastal ocean models run by NCSU and Fathom Science. The model quantifies interactions between terrestrial hydrology and the coastal ocean for the two study locations, Albemarle-Pamlico Sound, NC and St. John's River, FL. Model can provide HAB trajectory forecasts for river and estuarine environments.

Education and Outreach

- Maintain the Red Tide Data Resources for Florida page.

Additional SECOORA Investment Opportunities:

Observing Assets

- Invest in additional buoys that collect meteorological and physical oceanographic core variables. Priority locations for moorings are listed in section 3.2.1.
- Invest in ecosystem moorings in key locations or add additional biogeochemical and biological sensors to existing moorings. See section 3.2.1.
- Increase number of coastal stations that collect meteorological and physical oceanographic core variables. See section 3.2.2.
- Use drones to capture images/video footage at regular intervals for detection and tracking of HABs.
- Increase number of standard and event driven SECOORA glider missions annually (minimum of 6) to include the SAB and GOM.
- Work with partners to deploy Wave Gliders or profiling gliders to collect physical oceanographic and biogeochemical measurements for HABs.

Data Management and Communications

- Support the analysis of satellite data for HABs detection and tracking.

Products

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

Emerging Technologies

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

Education and Outreach

- Expand SECOORA HABs data resources pages beyond red tide to provide resources for other HAB events and species.
- Collaborate with partners to implement a citizen science project to report HABs.

2.2.5 Coral Health

Florida's coral reef system is the third largest living reef on the planet and the only barrier reef system in the continental U.S. 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 coral disease for which the pathogen has yet to be identified (NOAA 2019d). Additionally, deep water corals are found throughout the southeast Atlantic.

Figure 8 Coral reef in Florida Keys National Marine Sanctuary. Photo Credit: Bill Goodwin, NOAA

Challenges:

- Climate change impacts to corals, including bleaching and ocean acidification, are difficult to mitigate.
- 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.

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 in Key Largo, FL 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.

Core Variables Required:

- Physics: wind speed and direction, air temperature, water temperature, salinity, surface waves, currents, heat flux, sea level

- Biogeochemistry: colored dissolved organic matter, optical properties (chlorophyll), pCO_2, acidity, DO, dissolved nutrients, pathogens, contaminants
- Biology and Ecosystems: coral species and abundance

Other Variables Required:

- eDNA
- barometric pressure
- key coral species genetics, growth, disease identification, recovery
- Photosynthetically Active Radiation (PAR)

Current SECOORA Investments:

Observing Assets

- SECOORA and FACT Network partners operate and maintain 30 temperature sensors at acoustic receiver locations in south FL. These data will help monitor temperature near coral reefs in south FL.
- Support ocean acidification monitoring at the Gray's Reef NMS for Oculina coral research.

Additional SECOORA Investment Opportunities:

Observing Assets

- Invest in ecosystem moorings in key locations or add additional biogeochemical and biological sensors to existing moorings. See section 3.2.1.
- Expand non real-time bottom temperature data collection throughout SECOORA domain.
- Expand HFR coverage for surface current mapping in the Florida Keys to identify how currents may carry disease-causing pathogens throughout the reef tract.
- Work with partners to deploy Wave Gliders or profiling gliders at deep water coral reefs, Oculina Bank, and the FL Keys reef tract 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.

Modeling

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

Emerging Technologies

- Evaluate emerging technologies that identify and quantify ocean pollutants and pathogens.

2.2.6 Coastal and Ocean Acidification

Ocean acidification (OA) is a term that describes the change in the carbonate chemistry of ocean waters, largely due to increased carbon from the atmosphere entering the ocean. In addition, coastal acidification can occur from changes to river discharge (e.g., from increased precipitation and land use change), warming, and nutrient inputs. These changes can reduce the buffering capacity of coastal waters and enhance respiration-driven acidification through organic carbon and nutrient loading (NOAA 2019e). These changes in ocean and coastal water chemistry can have significant impacts on marine calcifiers, including coral 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. 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).

Challenges:

- Current monitoring and research for OA 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.

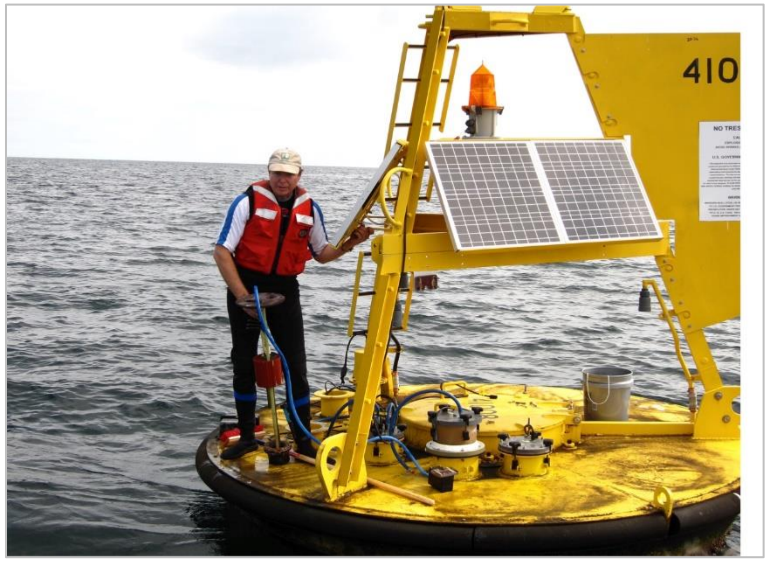


Figure 9 The Greys Reef mooring is the only mooring in the SECOORA region with ocean acidification monitoring. Photo Credit: NOAA Gray's Reef National Marine Sanctuary

Priority Geographic Areas(s):

- Estuarine waters in the SECOORA domain that support the shellfish aquaculture industry.
- Additional priority locations for OA monitoring in the southeast identified through SOCAN stakeholder workshop (SOCAN 2017).
- 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.

Core Variables Required:

- Physics: wind speed and direction, air temperature, water temperature, salinity, surface waves, currents, sea level
- Biogeochemistry: pCO_2, acidity, DO
- Biology and Ecosystems: coral species and abundance, invertebrate species and abundance

Other Data:

- total alkalinity
- dissolved inorganic carbon
- river discharge
- upwelling
- dissolved inorganic nutrients (NO_3, NH_4)

Current SECOORA Investments:

Observing Assets

- Support ocean acidification monitoring at the Gray's Reef NMS. The sensors deployed at this station include pCO_2, pH, DO, turbidity, chlorophyll, salinity and water temperature.

Education and Outreach

- Support regional partnerships based on national and regional concerns (e.g. SOCAN, FACT, SCDRP).

Additional SECOORA Investment Opportunities:

Observing Assets

- Invest in ecosystem moorings in key locations or add additional biogeochemical and biological sensors to existing buoys. See section 3.2.1.

Modeling

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

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).

2.3 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.

2.3.1 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. Additionally, SECOORA's MWP was developed specifically to address safety at sea concerns for the recreational boating and fishing communities.

Challenges:

- Lack funding to expand mooring and HFR coverage to priority gap locations.
- The SECOORA MWP is not reaching all possible users.

Priority Geographic Areas(s): Myrtle Beach, SC, Georgia coastline, east coast of FL, key locations on the West Florida Shelf

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.

Core Variables Required:

- Physics: wind speed and direction, air temperature, water temperature, surface waves, currents, sea level, bathymetry
- Biogeochemistry: contaminants
- Biology and Ecosystems: None

Other Data:

- barometric pressure
- visibility

Current SECOORA Investments:

Observing Assets

- 12 buoys offshore of NC, SC, and the West Florida Shelf to that collect core physical and biogeochemical variables.
- 6 coastal stations (5 in FL and 1 in SC) that monitor physical and biogeochemical variables.
- 20 HFRs that collect surface current data.

Data Management and Communications

- The SECOORA Hurricane Tool provides data assimilation capabilities that link observations with regional-scale forecasts and models before, during, and after storm events.

Modeling

- CNAPS model provides four-dimensional marine environment nowcasts and forecasts.
- 2019 COMT project links the NOAA NWC National Water Model to coastal ocean models run by NCSU and Fathom Science. The model quantifies interactions between terrestrial hydrology (water run-off and riverine input) and the coastal ocean for Albemarle-Pamlico Sound, NC and St. John's River, FL. Modeling supports NOAA Coastal Survey Development Lab need for navigation products and identification of marine hazards.
- TBCOM and the WFCOM provide circulation, HABs tracking and modeling, and oil spill trajectory modeling for the eastern GOM.

Products

- The MWP meets the marine weather nowcast and forecast needs (including tropical forecasts) of boaters, mariners, and beachgoers in the southeast and Gulf of Mexico.

Education and Outreach

- The SECOORA Hurricane Resources webpage provides a consolidated list of hurricane data resources for the southeast (updated annually). Additionally, SECOORA supports individual hurricane data pages for storms that could potentially make landfall within the SECOORA region.
- SECOORA hosts education materials based on common terminology and concepts for meteorology and physical oceanography. Waves, Build-a-Buoy, and Ocean Observing Technology are featured.

Additional SECOORA Investment Opportunities:

Observing Assets

- Invest in additional buoys that collect meteorological and physical oceanographic core variables. Priority locations for moorings are listed in section 3.2.1.
- Install physical oceanographic and water quality sensors at major river entrances and ports, such as the Savannah River, GA, Cape Fear River, NC, Tampa Bay, FL, and Charlotte Harbor, FL.
- Expand HFR coverage for surface current mapping.
- Add wave buoys to expand wave data availability, and when possible, to validate HFR derived waves.

Data Management and Communications

- Ingest and share data from Hurricane Hunter missions in the SECOORA data management system.

Products

- Implement a Text-A-Buoy system, where users can get the latest ocean and weather information from their favorite buoy in the region.

Education and Outreach

- Develop better connections with USCG and USACE for use of HFR data to include provision of training opportunities as needed.
- Foster partnerships with marinas, fishing and tackle shops, and others to broaden the use of the MWP.
- Advance outreach and education materials on ocean observing technology and associated public benefit through the use of videos on the SECOORA website.

2.3.2 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). The United States Lifesaving Association estimates that the annual number of deaths due to rip currents on our nation's beaches exceeds 100. Rip currents account for over 80% of rescues performed by surf beach lifeguards (Rip Currents, USLA). 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.
- Web cameras are available at many area beaches; however, there is a lack of standardization in camera deployment, data storage, and image processing for rip current detection (Dusek et al. 2019).

Figure 10 Web camera from the Web Camera Applications Testbed (WebCAT) project in Cherry Grove, SC. Photo Credit: Surfline, inc.

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

Partner Activities:

- NOAA CO-OPS sponsored the development of a statistical rip current forecast model and is supporting the operationalization of the model with 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).
- The United States Lifesaving Association, in partnership with NWS and National Sea Grant Program, work to raise awareness about the dangers of rip currents. New outreach materials and signage have been developed based on the most recent scientific research.
- NC Sea Grant, SC Sea Grant, and FL Sea Grant conduct outreach to improve rip current identification and increase swimmer safety.

Core Variables Required:

- Physics: wind speed and direction, surface waves, nearshore/surfzone bathymetry, currents, water level
- Biogeochemistry: None
- Biology and Ecosystems: None

Other Data:

- camera imagery

Current SECOORA Investments:

Observing Assets

- 12 buoys offshore of NC, SC, and the West Florida Shelf to that collect core physical variables.
- SECOORA and partners operate and maintain 7 beach web cameras in NC, SC, and FL.

Additional SECOORA Investment Opportunities:

Observing Assets

- Invest in additional buoys that collect meteorological and physical oceanographic core variables. Priority locations for moorings are listed in section 3.2.1.
- Invest in additional coastal stations that collect meteorological and physical oceanographic core variables. Priority locations for coastal stations are listed in section 3.2.2.
- Install web cameras at popular recreational beaches for rip current detection.

Data Management and Communications

- Work with partners to standardize image processing for rip current detection.

Products

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

Emerging Technologies

- Develop machine learning algorithms to identify rip currents.

2.3.3 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 offshore finfish aquaculture, mining sand resources for beach nourishment, developing natural gas pipelines, potential drilling for hydrocarbons, and evaluating alternative energy efforts to harness wind and currents. Through active partnerships with BOEM, state departments of energy, state and local permitting authorities, port operators, industry, and other stakeholders, SECOORA can provide a network of expertise to support investigation, installation, and monitoring of offshore resource-based projects.

Figure 11 The Port of Miami contributes more than $43 billion annually to state of Florida and supports more than 334,000 jobs. (data)

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) Oil and Gas Leasing Draft Proposed Program and OCS Renewable Energy Leases.
- Sand resources and borrow areas, particularly on the OCS.
- Areas with high potential for 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 NC.
- USACE and BOEM have a memorandum of understanding to coordinate on offshore sand, gravel, and shelf resources. They also partner with various state and local agencies through regional sand management working groups.
- NOAA NCCOS is working with private industry groups to site finfish aquaculture pens on the West Florida Shelf.

Core Variables Required:

- Physics: wind speed and direction, air temperature, water temperature, salinity, surface waves, bathymetry, bottom character, currents, sea level
- Biogeochemistry: DO, dissolved nutrients, optical properties (chlorophyll)
- Biology and Ecosystems: sound, coral species/abundance, phytoplankton species/abundance, zooplankton species/abundance, invertebrate species and abundance, fish species/abundance, sea birds species/abundance, sea turtles species/abundance, marine mammal species/abundance

Other Data:

- isotopes
- barometric pressure
- telemetry data from tagged fish
- habitat mapping and habitat classification

Current SECOORA Investments:

Observing Assets

- 12 buoys and 4 non real-time moorings offshore of NC, SC, and the West Florida Shelf to that collect core physical and biogeochemical variables.
- 6 coastal stations (5 in FL and 1 in SC) that monitor physical and biogeochemical variables.
- 20 HFRs that collect surface current data to support fisheries management and research.
- Hydrophones are deployed in estuarine waters of SC, on both coasts of FL, and on two gliders in order to record sound in the marine environment to better understand how sounds affect fish movement patterns, foraging, and courtship.

Data Management and Communications

- Host the FACT node so that over 45 partners agencies and institutions using acoustic telemetry to resolve the movements of aquatic species can summarize and share data with BOEM.

Additional SECOORA Investment Opportunities:

Observing Assets

- Leverage Fishery Independent Research Program capabilities in the South Atlantic region (MARMAP and SEAMAP) to deploy hydrophones to capture baseline noise levels.
- Work with partners to deploy Wave Gliders to collect physical oceanographic, biological (fisheries), and biogeochemical measurements.
- Use drones to capture images/video footage at regular intervals for shoreline assessments.

3. RCOOS Subcomponents

A 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..
- **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.
- **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.

3.1 National Efforts

Many national efforts are underway 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 January 2017. There are 370 existing coastal moorings located within the U.S. Exclusive Economic Zone. 215 are operated by federal entities (NOAA and USACE) and 155 by non-federal entities (IOOS RAs and the National Science Foundation (NSF) Ocean Observatories Initiative). The Strategy evaluates this existing inventory and provides ten recommendations to guide 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).

The National Academies of Science Gulf Research Program (GRP) is an independent, science-based program founded in 2013, as part of legal settlements with the companies involved in the 2010 *Deepwater Horizon* disaster. Beginning in 2018, the GRP has announced a series of funding opportunity aimed at improving understanding and prediction of the GOM Loop Current System. Through this endeavor, HFRs are being deployed along the southern Florida Keys and moorings are being deployed along the West Florida Shelf.

3.2 Observing Assets

3.2.1 Moored stations

Background
The National Strategy for a Sustained Network of Coastal Moorings (2017) states, "meteorological measurements and in-situ oceanographic observations of physical, chemical, and biological conditions throughout the water column...provide the backbone of coastal intelligence." 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 USF, maintains ocean moorings in coastal and offshore NC, SC, and FL. Fixed moorings operated by SECOORA augment the NOAA NDBC mooring array with regional observations for the marine environment. The SECOORA funded mooring data are used by an array of stakeholders, such as NOAA NWS for nowcasts/forecasts of weather and ocean conditions, USCG to initiate their SAROPS model, and state agencies to assist with HAB tracking.

Core Variables Collected
Data collected by sensors on moorings directly address the need to document variability in the nearshore and offshore environments. The SECOORA real-time moorings 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 moorings and the variables collected.

	Wind Speed, Gust, Direction	Air Temp	Barometric Pressure	Relative Humidity	SW/LW Radiation	Water Temp	Currents	Waves	Cond/ Salinity	Fish Acoustic Sensors
UNCW 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	X
ILM2Wave						X		X		
SUN2 - Northern Long Bay	X	X	X	X		X			X	X
SUN2Wave						X	X	X		
CAP2 - Inshore Capers Island	X	X	X	X		X			X	
FRP2 - Inshore Fripp Island	X	X	X	X		X			X	
OB27 - Onslow Bay*						X	X	X	X	X
USF Moorings										
C10 - WFS Central nearshore	X	X	X		X	X				
C12 - WFS Central offshore	X	X	X		X	X				
C13 - WFS South	X	X	X		X	X				
C11 - WFS Subsurface*						X	X	X		
C15 - WFS Subsurface*						X	X	X		
C21 - Tower*	X	X	X	X		X	X	X		
*Non real-time station										

Table 1. SECOORA moorings and variables collected

Additional SECOORA Investment Opportunities *(see Figure 12 for proposed stations)*
A consistent array of moorings that provide surface and subsurface data (i.e. atmospheric, physical oceanographic, and biogeochemical) are needed throughout the SECOORA domain to better address significant regional issues related to fisheries management, water quality, climate variability, coastal and marine hazards, and environmental threats such as OA, HABs, and coral disease. During the 2017 SECOORA Members Meeting, members and stakeholders reviewed locations of currently deployed moorings. They then identified locations where new moorings should be deployed and identified existing moorings that could benefit from the addition of new sensor suites (e.g. pH and pCO_2 for OA, acoustic sensors for fish tracking).

The SECOORA domain was broken into three sub-regions and in situ observing priorities were identified by sub-region. The sub-regions included: 1) NC, SC, and GA; 2) east coast of FL; and, 3) west coast FL/GOM. The outcomes from this session are found in the SECOORA Build-out Plan addendum.

North Carolina, South Carolina, and Georgia
The NC, SC, and GA region includes real-time moorings established by the UNCW Coastal Ocean Research and Monitoring Program (CORMP), NOAA NDBC, SCRIPPS/USACE CDIP moorings, University of Georgia (OA monitoring), and project related moorings that provide a short term increase in observation (e.g., NSF funded project moorings). The mooring priorities for the NC, SC, and GA region range from low-cost options, such as adding additional sensors to existing moorings, to higher cost options of deploying new real-time or non-real-

time moorings in key locations (e.g. nearshore within river plumes and seafloor instruments under the Gulf Stream). The priorities for the fixed platforms in the coastal and ocean region offshore of NC, SC, and GA are as follows:

- Equip a subset of the existing SECOORA moorings operated by UNCW with additional sensors (Table 1: ILM2, ILM3, LEJ3, SUN2, CAP2, FRP2). Sensors that could be added to the moorings include pH and pCO_2 (for OA research), chlorophyll, CTDs throughout the water column, and water column currents.
- Deploy ecosystem moorings or OA buoys in the following locations: 1) offshore of Sapelo Island, GA; and, 2) east of the Gray's Reef OA buoy, near the Gulf Stream (SOCAN 2017).
- Equip NDBC stations 41013 (Frying Pan Shoals) and 41010 (Canaveral East) with OA sensor suite.
- Add mid-shelf (20-50 m) and outer-shelf (60 m) moorings in Long Bay, SC offshore of the Myrtle Beach region and within the Caswell/Georgetown HFR coverage area.
- Add moorings near the shipping channels at entrances to the Charleston Harbor, Savannah River, and Cape Fear River that provide air temperature, barometric pressure, wind speed, gust, direction, surface water temperature and salinity, waves, currents, and potentially visibility to increase safety into and out of the ports.
- Extend Long Bay mooring line with 2-3 CPIES deployed on the seafloor, under the Gulf Stream. These stations will also be within the Caswell/Georgetown HFR coverage area.

Florida East Coast
The SCRIPPS/USACE CDIP program deployed four WaveRider buoys on the east coast of FL and one offshore of Key West, which have helped fill some data gaps. Additionally, SECOORA and its partners successfully petitioned NOAA to maintain the Cape Canaveral NDBC mooring (41009) which provides vital information to NASA, SpaceX, and Port Canaveral. The CDIP and NDBC moorings provide valuable data for marine safety and transportation sectors and coastal process modeling; however, since the CDIP moorings only provide spectral wave and surface water temperature data, they do not provide the meteorological and additional in-water data required by many SECOORA stakeholders.

Meteorological and physical oceanographic buoys and coastal stations are needed on the east coast of FL, within the 10 – 50 meter isobaths. These stations are required to fill data gaps for marine safety and transportation and coastal hazards. Additionally, 1-2 of these moorings should include biogeochemical sensors to better understand ecosystems, fisheries, and water quality (i.e. productivity, HABs tracking, OA). Moorings are needed in the following locations off the east coast of FL (ranked by importance) as few stations exist in these areas:

- Miami
- Sebastian Inlet
- Jacksonville
- Delray Beach
- Fort Pierce buoy could extend HAB tracking for the Indian River Lagoon into coastal waters.
- SOCAN identified the need for an OA buoy within Biscayne National Park, the northern end of the Florida Reef Tract.

Florida West Coast
The west coast of FL has buoys and coastal stations already established by the USF Coastal Ocean Monitoring and Prediction System (COMPS), NOAA NDBC, SCRIPPS/USACE CDIP moorings, and Tyndall Air Force Base. While there are seemingly a large number of stations on the Gulf Coast, most are shore-based stations supporting water level and meteorological data collection. The offshore moorings, operated and maintained by COMPS, NDBC, CDIP, and the Air Force, provide valuable data for marine safety and transportation sectors and coastal process modeling; however, more stations are required in the following priority locations to support fisheries

management, water quality, climate variability, coastal and marine hazards, and environmental threats such as OA and HABs. The following locations off the west coast of FL were identified as the priority locations for mooring deployments:

- Northwest of the Pulaski Shoals Light (PLSF1). Needs meteorological data, in-water currents, waves, salinity, and temperature.
- DeSoto Canyon, along shelf break south of Destin, FL. Needs meteorological data and in water waves, currents, temperature, and salinity.
- South of Tallahassee (and northeast of NDBC mooring 42036). Needs surface meteorological data.
- East of 42036, at the 20 m isobath. Needs meteorological data, waves, water temperature and salinity.
- Florida Bay, 20 m isobath west of Naples. Needs meteorological data, waves, and water temperature.
- Ecosystem moorings are required in Pensacola Bay, the Middle Ground, and north of Key West at the 10 m isobath. These are major fisheries areas within the GOM.
- Upgrade the Conch Reef/Aquarius Reef Base Station (operated by Florida International University) to include meteorological, water temperature, salinity, currents, waves, chlorophyll, nutrients, OA sensors, and acoustics to support fisheries and ecosystem monitoring.

The overwhelming need for nearshore and offshore moorings highlights stakeholder desire for traditional observing stations that contain a suite of instruments. As funding levels have remained consistent, SECOORA has been able to maintain many of the stations that are currently deployed. New stations have required SECOORA and its members to leverage funds with other state and federal agencies, and even employ a crowdsource funding campaign, to fill gaps. The long list of priority moorings, and sensor additions to existing moorings identified by SECOORA stakeholders and members, will not be achievable through SECOORA efforts alone. Therefore, it is essential for SECOORA to work with stakeholders and members to identify additional funding mechanisms to fill gaps within the region.

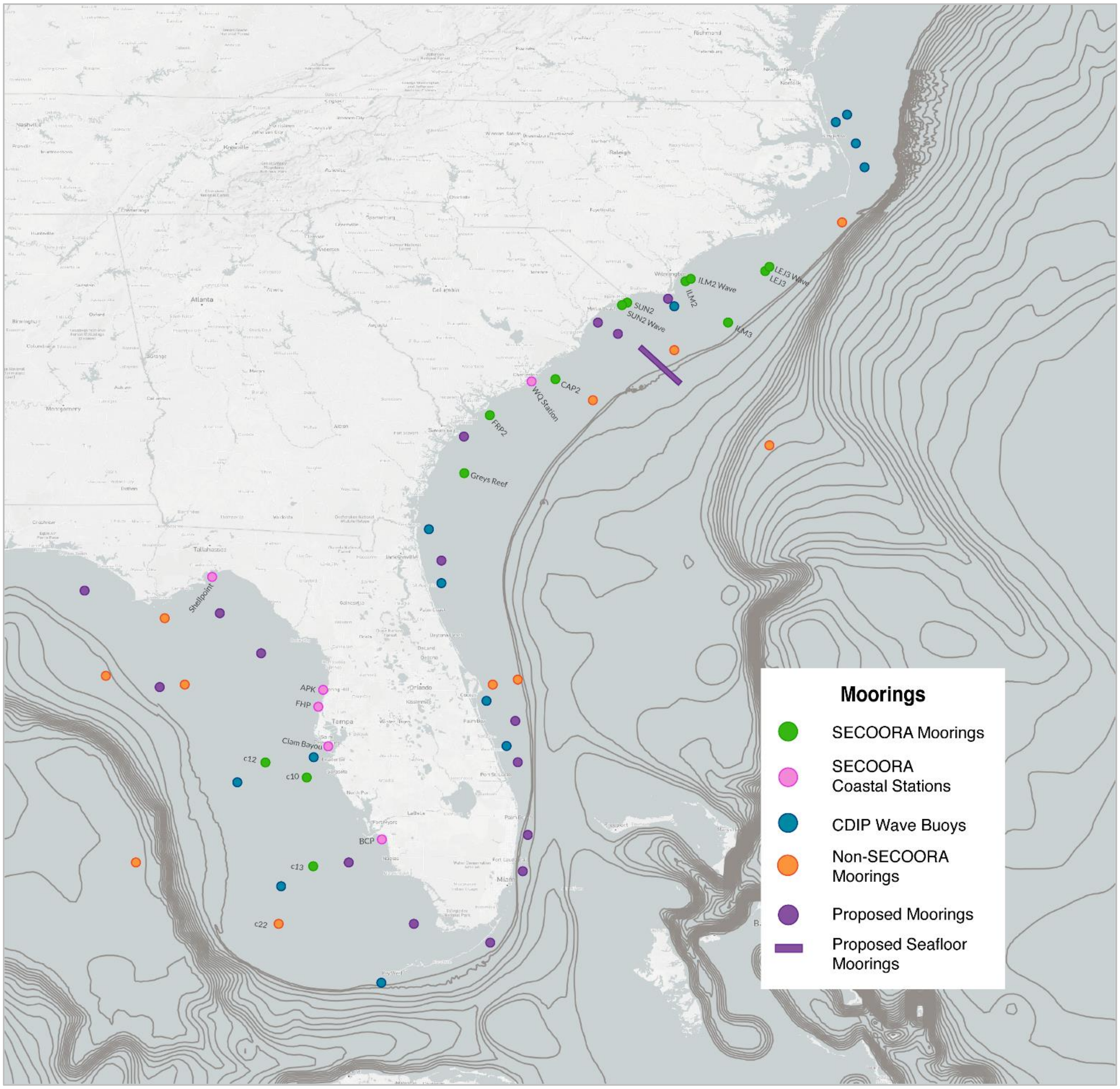


Figure 12 The purple dots indicate locations for future real time moorings and coastal stations; the purple line off of SC indicates the location for proposed seafloor moorings for Gulf Stream studies.

3.2.2 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 sites in the southeast. They collect water quality and meteorological stations, and other meteorological, physical, and biogeochemical shore and estuarine stations. SECOORA has previously funded instrumentation for deployment at the North Inlet - Winyah Bay NERR in order to expand water quality monitoring.
- Indian River Lagoon Observatory Network of Environmental Sensors (IRLON) operates ten sites in the Indian River Lagoon and the St. Lucie Estuary on the east coast of FL.

Current Capacity

SECOORA, with partners at USF and SCDNR, maintains 6 coastal stations that provide water quality, water level, and meteorological data. Five of the stations are on the west coast of FL and one station is in the Charleston, SC area.

Core Variables Collected

Data collected by sensors at coastal stations directly address the need to document variability in the nearshore environment. The SECOORA coastal stations measure meteorological conditions as well as water level and, in Charleston Harbor and Clam Bayou, water quality. See Table 2 for a list of SECOORA coastal stations and the variables collected.

	Wind Spd, Gust, Dir.	Air Temp	Barometric Pressure	Water Temp	Cond/ Salinity	Water Level	Fish Acoustic Sensors	DO	pH	Chl	Turbidity	Precip
USF Coastal Stations												
Shell Point, FL	X	X	X			X						
Aripeka, FL	X	X	X			X						
Fred Howard State Park, FL	X	X	X			X						
Clam Bayou, FL*	X	X	X	X	X	X		X	X	X	X	X
Big Carlos Pass, FL	X	X	X			X	X					
SCDNR Coastal Stations												
Charleston Harbor, SC				X	X	X		X	X	X	X	

Table 2. SECOORA coastal stations and variables collected

*Also has water pressure, blue green algae-phycoerythrin concentration, FDOM

Additional SECOORA Investment Opportunities *(see Figure 12 for proposed stations)*

- Install water quality sensors at inshore locations such as Biscayne Bay, FL and at major river entrances, such as the Savannah River, GA and the Cape Fear River, NC. These could be piling stations or SECOORA could work with the USCG to instrument aids to navigation. These stations should be instrumented, at a minimum, to match the SECOORA funded Charleston Harbor water quality station (Table 2).
    - 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).
- Work with partners to establish:
    - Meteorological and water quality stations at beach and shellfish harvest areas. Stations could also include instrumentation to monitor for HABs, such as radiometers or ocean color.
    - Meteorological and water quality stations located on commercial ocean fishing piers.
    - Physical and water quality stations near key acoustic receiver locations.
    - Water level stations to address coastal flooding and inundation.
    - Visibility sensors at port entrances.

3.2.3 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. Additionally, 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 IOOS RAs to help characterize the vertical and horizontal structure of the water column, providing important observations for assimilation into numerical models, and to support many focus areas (Price and Rosenfeld 2012). Additionally, autonomous surface vehicles, such as Wave Gliders, are being used by some RAs (e.g., PacIOOS), and by academic and federal programs in support of research projects. For example, BOEM Wave Gliders provide fisheries and physical oceanographic data at shoals designed as borrow sites for beach nourishment projects and researchers at FAU's Harbor Branch Oceanographic Institute have used sensors deployed from a Wave Glider to identify fish spawning locations.

Figure 13 Glider deployment in September 2019. Photo Credit: Fran LaPolla, SkIO vessel operator

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. Profiling gliders are self-propelled (buoyancy driven), autonomous underwater vehicles (AUVs) that are deployed for days-to-months and profile the water column collecting environmental data (NOAA 2016a). The SAB is affected by a variety of processes and characteristics that are unique to the region; namely, the broad and shallow shelf, influence of strong boundary currents due to the Gulf Stream, strong tidal forcing, distributed river input, passage of powerful tropical storms and hurricanes. These processes have wide ranges of spatial and temporal scales not easily observed with traditional technology, which has led to a historic lack of information on density stratification (Castelao 2011) and horizontal and vertical structure of biologically relevant variables. The SECOORA glider observatory is working to spatially and temporally characterize the SAB, with plans to add the West Florida Shelf as soon as funding allows.

The SECOORA funded glider observatory consists of Slocum autonomous profiling gliders as these gliders were already in operation by the SECOORA glider PIs. Many of these gliders are over 10 years old and maintenance issues are a concern since spare parts and sensors are being phased out for the older systems. Through the IOOS Association 2017-19 Fill the Gaps Campaign, SECOORA received funding to purchase a new G3 Slocum glider. This new glider was incorporated into the SECOORA glider fleet in Spring 2019. The glider is housed at Skidaway Institute of Oceanography (SkIO) and is operated by SkIO and USF. With the incorporation of the new glider into the glider fleet, SECOORA should be able to fulfill its mission to achieve three 25-day glider missions annually.

Glider Fleet: Gliders currently being used for the SECOORA Glider Observatory are owned by SECOORA (operated and maintained by SkIO and USF), SkIO, UNCW (operated and maintained by SkIO), USF, and North Carolina State University (NCSU).

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. As pH sensors mature, gliders will provide excellent platforms for monitoring ocean acidification.

Glider Name	Owner	Year manufactured	Conductivity	Temp.	Salinity	DO	Chl-a	CDOM	Back-scatter	Water column biomass	Acoustic receiver (tags)	Hydro-phone (sound)
Franklin	SECOORA	2019	X	X	X	X	X	X	X		X	X*
Salacia	NCSU	2008	X	X	X							
Angus	SkIO	2018	X	X	X	X	X	X	X		X	X*
Pelagia	UNCW	2006	X	X	X	X	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
Stella	USF	2019	X	X	X	X	X	X	X	X	X*	
Gansett	USF	2019	X	X	X	X	X	X	X	X	X*	

Table 3. SECOORA gliders and variables collected

*Glider can be outfitted with the sensor; however, the sensor is not on the glider at all times.

Additional SECOORA Investment Opportunities

SECOORA's priorities for its autonomous vehicle observatory include: increasing the annual number of days at sea; inclusion of other vehicle technologies (e.g. Wave Gliders, Saildrones, Spray Gliders); establishing autonomous vehicle surveys in the GOM; expanding capabilities for the SECOORA data portal to support visualization of autonomous vehicle tracking and data; and, working with the IOOS Glider DAC to ingest more types of autonomous vehicle data (e.g. Wave Gliders) and delayed-mode glider data.

The 2014 IOOS white paper, Toward a U.S. IOOS Underwater Glider Network Plan: Part of a comprehensive subsurface observing system, notes that expansion of the glider observatory will allow for more robust subsurface ecosystem and physical oceanographic observations, and enhance modeling efforts around the nation. Existing and near-term uses for SECOORA autonomous vehicle operations include the following:

- Water column profiling to validate oceanographic models.
- Assessment of HABs to help better understand bloom dynamics and enable modeling/forecasting of bloom trajectories.
- Fisheries and marine mammal research through environmental monitoring and animal tracking with acoustic monitoring.
- Acoustic telemetry surveys for tagged animals to better understand habitat use and spawning locations.
- Oil spill or other harmful chemical monitoring and tracking.

SECOORA's goal is to expand from three mapping missions per year to six mapping missions per year that include the SAB and GOM. SECOORA will endeavor to incrementally expand glider operations so that we can work toward achieving greater spatial and temporal data coverage along the southeast U.S. coastal and ocean region. Opportunities to expand mapping missions include SECOORA participation in the collaborative effort between NOAA IOOS, AOML, the U.S. Navy, and other RAs to fly hurricane "picket lines" whereby gliders conduct additional surveys during the active Atlantic hurricane season (2018 - 2020).

In the future, SECOORA would like to work with GCOOS to coordinate glider deployments in the GOM as both RAs work in the West Florida Shelf. SECOORA, GCOOS, and mutual stakeholders have an interest in using gliders along shelf missions to support oceanographic modeling and to monitor HABs and hypoxia events. GCOOS has identified priority glider tracks along the west coast of Florida in its Build Out Plan (version 2.1). Collaboration will insure efficient, and hopefully robust, data collection and sharing as well as collaborative research, monitoring, and modeling opportunities.

SECOORA and FACT partners are actively using autonomous surface vehicles (ASVs) for fisheries, HABs, and water quality projects. ASVs represent a field of emerging, integrated, marine observing technologies that includes hardware, software, platforms, sensors, data acquisition, storage, processing and transfer technologies, on a vessel moving across the water surface in an intelligent manner. The Liquid Robotics Wave Glider (in use by NASA and FAU's Harbor Branch Oceanographic Institute), Saildrone and Autonaut are three ASVs that are capable of long range, multi-month deployments, and carry comprehensive scientific instrument suites (atmospheric, ocean surface, and subsurface sensors). For example, the Wave Glider science payload for NASA deployments at Cape Canaveral include acoustic receivers for detecting acoustically tagged animals, plus sensors for measuring water temperature, turbidity, chlorophyll, CDOM, DO, ambient biological noise, and meteorological sensors. Partnering with members and other agencies/institutions for ASV deployments can expand SECOORA observing capabilities for targeted research projects as well as routine ecological monitoring.

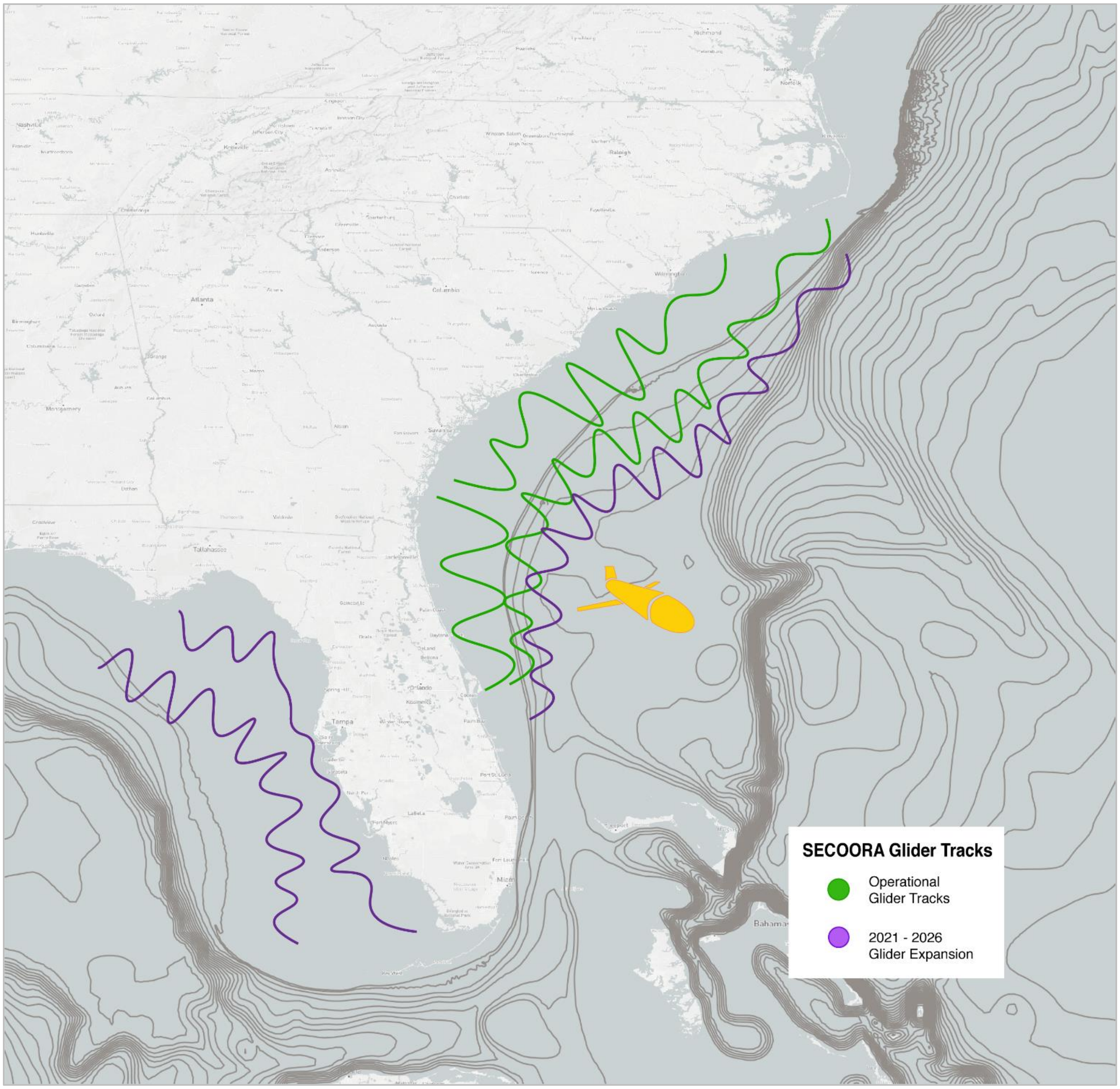


Figure 14 The green lines are representative glider missions in the South Atlantic Bight. The purple lines indicate proposed areas of operations for SECOORA gliders.

3.2.4 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). 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 20 stations throughout the SECOORA region. See Table 4 for a list of HFR locations, operators, the year installed, and frequency for each station.

Operator	Station Name	Year Installed	Location	HFR Type	Frequency (mHz)
Coastal Studies Institute and UNC-CH	DUCK	2003	Duck, NC	CODAR	5
Coastal Studies Institute and UNC-CH	HATY	2003	Cape Hatteras, NC	CODAR	5
Coastal Studies Institute and UNC-CH	OCRA	2017	Ocracoke, NC	WERA	13
UNC-CH	CORE	2013	Core Banks, NC	CODAR	5
USC	CSW	2013	Caswell Beach, NC	WERA	8
USC	GTN	2012	Georgetown, SC	WERA	8
USC	(TBD)	(TBD)	(TBD, SC)	WERA	13
SkIO	CAT	2006	St. Catherine's Island, GA	WERA	8
SkIO	JEK	2009	Jekyll Island, GA	WERA	8
SkIO	(TBD)	(TBD)	(TBD, FL)	WERA	13
SkIO	(TBD)	(TBD)	(TBD, FL)	WERA	13
FIT	(TBD)	(TBD)	(TBD, FL)	WERA	13
FIT	PAFB	(TBD)	Patrick Air Force Base, FL	WERA	13
UM	STF	2008	Dania Beach, FL	WERA	13
UM	VIR	2008	Virginia Key, FL	WERA	13
UM	CDN	2004	Crandon Park, FL	WERA	13
UM	NKL	2004	North Key Largo, FL	WERA	13
USF	RDSR	2003	Reddington Shores, FL	CODAR	5
USF	VENI	2004	Venice, FL	CODAR	5
USF	NAPL	2005	Naples, FL	CODAR	5
USF	FDS	2010	Ft. DeSoto Park/St. Petersburg, FL	WERA	13
USF	VEN	2010	Venice, FL	WERA	13

Table 4: HFR operators, location, and frequency. Many of the HFR have been in operation for more than a decade.

Additional SECOORA Investment Opportunities

In 2014, Shay et al. completed the High Frequency Radar Observing Systems: SECOORA Gap Analysis, which outlined a plan for expanding the HFR network across the SECOORA domain. Recommendations from this document were included in the National Surface Current Plan (NOAA 2015b) which provides an overview of HFR needs within the U.S. and also identifies gaps within each RA. Based on information found within these documents, 39 HFRs are needed to provide full coverage for the SECOORA domain. Currently there are 15 existing SECOORA stations. Additionally, USF operates two WERA stations along with their SECOORA supported CODARs (see table 4) and Florida Atlantic University is operating two HFR near Miami, FL. These stations do not receive IOOS or SECOORA funding, but they do help fill gaps within the HFR network. Therefore, approximately 28 HFR are needed within the SECOORA domain to fill coverage gaps identified in the 2014 plan. SECOORA's HFR installations have evolved through a combination of research funding and state agency investment. SECOORA will continue to support both CODAR and WERA HFR within the region.

SECOORA has worked with partners to successfully increase the number of HFR stations within the region. HFR expansion since 2018 includes (and are noted as "in progress" on Figure 15):

1. Two 13.5 MHZ WERA operated by Florida Institute of Technology deployed at Patrick Air Force Base and Sebastian Inlet State Park.
2. One 12.7 MHz WERA operated by the University of Miami deployed in Key Largo, FL. This station provides radar coverage across the Florida Straits.
3. Four used 13 MHz WERA HFR that were part of the NSF funded "Processes driving Exchange at Cape Hatteras" project were purchased by SECOORA and SkIO. These HFR are being deployed in NC Outer Banks, near Myrtle Beach, SC and along the coasts of GA and northeastern FL.

SECOORA will continue to work with the IOOS and stakeholders to identify opportunities to fill gaps in HFR coverage. For example, USF has received funding through the National Academy of Science (NAS) to expand HFR coverage within the Florida Keys and Dry Tortugas. Additionally, ports within the region have expressed interest in Very High Frequency Radars to provide currents nearshore and in shipping lanes.

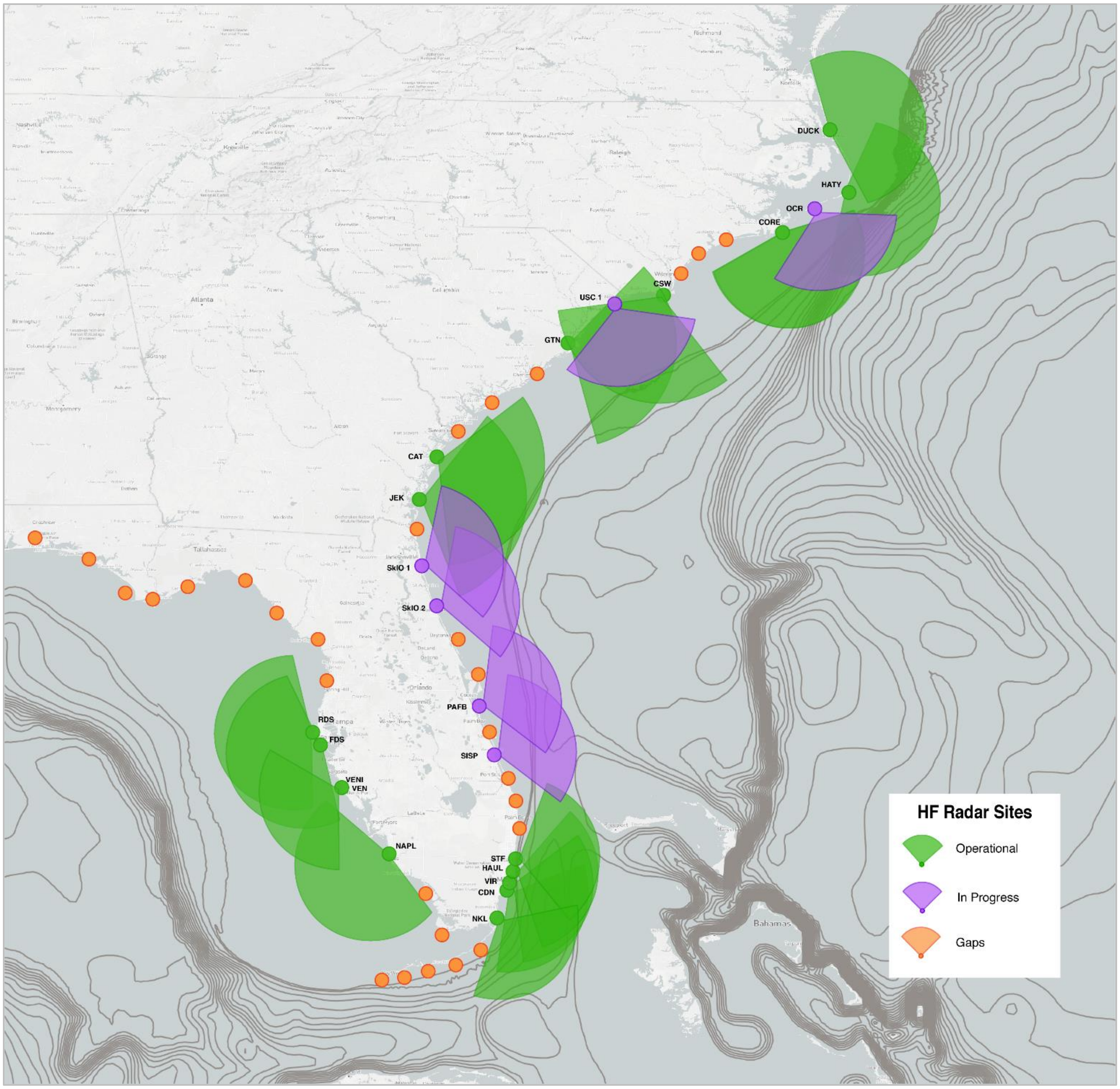


Figure 15 SECOORA is working with partners to fill gaps in HFR coverage; however, large areas of the region need coverage

3.2.5 Web Cameras

Background

Shore based web cameras are becoming more readily available to the science community and are transforming coastal environmental monitoring. 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.

Current Capacity

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. Camera operators often follow unique installation procedures and collect, store, and process imagery data according the operators own processes. These inconsistencies significantly limit the ability for imagery data to be shared and used across research and operational disciplines. The WebCAT project relied on the expertise of the private industry partner Surfline, Inc. to install and operate seven web cameras. Project partners from NOAA, USGS, USACE, state agencies, and academia conducted projects with the web cameras to highlight their utility for a range of needs. (Dusek et al. 2019; WebCAT 2019). The WebCAT project team developed best practices on web camera installation so that future camera installations can meet standards for scientific use.

Additional SECOORA Investment Opportunities

The WebCAT team identified specific recommendations for web camera operation in order to continue to standardize data delivery (Dusek et al. 2019):

- standardize imagery products (e.g., time-exposure images, variance images, time-stacks)
- develop common data collection methods, quality assurance/quality control (QA/QC) procedures, and data and metadata formats
- attach metadata to all camera video or images
- have personnel to maintain and calibrate each camera
- make camera coordinates available for research personnel

Additionally, SECOORA should continue partnering with private, local, and state entities who operate web cameras and explore ingesting and storing web cam imagery from this wide range of sources into the SECOORA WebCAT portal. Private industry groups have expertise in the deployment and video footage processing and archival. This expertise can be leveraged for continued research and application development with SECOORA principal investigators. SECOORA can work with partners to standardize practices and storage approaches in order to use the data to meet stakeholder needs.

3.2.6 Unmanned Aircraft Systems

Background

Unmanned aircraft systems (UASs) 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, UASs can collect geospatial data faster, at higher resolution and lower cost than conventional platforms (e.g., aircraft, ships, satellites). UASs 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 UASs 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 UASs 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 members operate UASs for their specific research needs. Academic and government partners are operating drones in a range of sizes and capabilities. For example, researchers at NCSU have a fleet of UASs; one of which is the EagleRay XAV, an experimental UAS that can transition operations from the air to underwater (ACT 2018b). Drone data has not yet been incorporated into the SECOORA data management system.

Additional SECOORA Investment Opportunities

In 2020, SECOORA, NOAA SECART, Duke University, and NOAA Office for Coastal Management are sponsoring a Drone workshop. This event will highlight regulatory oversight for UAS use, on-board sensor selection, operational policies and procedures (e.g. mission planning and execution), data analysis workflows, and software and data management requirements. SECOORA would like to support the use of UASs for a range of management needs, including monitoring shoreline change, storm damage assessments, elevation mapping, monitoring HABs in the nearshore, and marine species monitoring/counts.

3.2.7 Emerging Technologies for Future Investment

Section 2 of this document outlines the current and future investments that SECOORA has identified for each focus area. The list of instrumentation and data types that can be collected is not exhaustive nor does it take into account emerging technologies that will become more mainstream over the next one to five years. Some additional technologies that may enable a better, more comprehensive understanding of our ecosystems, climate, and marine environments are worth noting and include:

- OMICS refers to the collective technologies used to explore the roles, relationships, and actions of molecules that make up the cells of an organism. These technologies include genomics, proteomics, metabolomics, transcriptomics, glycomics, and lipomics (Ward 2014). Within this area, Environmental eDNA (eDNA) has shown promise for monitoring and management of marine biodiversity and resources. eDNA can be used to identify species in the environment without having to capture or visibly identify the species (Thomsen and Willerslev 2014).
- Artificial Intelligence (AI)/Machine Learning makes it possible for machines to learn from experience, adjust to new inputs and perform human-like tasks. Most AI examples, such as chess-playing computers and self-driving cars, rely heavily on deep learning and natural language processing. Through ingestion of large volumes of data, 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 can also be used to improve environmental models, quickly analyze millions of seafloor images and create 3-D color reconstructions of the seafloor, and even identify specific underwater noises collected by acoustic sensors (Schmidt Ocean Institute 2018). Two of the challenges of using artificial intelligence include the need for large volumes of data for the machine learning process as well as the fact that “good” data is required for the learning process to be effective.

3.3 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

From 2016-2021 SECOORA funded modeling efforts by NCSU and USF. NCSU has developed the Coupled Northwest Atlantic Prediction System (CNAPS). 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 (NCSU 2019). CNAPS is designed to predict coastal ocean conditions over the entire SECOORA footprint with a high degree of scientific accuracy and provide detailed sub-regional information through relocatable grid refinement and nesting technology, and update and transmit such information to stakeholders in a timely and clear fashion.

The West Florida Coastal Ocean Model (WFCOM) was developed, and is maintained, by the USF College of Marine Science Ocean Circulation Group. WFCOM, with focus on the eastern Gulf of Mexico, 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 circulation nowcast/forecasts from just west of the Mississippi River Delta to just south of the Florida Keys. The model simulations include real time river inflows versus climatology 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 of the inlets connecting these with the Gulf of Mexico. Both WFCOM and TBCOM in collaboration with the FL FWC, Florida Wildlife Research Institute provide short-term (4.5-day) HAB trajectory forecasts for both the surface and the near bottom waters that are used by local, state and public entities for HAB tracking.

SECOORA and Fathom Science were funded for modeling and product development through a NOAA COMT award. This modeling project focuses on the land-sea boundary where multiscale, two-way model coupling methodology which accurately describes interactions between terrestrial hydrology (i.e. river input, precipitation, and run-off) and the coastal ocean is needed. The goal of this project is to develop an integrated coastal water predictive capability to deliver new water intelligence products and information vital for decision making both during high-impact events, such as hurricanes and nor'easters, and for routine water management for transportation and agriculture. The project team will address this need by developing a prototype prediction system that couples coastal ocean predictions with NOAA's National Water Model forecasts.

Additional SECOORA Investment Opportunities

SECOORA plans to continue advancing modeling/prediction sub-systems that may include: regional-scale models of the atmosphere, ocean circulation, and surface waves nested within nationally-provided models; nesting of very high-resolution inner shelf and estuarine models; the coupling of dynamical models (coastal mesoscale meteorological, coastal circulation, coastal hydrological, and coastal wave models); the coupling of application models (e.g., ecosystem and sediment transport); and the utilization of advanced numerical modeling methods (e.g., data assimilation schemes, non-hydrostatic models, and unstructured and adaptive grids). The modeling framework will encompass both comprehensive baroclinic operational circulation models (essential for water column transport, storm prediction, water quality and marine ecosystem models) and integrated barotropic operational tide, storm surge, and wave models (essential for coastal inundation estimates). Model applications in Observing System Simulation Experiment (OSSE) provide a scientific and cost-effective approach to testing of different designs of new observing subcomponents before instruments are actually built or deployed. Regional-scale OSSE capability should be developed to help guide the new design or refinement of the existing SECOORA observing network.

3.4 Data Management and Communications

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 certified as a RICE, which recognizes that SECOORA meets federal standards and opens doors for greater collaborations. 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 is implementing recommended and standard practices as defined by the IOOS DMAC committee. This will ensure 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. These practices apply to data standards, metadata and data formats, transport and access, archival, information technology security, QA/QC, and are described in the NOAA IOOS Program Office DMAC White Paper (v1.0), These DMAC requirements apply to all IOOS RAs and other IOOS grant recipients who are providing data to IOOS.

SECOORA has a detailed DMAC Plan for a period of five years from 2016-2021. Any data collection or product development that is proposed to SECOORA should consider all of the documented requirements outlined in the 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.

Additional SECOORA Investment Opportunities

SECOORA will revise the DMAC Plan for 2021-2026 based on priority SECOORA activities.

3.5 Products

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 integrates datasets from many different sources. You 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, such as the Marine Weather Portal (MWP) and How's the Beach. The MWP is designed specifically to meet the marine weather and forecasting needs of boaters, mariners, and beachgoers in the southeast. The project team closely collaborates with coastal NWS Weather Forecast Offices from NC around to Texas. The goal is to provide 24/7 access to real-time ocean data, marine forecast and hazards products, and models.

How's the Beach was developed to forecast Enterococci levels at popular swimming beaches. Enterococci are bacteria that normally inhabit the intestinal tract of humans and animals. Their presence in coastal waters can be an indicator of fecal pollution, which may come from stormwater runoff, pets and wildlife, and human sewage. The project team is working with environmental quality managers in NC, SC, and FL to identify beaches of concern and tailor forecasts based on specific conditions in the area to include meteorological, physical and biological data.

Additional SECOORA Investment Opportunities

SECOORA continues to work with stakeholders to identify product development opportunities based on user needs, and to evaluate existing products to determine ongoing support and expanding geographic coverage. These products should fit within the identified SECOORA and IOOS focus areas and provide environmental and/or economic benefit to our stakeholders. Examples include products developed from satellite remote sensing imagery, acoustic data (i.e. soundscapes or fish tags), HFR, or other SECOORA supported technologies.

3.6 Outreach and Education

Current Capacity

SECOORA uses formal and informal communications to engage members, stakeholders and students. Outreach activities and products include an annual report, informational one-pagers, presentations at meetings, news stories, e-newsletters and content for the website and social media outlets. SECOORA hosts forums and webinars to increase awareness of the focus areas outlined in Section 2 (see scheduled events and archived webinars). 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 stakeholders' 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, graduate student, or early career professional to support their research and to provide travel support to present 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, funding undergraduate and graduate students through PI awards, undergraduate field excursions, and provision of online educational resources.

Additional SECOORA Investment Opportunities

To increase public awareness and interest in observing, SECOORA is assessing stakeholder needs for educational products as well as learning from successful outreach campaigns launched by other RAs in the IOOS network. Potential outreach and educational activities include:

- A comprehensive needs assessment of SECOORA stakeholders, with workshops and analysis by focus area, to inform RCOOS priority funding and key asset locations for the future.
- A Text-A-Buoy system, where users can get the latest ocean and weather information from their favorite buoy in the region.
- A video library of short, news style videos introducing topics of interest. These could focus on technology, data, tools, or articulating one of the focus area challenges.
- Work with partners to create new or enhance existing citizen science programs in the southeast.

SECOORA also plans to increase its focus on education through small awards for educators to update existing educational resources with a focus on observing data access, analysis and utilization. Also, neighboring RAs have developed teacher toolboxes full of lesson plans and required equipment. Leveraging this work will increase SECOORA's educational offerings.

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Investment Opportunity Matrix

The following matrix provides a high-level overview of the document and is broken down by RCOOS subcomponent and cross referenced against the focus areas in which SECOORA has already invested or could invest in the future. The matrix is meant to be a quick reference guide to the RCOOS Plan.

	Coastal Hazards and Climate Variability		Ecosystems: Living Marine Resources and Water Quality						Marine Operations		
	Storm Tracking & Fore-casting	Coastal Flooding & SLR	Fisheries	Ocean Sound	Public Health	HABS	Coral Health	Coastal & Ocean Acidifi-cation	Marine Safety	Rip Currents	Offshore Resources
Observing Assets											
Current SECOORA Investments											
12 buoys, 4 non real-time stations offshore of NC, SC, and West Florida Shelf (WFS)	X	X	X		X	X			X	X	X
6 coastal stations (Charleston & WFS)	X	X	X		X	X			X		X
20 HFRs distributed from Cape Hatteras, NC to WFS			X			X			X		X
3-5 South Atlantic Bight glider missions annually	X		X	X		X					
Acoustic receivers to detect tagged fish (located on moorings and gliders)			X								
Hydrophones to record sound in the marine environment (located on moorings and gliders)			X	X							X
30 non real-time temperature sensors installed at acoustic receiver locations in south FL			X				X				
Multi-asset HABs monitoring on WFS (ships, gliders, satellite remote sensing)						X					
Support ocean acidification monitoring at the Gray's Reef National Marine Sanctuary							X	X			
7 beach web cameras in NC, SC & FL		X			X					X	

	Coastal Hazards and Climate Variability		Ecosystems: Living Marine Resources and Water Quality						Marine Operations		
	Storm Tracking & Fore-casting	Coastal Flooding & SLR	Fisheries	Ocean Sound	Public Health	HABS	Coral Health	Coastal & Ocean Acidifi-cation	Marine Safety	Rip Currents	Offshore Resources
Observing Assets											
Additional SECOORA Investment Opportunities											
Expand meteorological & physical oceanographic buoy network	X	X			X	X			X	X	
Increase coastal stations to collect meteorological & physical oceanographic core variables	X	X			X	X				X	
Invest in 3-4 ecosystem moorings and add biogeochemical sensors to existing buoys			X		X	X	X	X			
Install webcams at strategic locations		X			X					X	
Use drones to capture images/video footage at regular intervals	X	X			X	X	X				X
Partner with communities to install low cost water level sensors		X									
Increase number of standard and event driven glider missions annually (minimum of 6) to include SAB and GOM	X		X	X		X					
Expand HFR coverage			X				X		X		
Expand non real-time temperature data collection			X				X				
Support continued acoustic tagging and tracking of key species			X								
Leverage Fishery Independent Research Program (MARMAP and SEAMAP) to deploy hydrophones			X	X							X
Install physical oceanographic and water quality sensors at major river entrances and ports					X				X		
Work with partners to deploy Wave Gliders or profiling gliders			X	X		X	X				X
Add wave buoys w/in HFR footprint to validate HFR derived waves	X								X		

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Data Management and Communications											
Current SECOORA Investments											
Data management structure allows for integration and sharing of data through SECOORA's data portal and data catalog	X	X	X	X	X	X	X	X	X	X	X
SECOORA Hurricane Tool provides links observations with regional-scale forecasts and models before, during, and after storm events	X								X		
Advance the IOOS MBON through fisheries data stewardship for the southeast region			X								
Host the FACT node (data sharing system for fish tag data)			X								X
Additional SECOORA Investment Opportunities											
Ingest and share data from Hurricane Hunter missions	X								X		
Partner with USGS Surge, Wave, and Tide Hydrodynamics (SWaTH) network to share water level and wave data, post-storm event	X	X									
Develop data analysis tools and visualizations that combine oceanographic and biogeochemical data with fish tag detections			X								
Support the analysis of satellite data for HABs detection and tracking						X					
Work with partners to standardize beach camera image processing		X								X	

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Modeling											
Current SECOORA Investments											
Coupled Northwest Atlantic Prediction System (CNAPS) model provides four-dimensional marine environment nowcasts and forecasts	X		X			X			X		
2019 COMT: link the NOAA NWC National Water Model to coastal ocean models to accurately quantify terrestrial hydrology and ocean to understand compound flooding	X	X				X			X		
Tampa Bay Circulation Model (TBCOM) and the West Florida Coastal Ocean Model (WFCOM) provide marine circulation for the eastern Gulf of Mexico	X		X			X			X		
Additional SECOORA Investment Opportunities											
Incorporate coastal ecosystem data into models to address impacts of storm surge and sea level on natural environments (e.g. marsh, mangroves) and built environment	X	X	X								
Develop model prediction and data analysis tools to quantify seasonal variation of surface and subsurface temperature, salinity, circulation, chl-a, NO3, DO, and other variables			X								
Incorporate HFR data into water quality models			X		X						
Develop high-resolution coupled physical-biogeochemical models to link marine carbonate ecosystem data with oceanographic processes			X				X	X			

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Products											
Current SECOORA Investments											
Marine Weather Portal (MWP)	X								X		
Forecast and hindcast products from the 2019 COMT project	X	X									
Pilot visualization tool with GA DNR to better understand fish movement patterns			X								
"How's the Beach," a tool that provides water quality nowcasts					X						
Additional SECOORA Investment Opportunities											
Expand water quality and beach notification data products regionally to meet stakeholder needs					X	X				X	
Implement a Text-A-Buoy system to access latest ocean and weather information	X								X		
Create soundscape data products for stakeholders			X	X							
Emerging technologies											
Current SECOORA Investments											
Work with partners to develop machine learning techniques			X	X	X						
Additional SECOORA Investment Opportunities											
Evaluate emerging technologies that identify and quantify ocean pollutants (microplastics) and pathogens in coastal and estuarine waters			X		X		X	X			
Work with partners to develop machine learning techniques										X	
Support development and implementation of technologies to detect HAB species and toxins						X					

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Education and Outreach											
Current SECOORA Investments											
The SECOORA Hurricane Resources webpage and individual hurricane (named storm) data pages	X								X		
SECOORA hosted K-12 education materials	X	X							X		
Participate in FACT meetings and host website			X								
Partner with USF and YSI Xylem to host undergraduate student water quality field trips to Clam Bayou station					X						
Maintain the Red Tide Data Resources for Florida webpage						X					
Support regional partnerships based on national and regional concerns (e.g. SOCAN, FACT, SCDRP)		X	X					X			
Additional SECOORA Investment Opportunities											
Support training for fisheries managers in using SECOORA supported data visualization, models and model products			X								
Collaborate with partners to implement citizen science projects			X		X	X					
Expand SECOORA HABs data resources pages beyond Red Tide to provide resources for other HAB events and species						X					
Develop better connections with USCG and USACE for use of HFR data to include provision of training opportunities as needed									X		
Foster partnerships with marinas, fishing and tackle shops, and others to broaden the use of the MWP									X		
Advance outreach and education materials on ocean observing technology through the use of videos on the SECOORA website	X								X		