A Strategic Implementation Plan for Florida COOS: 2008-2010

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Written by

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Contents

Executive Summary

The ocean plays a large role in Florida's economy. A recent economic report finds that, in addition to the over $560 billion of Florida's Gross Domestic Product generated in its coastal counties, almost $25 billion of Florida's economy is directly related to its ocean environment *[Kildow, 2008]*. Therefore, monitoring, understanding, forecasting and thus providing the tools to protect Florida's coastal ocean domain is of great importance.

The Florida Coastal Ocean Observing System (FLCOOS) Consortium is continuing the development of a scientifically sound, integrated and sustained coastal ocean observing system that will provide the necessary tools to assist in the protection Florida's coastal ocean. Through a combination of *in situ* and remote observations and models, the FLCOOS will eventually provide real-time and forecast information on the physical, chemical, biological, geological, and marine meteorological conditions in the region, extending from Florida's estuaries to its Exclusive Economic Zone. This service will aid in the stewardship of Florida's coastal ocean environment, for the benefit of its citizens, by addressing issues related to climate and weather, safety and efficiency of maritime operations (including search and rescue), hurricanes, coastal inundation and other natural hazards, ocean health and water quality, homeland security, public health, fisheries, and other natural resources.

The Florida Coastal Ocean Observing System Consortium is a private-public partnership of (currently) 18 academic, non-profit and for-profit private marine science organizations with a common interest in understanding and protecting Florida's ocean environment. This implementation plan for an integrated and sustained coastal ocean observing system network for Florida waters provides a guideline for continuing FLCOOS development during 2008-2010. This is a reasonable time period for planning purposes given the uncertain federal and state funding environment. The plan will be reviewed annually and updated for the subsequent years based on progress achieved.

The long-term goal of a Coastal Ocean Observing System (COOS) is to integrate reliable automated interdisciplinary observations, data management, and models to provide a real-time system in support of operational forecasts. This plan looks at these three components in the light of: existing elements (including federal and state assets); elements for an ideal Florida COOS; and specific planned elements for 2008-2010. The development of a Florida COOS is in accordance with three guiding principles: first, to sustain assets across Florida's entire coastal ocean; second, to develop a mix of assets necessary to simultaneously address a range of applications; and third, to utilize leveraging opportunities through diversification of assets since the present funds are limited and insufficient to build and sustain an integrated COOS.

This plan also discusses FLCOOS funding mechanisms. Funding to sustain as many existing elements as possible is obtained by individual PIs from a variety of sources. However, in the current economic climate, atrophy of existing elements and personnel will begin in 2008 and will continue until the necessary levels of sustainable funding can be found. It is also noted that until the financial situation improves substantially at the state and federal levels, the necessary funds to sustain and continue development of a COOS for Florida through the state or federal agencies will take many years (possibly decades).

Florida COOS Plans for 2008-2010

Targeted priorities, listed below, provide specific guidance for the following two years. The list is broad enough to address each funding opportunity as it arises. With the exception of sustaining existing observations, data management and model assets, the list is not structured numerically in order of importance. All components are of equal importance in building a complex and technologically advanced COOS that provides an end-to-end system of observations, data management and models for forecasting. This list will be re-assessed annually to take advantage of all unexpected funding and cost-sharing opportunities.

- Sustain all assets: This is the highest priority for observations, data management, and models.

Observations:

- Begin physical *in situ* surface and sub-surface observations in data-sparse regions
- Continue installation of coastal HF Radars to extend the existing radar footprints
- Test and deploy suitable chemical & biological sensors
- Continue deployment of multi-platform and interdisciplinary observing arrays
- Provide high-resolution satellite information and develop near-shore satellite capabilities

Data Management:

- Provide accessibility to archived data
- Continue to participate in regional and state data management activities
- Provide easy accessibility to all FLCOOS data and data products

Models:

- Continue to plan, support and develop scientifically justifiable models from large-scale to shelf, coastal and estuarine-scale
- Continue to support and adapt scientifically robust models for specific applications

Introduction

1.1 Background

The US national Integrated and Sustained Ocean Observing System (IOOS) is part of a Global Ocean Observing System, which is an end-to-end system that includes the development of observing systems, data management, and models for forecasting for both deep-ocean and coastal ocean environments. Recognizing the diversity of coastal ocean processes and impacts on society, the coastal ocean component of IOOS has been divided into 11 geographical areas. Development of these Regional Coastal Ocean Observing Systems (RCOOS) will be overseen by Regional Associations (RAs).

Florida, which has the longest coastline in the contiguous United States, is enveloped by the Loop Current-Florida Current, and is geographically straddled by two Regional Associations (RAs): the Gulf of Mexico Regional Association (GCOOS-RA) and the Southeast Atlantic Regional Association (SECOORA) (Figure 1). As such, its coastal ocean is a conduit connecting the Gulf of Mexico to the North Atlantic. It is also the only state that abuts the Caribbean Regional Association (CaRACOOS), and by virtue of the Loop Current, is directly affected by the Caribbean Sea.

The Florida Coastal Ocean Observing System (FLCOOS) Consortium has developed this implementation plan for an integrated and sustained Coastal Ocean Observing System (COOS) network for Florida waters (extending out to the Exclusive Economic Zone). A Coastal Ocean Observing System (COOS), in accordance with the IOOS, is an end-to-end system of observations, data management, and models to better describe, understand and forecast the coastal ocean environment. This plan is designed to complement and integrate with the federally operated National Backbone and state operated observations. Due to the uncertain federal and state funding environment and the continuing development of both Regional Association Coastal Ocean Observing Systems (RCOOS), this plan is for a two year period (2008-2010). This is a reasonable time period for planning purposes, and this implementation plan will be reviewed annually and updated for the subsequent years based on progress made.

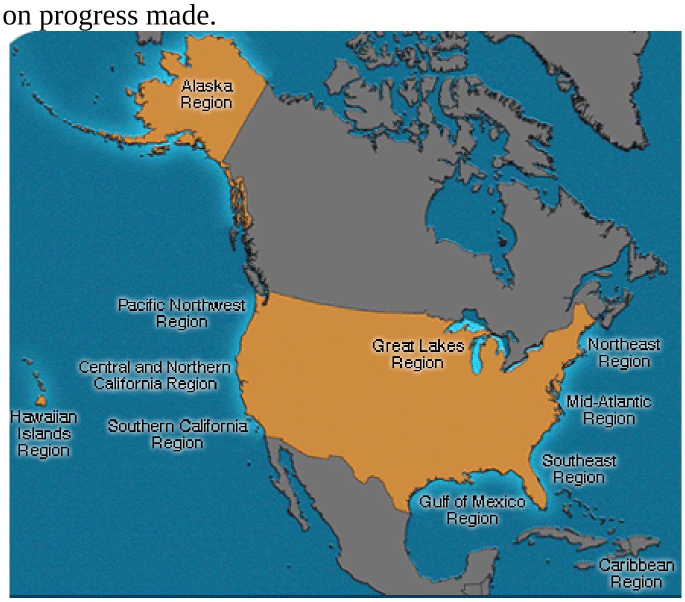

Figure 1: The Regional Associations that form part of the IOOS network. Figure from NOAA/IOOS Office.

1.2 The Importance of Florida's Ocean Environment

The ocean plays a large role in Florida's economy. In 2008, the National Ocean Economics Program released Phase II of a report on Florida's Ocean and Coastal Economies *[Kildow, 2008]*. Florida's direct Ocean Economy (Gross State Product) generates $25 billion for the State. The report highlights the importance of Florida's coastal oceans to the state's economy. An additional $562 billion is generated in its coastal counties where 77% of the population lives and 22 million visitors enjoy Florida's coasts each year. Additionally, over $100 billion of US international trade and 56% of US cruise embarkations are conducted via the 14 ports in Florida. Other sources show that Florida is the premier state for coastal recreation, with four times as many anglers as any other state, resulting in a multi-billion dollar industry that supports over 75,000 jobs in Florida (U.S. Census Bureau, 2007).

There are strong linkages between offshore waters and near-shore processes, including wave and current dynamics, water quality effects and migrations of marine life. For example, the generation of Harmful Algal Blooms can occur 20 miles offshore on the west Florida shelf and then move in toward the coast. Many important fisheries species are estuarine/coastal dependant, yet also inhabit the offshore shelf environment. Along the Florida Keys and on the east coast, the proximity of the Gulf Stream to the coast provides a highly varying and dynamic coastal environment, which affects ecosystems such as the coral reefs. The estuaries and near-shore environs are affected by land processes, and in turn, land use impacts on aquatic environments extend to the offshore environment. The ocean also affects the middle of the state; for example, in summer, frequent thunderstorms over land are in response to the land-sea breeze as part of coastal marine weather. Therefore, understanding and monitoring Florida's coastal ocean is critical for its economy and for the well-being of the environment and all its citizens. In particular, an integrated and sustained Coastal Ocean Observing System that provides interdisciplinary real-time data on the physical, chemical, biological, and geological conditions in the ocean as well as meteorological conditions in the marine atmosphere would simultaneously address many needs, including the management needs of state environmental agencies outlined in the Florida Ocean and Coastal Council's (FOCC) Annual Science Research Plan for FY 07-08. Florida's coastal ocean includes Florida waters and contiguous waters important to and affecting the Florida coastline (FOCC Annual Science Research Plan, FY 07-08).

1.3 The Florida COOS Consortium: Overview & Mission

The Florida Coastal Ocean Observing System (FLCOOS) Consortium is a private-public partnership of (currently) 18 academic, non-profit and for-profit private marine science organizations based in Florida who have an interest in Florida's ocean environment[1]. As a state almost completely surrounded by water, Florida's coastal ocean environment has a large impact on what occurs on land and in the rivers and estuaries within the state. The Consortium's objective is to develop a coordinated and scientifically sound approach to coastal ocean observations around Florida, from the estuaries to the EEZ. To achieve this objective, the FLCOOS Consortium's approach is two-fold: 1) to continue to plan, design and implement a scientifically defensible and comprehensive Florida-wide integrated, sustained and interdisciplinary Coastal Ocean Observing System (COOS) that would aid in the stewardship of its coastal ocean environment, for the benefit of its citizens, by addressing issues related to climate change and weather, safety and efficiency of maritime operations, natural hazards, ocean health and water quality, homeland security, public health, fisheries, and other natural resources; and, 2) to promote dialogue between Floridians interested in the marine environment by hosting informative meetings (FLCOOS caucuses) around the state.

[1] Membership continues to grow with the addition of other state-wide concerns interested in marine issues.

1.4 Consortium Members, Governance & Administration

Currently the Consortium has 18 members:
1. University of Miami Rosenstiel School of Marine and Atmospheric Science, Miami
2. Nova Southeastern University Oceanographic Center, Dania Beach
3. University of South Florida College of Marine Science, St. Petersburg
4. Florida Atlantic University Harbor Branch Oceanographic Institution, Inc., Fort Pierce
5. Mote Marine Laboratory, Sarasota
6. Florida Institute of Technology Dept. of Marine & Environmental Systems, Melbourne
7. Florida State University Department of Oceanography, Tallahassee
8. Florida Atlantic University Department of Ocean Engineering/SeaTech, Dania Beach
9. University of Florida Civil and Coastal Engineering, Gainesville
10. Roffer's Ocean Fishing Forecasting Service, Inc., Miami
11. University of North Florida College of Computing, Engineering & Construction, Jacksonville
12. Florida International University Southeast Environmental Research Center, Miami
13. Florida Gulf Coast University Dept. of Marine and Ecological Sciences, Fort Myers
14. State of Florida Institute of Oceanography, St. Petersburg
15. Weatherflow, Inc., New Smyrna Beach
16. HARRIS Corporation, Melbourne
17. University of Central Florida Department of Biology, Orlando
18. University of West Florida, Pensacola

An administrative office for the FLCOOS Consortium has been established at the Florida Institute of Oceanography (FIO). Each Consortium member has signed a Memorandum of Agreement with FIO and has agreed to the FLCOOS Consortium By-Laws containing details regarding the management and administrative structure for the Consortium (Figure 2). The FLCOOS Consortium is managed by the Executive Director, housed in the administrative office, who provides a vehicle for coordinating activities around Florida amongst FLCOOS Members, with state and federal agencies and other organizations, as well as coordinating with the Regional Associations.

1.5 Funding Strategies

An integrated and sustained Florida COOS will be built upon existing COOS elements that have been developed, implemented and sustained by individual Consortium members as well as by state and federal agencies, and other private and non-profit organizations. Funding for these elements comes from a variety of sources, including state and federal funds. Ideally, funding to continue the development of an integrated and sustained COOS would be sought from both federal and state agencies in a leveraged manner. This implementation plan will be subject to change to reflect the funding situation until dedicated funds are available from federal, state and private sources to sustain an integrated COOS.

Funding strategies for 2008-2010 will be discussed in section *2.3 Planning for 2008-2010.*

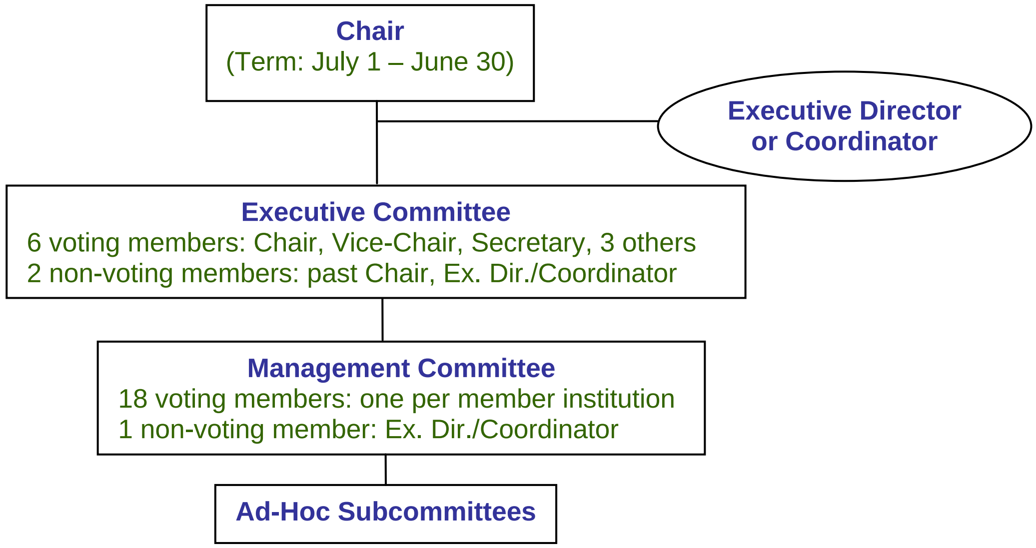

Figure 2: Organizational Structure of the Florida COOS Consortium

1.6 Outreach and Education

Outreach and education has been, and will continue to be, an important component of the FLCOOS Consortium. The goal of improving communication between people interested in the marine environment has been facilitated by Consortium members hosting themed meetings (FLCOOS caucuses). A complete list of the caucuses and power-point presentations may be found on the FLCOOS Consortium website (www.marine.usf.edu/flcoos). This website also hosts a list of upcoming meetings, conferences, and workshops of interest as a reference for the marine community at large. An Outreach and Education ad-hoc sub-committee will further assist in communicating the importance of Florida's ocean environment to its citizens. Outreach and educational activities also promote awareness of the observations and model results produced by Florida's COOS, allowing feedback from end-users that may be used to provide COOS products responsive to their needs.

2. An Integrated and Sustained Coastal Ocean Observing System for Florida

The continued development of an interdisciplinary integrated and sustained COOS for Florida integrates all components of a COOS: observations, data management, and models. This plan looks at these three components in the light of: existing elements; elements for an ideal Florida COOS; and specific planned elements for 2008-2010 (including those being implemented in early 2008). Any COOS implementation in 2008-2010 will complement existing FLCOOS members', federal and state work. The development of a Florida COOS must be in accordance with three guiding principles: first, to sustain assets across the entirety of Florida's coastal ocean; second, to develop a mixture of assets necessary to simultaneously address a range of issues; and third, to utilize leveraging opportunities through diversification since the present funds are limited and insufficient to build and sustain an integrated COOS. The long-term goal is to integrate reliable automated interdisciplinary observations, data management, and models to provide a real-time end-to-end system for operational forecast use. To develop such a scientifically justifiable forecasting system first requires the description and understanding of the coastal ocean environment through a combination of *in situ* and remote observations and models, and information about user needs.

2.1 Existing Florida COOS Elements

2.1.1 Observations

A federal National Backbone of coastal ocean observations is already partly in place and includes National Data Buoy Center (NDBC) buoys, Coastal-Marine Automated Network (CMAN) stations, tide and river gauges, (Figure 3) and satellite observations.

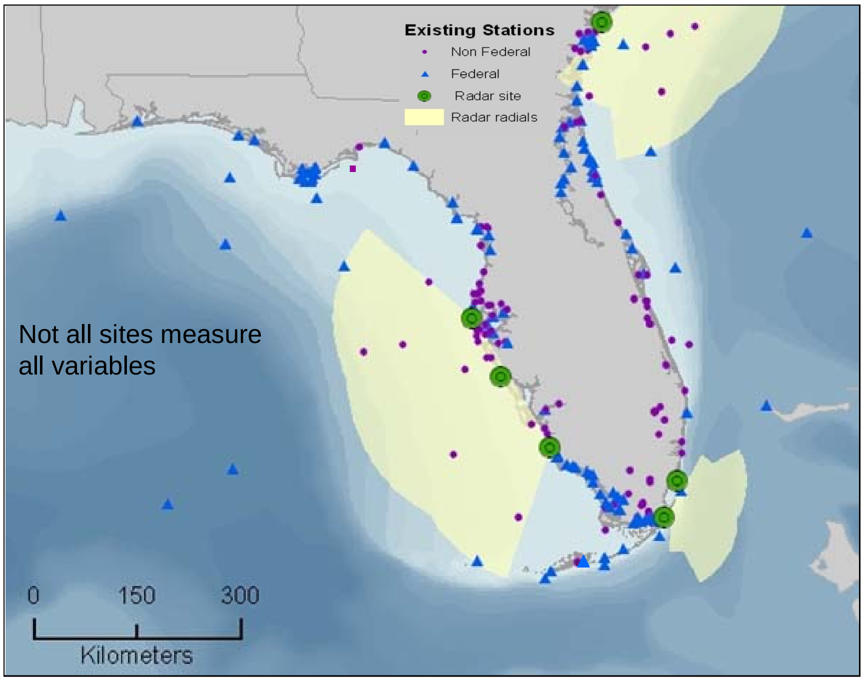

Figure 3: Federal and non-federal observations around Florida (not shown: satellite remote sensing and all coastal stations). (Adapted from SEACOOS).

Non-federal observations shown are from FLCOOS Consortium members and state agencies. Various state agencies have on-going monitoring programs, and the Florida Water Resources Monitoring Council is developing a plan to coordinate all water resource monitoring around Florida. For example, the Florida Fish and Wildlife Conservation Commission/Florida Wildlife Research Institute (FWC/FWRI) monitors the cell counts of *Karenia brevis* and issues a weekly Red Tide report. The St. Johns River Water Management District (SJRWMD) monitors *Mycrocystis* blooms in the St. Johns River Estuary. FLCOOS Consortium members have offshore and coastal *in situ* observations. In addition to *in situ* observations, there are two coastal High Frequency (HF) Radars on the southeast coast and three HF Radars on the west coast of Florida. These provide real-time high-resolution data on surface currents and waves offshore from Miami-Dade County and on surface currents on the West Florida Shelf. Other remote sensing observations are provided by satellite data, currently available for ocean surface temperature, ocean color and chlorophyll, and winds. Most offshore *in situ* sites observe physical parameters (currents, T/S, and meteorological) because sensor technology is more advanced for those types of observations. Coastal stations (on piers, pilings etc) carry an assortment of physical, chemical and biological observations because these platforms are easier to access and maintain. Sensor technology is one of the principal hurdles to implementing an interdisciplinary automated COOS [*e.g. Virmani and Estevez, 2007*].

2.1.2 Data Management & Communication

The existing integrated data management process follows the conventional definition and refers to integration of the following steps: (a) download and store raw data via telemetry (for real-time) or directly from the instrument (for delayed-mode); (b) perform Quality Control (QC) procedures on the data; and (c) format the data for use by the end-user. This includes creating the metadata[2]. The IOOS Data Management and Communication (DMAC) compliant technologies are being implemented and are outlined in the Guidelines for IOOS data and metadata interoperability standards and practices (http://dmac.ocean.us/dacsc/imp_plan.jsp). Further information and guidance on metadata standards is available from the Marine Metadata Interoperability web site (www.marinemetadat.org). Broad metadata standards are also being developed within Florida by the Florida Water Resources Monitoring Council. These will include terrestrial freshwater data and offshore marine water and atmospheric data, and therefore will be as broad as possible so all groups can meet the same basic standards.

Some programs within FLCOOS (Consortium members) are already actively engaged in regional IOOS DMAC compliant data management through the RAs and Southeastern Universities Research Association (SURA), and other members will become engaged in these activities. An initial effort to coordinate relevant activities in Florida is being undertaken as part of the FOCC Integrated Data Management, Research Review, Resource Assessment, and Geospatial Analyses of Marine Ecosystems (GAME).

QC procedure will follow existing national and international oceanic and meteorological QC procedures so that the data can be distributed as widely as possible. For delayed-mode data QA and QC procedures, a number of standard guidelines are already widely-used including, for example, World Ocean Circulation Experiment (WOCE, the ocean component of the World Climate Research Program), NOAA National Data Buoy Center (NDBC), and the World Meteorological Organization (WMO). For QA and QC of real-time data, the QARTOD (www.qartod.org) recommendations will be followed in agreement with the national oceanographic community. These recommendations have been developed in partnership and with guidance from federal agencies such as NDBC and NOAA National Ocean Service as well as with private companies that develop and sell oceanic instruments. The data are useful in a real-time mode for multiple reasons, including data assimilation into models for accurate forecasting of the movement of pollutants (for example). The real-time dissemination of data only allows time for very cursory QC techniques such as manufacturers' limits, climatological limits, and standard deviation checks. In the post-recovery delayed-mode, there will be time for more stringent screening of the data, including investigation of values outside the standard deviation checks.

2.1.3 Models

A substantial component of an integrated and sustained COOS are oceanic and estuarine models that provide gridded, high resolution products and forecasts for end-users. For example, they can be used to model the coastal effects of storms (e.g. storm surges) and climate change (e.g. sea level rise), and provide information on circulation and physical water properties for fisheries managers, the US Coast Guard, and the National Weather Service. Model development and refinement is an on-going process and requires observational data for model verification and for data assimilation to improve nowcast/forecast model results. A number of models are required to produce ensemble averages,

[2] A self contained description of the data itself.

which would minimize forecasting errors. Some model results are accessible by the general user via the Regional Association websites or by each model developer's institution or agency.

Computer models around Florida cover assorted scales. Operationally, in near real-time, the Naval Oceanographic Office runs the larger scale global and North Atlantic HYbrid Coordinate Ocean Model (HYCOM) with a coarse $1/12^o$ (~10km) grid resolution. HYCOM data are served in near real-time through the OpenDAP and ftp servers at FSU.

Embedded within this are higher resolution regional, shelf and coastal models. Two quasi-operational shelf-wide models, developed under the aegis of SEACOOS using federal funds, are the West Florida Shelf model (WFS model; USF) and the East Florida Shelf Information System (EFSIS; U. Miami). The WFS-ROMS model extends from the Mississippi River delta to the Florida Keys, with coarser resolution (6 km) at the open ocean boundary to finer resolution (4 km) closer to the coastline. The EFSIS model extends from the Florida Keys, includes the Straits of Florida and the East Florida Shelf to north of the FL-GA border. Both the WFS model and EFSIS use HYCOM to provide the open ocean boundary conditions. The South Florida Shelf (SoFLA) HYCOM model (U. Miami) will also soon become quasi-operational. This has a 1/25° (~4.5 km) resolution, with a domain that extends southward from (and including) the West Florida Shelf (WFS) and includes the Straits of Florida (SoFLA).

A number of other models have been or are under development for various domains around Florida. There are a number of very high resolution nested models for the near-shore, estuarine, and lagoonal regions, including one for the Florida Keys. A list of these models is available in Wolfe *[2007]*, however not all of them have been peer-reviewed. Peer-review ensures the scientific rigor of a model, and therefore its use in a scientifically justifiable COOS. This is required because of the lack of sufficient observations for model output validation.

2.1.4 Florida COOS and the End-User

There are a number of end-users for Florida's COOS. They range from the "super-user", who can use the raw data or model output without much processing, to the general public who require significant data-processing and repackaging of the data and model output. Both extremes of the spectrum of end-users currently exist and are actively using those elements of Florida COOS that have data and/or model output. A "super-user", for example, is NOAA/National Data Buoy Center (NDBC), who directly downloads information from real-time buoys and coastal stations (such as the COMPS and SEAKEYS arrays), performs their own quality check, and makes the data available in the same format as other NOAA buoys from the same website, for use by entities such as the NOAA/National Weather Service. During their quality checks, they also inform the data providers if there is a problem with an instrument. At the other end of the spectrum, the general public as an end-user is given COOS data via television. Many stations now provide a "marine forecast". The information for that forecast is from the National Weather Service, who gets the information from NOAA/NDBC, who in turn, as described above, uses information from a number of different data providers. Another, often over-looked end-user are scientists – in academia, state, federal, non-profit and for-profit organizations. They require the data to improve their understanding of the ocean environment.

An example of an Integrated COOS (observations-data management-models) at work in Florida is given in Box 1.

BOX 1: An example of an Integrated COOS at work in Florida: Red Tide

In October 1993, the first surface mooring with physical oceanographic instruments was deployed on the West Florida Shelf. This was the beginning of what is now known as the Coastal Ocean Monitoring and Prediction System (COMPS), and since then the array has been sustained and expanded by Prof. Weisberg at the University of South Florida to include up to 12 off-shore moorings, 6 with real-time telemetry of data. The system primarily makes observations of currents, temperature, and salinity below water, and meteorological variables above water. The data is managed and processed in-house by his group, the Ocean Circulation Group, who have also developed high-resolution models to provide a comprehensive picture of the ocean circulation on the West Florida Shelf. This is an example of an Integrated COOS – an end-to-end system.

Having a well-established and working physical observation system provided the backdrop for an interdisciplinary study to understand Red Tides. These HABs begin on the West Florida Shelf, and occasionally also appear on the East Coast. The “EcoHAB” (Ecology of Harmful Algal Blooms) study included bi-monthly ship transects (using the FIO vessels the R/V Suncoaster and Bellows) from 1998-2001, model development, and sensor development as a collaborative effort between USF, FWC-FWRI, and Mote Marine Laboratory. Investigators included: Profs. Carder, Muller-Karger, Vargo, Walsh, and Weisberg from USF; Drs. Heil and Steidinger from FWC-FWRI; and Drs. B. Kirkpatrick, G. Kirkpatrick, and Pierce from Mote Marine Laboratory. A number of research associates and graduate students were also involved.

The information from this multidisciplinary study has resulted in a better understanding of Red Tide, including a working hypothesis on bloom generation, advances in the ability to detect them from satellite data, and in 2007 an advanced, coupled ocean circulation-atmosphere-ecosystem model showing how the Red Tide went from the West Coast of Florida to Jacksonville, where it had an adverse economic impact on businesses in the Jacksonville Beaches area in 2007. A number of other useful products have emerged from this multi-agency collaborative effort ranging from forecast and warning products to sensor development:

1. FWC-FWRI issues a weekly Red Tide Bulletin for the general public.

2. Mote Marine Laboratory developed the BreveBuster – an instrument to detect Red Tide.

3. USF developed the Bottom-Stationed Ocean Profiler (BSOP) – a vertical profiler.

4. An experimental HAB-Forecast System is now available and will be one of the products regularly produced by the FWC/USF Center for the Prediction of Red Tides.

5. Mote Marine Laboratory has a warning system for the general beach-going public, funded by five counties on the west coast of Florida, to alert the public about daily beach conditions (available at: http://coolgate.mote.org/beachconditions/).

6. GCOOS-RA and GOMA are developing a HAB detection system for the entire Gulf of Mexico region, based on the work done on the West Florida Shelf.

This demonstrates the usefulness of an Integrated, sustained and interdisciplinary COOS to benefit society and a range of end-users, and it further demonstrates what can be achieved in a multi-institution collaborative effort.

2.2 Elements for an ideal Florida COOS

Based on existing FLCOOS elements, this section includes an outline of the elements required to form an ideal integrated and sustained interdisciplinary COOS for Florida. To continue to provide data and data products, of primary importance is the need to sustain existing observing, data management, and model elements, which includes equipment, personnel expertise, deployment and other operating costs, infrastructure and data dissemination costs. However, other factors are also important in the continued development of a Florida COOS. Building upon the outline of the Florida COOS Caucus White Paper (January 2006), these include:

- Identify and analyze existing observing and prediction systems, useful new technologies, data management systems, and applications and products.
- Implement projects in important data-void sub-regions. This includes regions where there are simply no observations at all, as well as regions where observations of a particular type are lacking.
- Plan an integrated environmental information system for Florida, from observations to models, including easy access to data and data products and model forecast results.
- Begin building infrastructure, including permanent technical personnel, equipment capitalization, new sensors and other technologies.
- Promote COOS data and product information and knowledge through outreach and education, focusing initially on users, the public and legislators.

2.2.1 Ideal Observations

An ideal network would consist of a mix of automated moorings and fixed platforms, remote sensing, autonomous non-stationary platforms (AUVs, gliders, drifters, and vertical profilers), continuous records from ship-towed instruments, and point characterizations from shipboard operations at defined stations to integrate the strengths and weaknesses of each approach.

Moorings carrying a full suite of sensors, vertical profiling where possible, to measure the NOAA/IOOS list of core variables (Table 1), including automated biogeochemical and meteorological sensors along the coastline and offshore at regularly spaced intervals both along and across shelf should provide a base network to address most societal needs (e.g. Figure 4). These would provide detailed *in situ* continuous oceanic and meteorological point observations, some as near real time reports available on the Internet. Complementing these point observations, remote observations, and a combination of 30 gliders, 50 autonomous vertical profiling floats, and satellite-tracked surface drifters would create synoptic maps of the surface and sub-surface fields. Low-frequency and extreme events could also be observed using targeted ship-board observations and a fleet of 5 mission-specific AUVs.

Remote sensing would provide high-resolution coverage of surface parameters from the coastline to the EEZ. High-Frequency (HF) Radars would provide high-resolution, real-time complete coastal ocean coverage of surface currents. Satellites would provide complementary surface fields including SST, Chlorophyll, CDOM, and winds.

NOAA’s data integration framework focuses on five core variables: ocean temperature, salinity, water level, currents and ocean color because these are required in NOAA’s decision tools and also address a range of other applications, such as coral bleaching parameters. At present, none of these variables are being observed in all areas around Florida. There are large data gaps, which are discussed further in Section 2.3.1.

Sensor Category	Variables Measured
GREEN: Automated; commercially available by multiple manufacturers; robust; reliable over long periods (months to years) without maintenance; return near real-time data that meets research standards	Salinity, temperature, sea level, surface waves, Surface currents, heat flux, momentum flux, sea ice**.
YELLOW: Require frequent maintenance therefore cannot be deployed for extended periods; have not been tested in various oceanic environments (not robust); are becoming commercially available; users other than the developers can operate with relatively minor training.	Bathymetry and bottom character (e.g. benthic habitats), optical properties*, dissolved nutrients* (N, P, Si), dissolved oxygen, chemical contaminants.
RED: New and emerging technologies	Fish species*, fish abundance*, zooplankton species, zooplankton abundance, phytoplankton species, phytoplankton abundance, waterborne pathogens.

*Sensors for these will soon become 'Green'
**Not relevant for Florida in the foreseeable future.

Table 1: IOOS Core variables observed by an ideal COOS and the level of sensor technology currently available.

However, limitations of funding, bandwidth, the lack of robust, automated, *in situ* biogeochemical sensors, and problems with biofouling hamper the development of this ideal vision. To achieve this eventually, existing infrastructure needs to be utilized and enhancements to the existing system needs to be incremental, logical and scientifically justifiable. Therefore, the 'ideal' array may require some adjustments to include existing observations (e.g. Figure 5) and take advantage of future leveraging opportunities. A list of priorities for a short period of time (2 years) has been identified (Section 2.3) and will be reviewed and updated annually for subsequent two year increments.

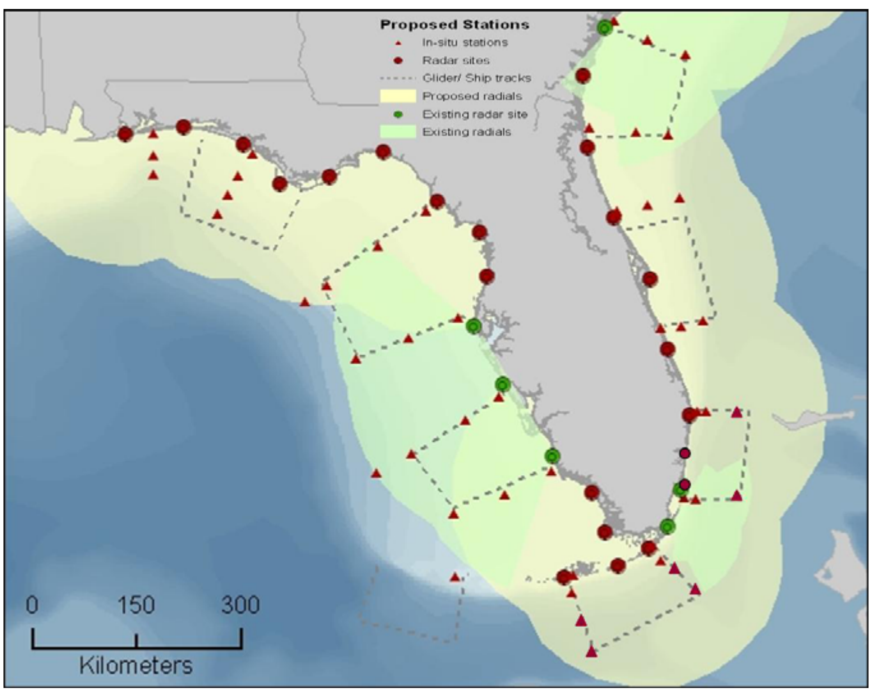

Figure 4: A schematic of an ideal Florida COOS offshore coastal ocean observational base network array based on unlimited funds and assuming no existing infrastructure or long-term observations (not shown: satellite remote sensing and coastal stations). (Adapted from SEACOOS).

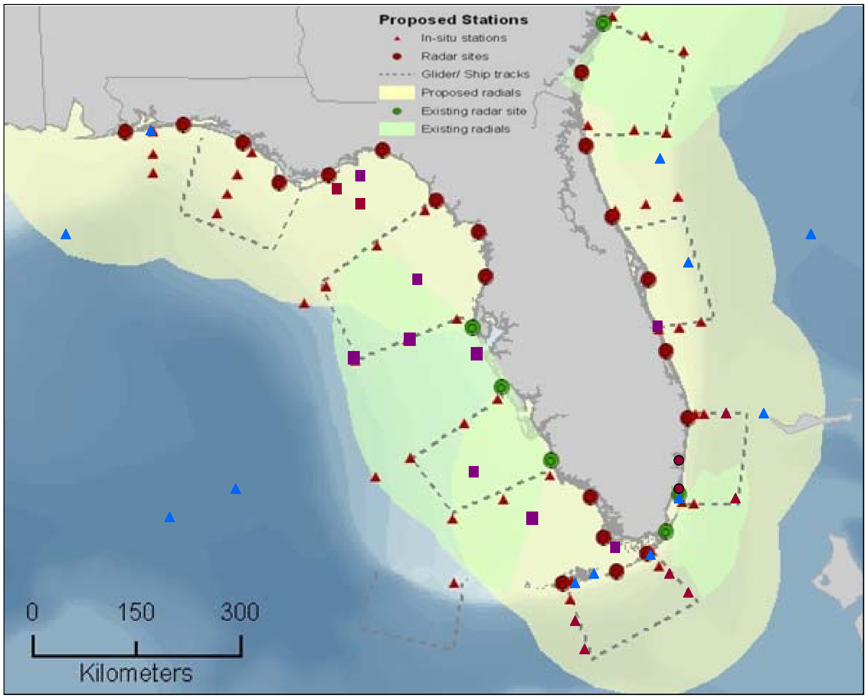

Figure 5: An array of offshore coastal ocean observations for Florida including existing infrastructure and the ideal basic scheme that could be implemented with sufficient funds (not shown: satellite remote sensing and coastal stations)

2.2.2 Ideal Data Management & Communication

The primary mission of any COOS is to provide good quality (QA/QC) data and data products for end-users: public, local, state and federal, scientists, private industry etc. Some of these data users are also data providers. There are a number of on-going activities from international to state level that deal with various aspects of DMAC. Within Florida COOS, we do not want to reinvent the wheel, therefore the ideal approach is to identify, partner, upgrade and leverage technologies that already exist or are being developed that are related to DMAC.

For example, within SECOORA, three data nodes are being developed in South Carolina, North Carolina and Florida (St. Petersburg) to gather all data and model output for the SECOORA region. Also located in St. Petersburg, is one of the GCOOS-RA network of nodes collecting data for the GCOOS region. Therefore, it would be redundant to have another, separate data node to store information for Florida. However, a preliminary survey with end-users in Florida highlighted the need for easy access to Florida-specific COOS data and model results. This is addressed in section 2.3.

2.2.3 Ideal Models

Models will eventually provide the forecasting capabilities required to address a number of coastal ocean issues. *In situ* and remote observations are needed at all stages of the development of forecasting models. Initially, these data would provide observational information for model comparisons and further development. Subsequently as models become more evolved, observations are required for data assimilation, continued model verification and re-initialization to produce the next set of forecasts. Long-term, high-resolution and accurate data are needed for model development, implementation and improving forecasting capabilities. Model development should occur concurrently with observational advances (as opposed to sequentially) for three reasons. 1. The data collected will provide descriptions and some preliminary understanding of the environment, but otherwise will be under-utilized in the absence of accompanying models. 2. Given the time taken to develop models, a sequential approach to building an end-to-end system will result in many years before forecasting capabilities are achieved. The forecasting capabilities of the models can improve as the quality and comprehensiveness of the COOS progresses. 3. More advanced and accurate models can assist in providing information for efficient allocations of resources within the COOS by highlighting weaknesses in the spatial and temporal nature of the observation datasets.

The development of good water circulation models to cover all geographical scales is needed; the larger scales will provide boundary conditions for high-resolution models and will show connectivity between various regions of Florida's coastal ocean. Water circulation depends not only on the physical characteristics of the water, but also critically on atmospheric boundary conditions. Data assimilation schemes and coupling ocean models with atmosphere and wave models is a necessary step in the development of accurate circulation models. Akin to climate and weather prediction models, the eventual goal is to have ensemble averages using multiple models to minimize errors from any one individual model. In addition to reliable coupled ocean-atmosphere-wave models for an area, other coupled interactions (e.g. biological, chemical) need to be added to address and predict ecosystem responses under various scenarios.

2.3 Florida COOS Development and Plans for 2008-2010

<u>Introduction</u>

To go from the existing systems outlined in Section 2.1 to the ideal system in Section 2.2 requires coordinated incremental increases in observations, data management and models. Most critical is the need to sustain existing elements to continue to provide uninterrupted long-term data sets and retain highly trained personnel. There is little benefit in continuing to 'build' without funds being available to sustain, therefore this will always remain the highest priority.

There are multiple approaches to developing the observing element of a coastal ocean observing system, including: focus on installing a particular instrument in all parts of the state; focus on a particular type of data; and, focus on a particular application of the COOS *[e.g. Virmani, 2007a]*. A combination of the first two approaches will address multiple needs simultaneously (coastal ecosystems, fisheries, homeland security, climate change, public health, improved safety and efficiency of maritime operations, mitigation of natural hazards such as coastal storm surge and inundation etc), thereby automatically addressing the third approach. However, if application-specific approaches are required, the concentration will be on the two Regional Association identified priority areas and the major foci for state management needs. Therefore, although the COOS can simultaneously address more applications, priority is given to: fisheries, coastal inundation, improved safety and efficiency of maritime operations (including search and rescue), water quality, human health, aquaculture and climate.

This combined approach will address the third guiding principle in developing a COOS: through diversification it will allow utilization of all leveraging opportunities (for example, The Census of Marine Life Ocean Tracking Network), since the present funds from any single source are limited and insufficient to build an Integrated and Sustained COOS.

<u>Developments in 2008</u>

The Florida Oceans and Coastal Council recognized that a fully developed Florida COOS would simultaneously provide information to address a number of needs for the state, and recommended funding for continued development in FY07. From January-June 2008, $1.25M were available to the FLCOOS Consortium through the Florida Department of Environmental Protection Contract #RM078. These funds were to continue building the system, not to sustain any existing elements. A number of projects were chosen that addressed the objectives outlined in previous sections, and are mentioned explicitly below.

Funding to sustain as many existing elements as possible is obtained by individual PIs from a variety of sources, including the Navy, NOAA (non-IOOS), MMS, the state and counties. However, in the current economic climate, atrophy of existing elements and personnel will begin in 2008 and will continue until the necessary levels of sustaining funding can be found. It has also been recognized that until the financial situation improves substantially at the state and federal levels, the necessary funds to sustain and continue development of a COOS for Florida through the state or federal agencies will take many years (possibly decades). Therefore, part of the funds from this Contract was to hold a Funding Strategy workshop for the Florida COOS Consortium. The attendees agreed upon pursuing two avenues for funds after June 2008 (in addition to on-going traditional methods such as proposals).

The first is the development of a Supercenter of Excellence for COOS, which would provide the required funding in a reasonable period. The State of Florida has (thus far) allocated ~$100M/year to develop Centers of Excellence to give "Florida a clear position of leadership in key emerging technology areas with the unique potential for economic and societal impact in the years to come." The strategy of the FLCOOS Consortium will be to develop a SCOE for COOS by taking a two-pronged approach addressing both the criteria for scientific excellence as well as political priorities.

After obtaining broad support for this Strategic Implementation Plan, including endorsement by the Florida Oceans and Coastal Council, a second avenue of potential funding will be to present this to legislators to ask for an injection of funds. This was suggested by Secretary Sole in a meeting with members of the FLCOOS Consortium in Tallahassee in March 2008 and may be a line item in FDEP, or via some other method.

Florida COOS Plans for 2008-2010

Targeted priorities, listed below, for the following two years provides specific guidance, but the list is broad enough to address each funding opportunity as it arises. With the exception of sustaining existing observations, data management and model assets, the list is not structured numerically in order of importance. All components are of equal importance in building a complex and technologically advanced COOS that provides an end-to-end system of observations, data management and models for forecasting. This list of priorities should be re-assessed annually to take advantage of all unexpected funding and cost-sharing opportunities.

Although a well-designed and implemented COOS will attract end-users (as seen in regions where observations are on-going), outreach activities to promote awareness of the data and data products produced by the COOS, and by extension the importance of Florida coastal oceans, will continue. These activities will also provide a mechanism for feedback from end-users on the further development, planning and evolution of a COOS that is responsive to their needs. To begin to address this, a Florida COOS Consortium video has been produced as part of this Contract, and will be used as a basis for an end-user survey. In a preliminary informal survey, the end-users indicated an awareness of marine data but were not aware that it came from observations made by entities outside NOAA. The DVD makes the connection that NOAA, and in particular the National Weather Service, uses data from existing Florida COOS observing platforms and models.

2.3.1 Observations

- Begin physical *in situ* surface and sub-surface observations in data-sparse regions: There are areas of the coastal ocean around Florida that are under-sampled and lack observations in basic physical measurements such as currents, T/S, waves and meteorological observations. These data are required to improve the description of the shelf circulation, understand the movement of water, and provide data for model verification and data assimilation in order to achieve accurate forecasting capabilities of water movement. These areas include, but are not limited to, the East Florida Shelf, from the Straits of Florida to the FL-GA border, the Big Bend region and the Northwest Florida Bight to the FL-AL border. Some installations may be in conjunction with the Florida Coastal Monitoring Framework, which addresses the monitoring needs for Florida. A plan for these installations (and models) is currently being drafted *[e.g. Florida Coastal Monitoring Interagency TAG, 2006; Virmani, 2007b]*. The funding provided in this Contract is being used for two projects that begin to meet this goal. Three sub-surface current-meter moorings were deployed in the data-sparse region of the Central-East Florida Shelf. A real-time mooring has also been deployed in the data-sparse region off Jacksonville, in North-East Florida, in a location that will allow sampling of both the St. Johns River and Nassau River plumes.
- Continue installation of coastal HF Radars to extend the existing radar footprints: HF Radars provide real-time high-resolution surface currents and waves that are of use to many user-groups, and are highlighted as an important piece of the regional and national (international) Ocean.US plan (Paduan et al, 2004). As a high priority observing system, there are opportunities to leverage funds. Funds from this Contract have been used to leverage $450k of HF Radar Equipment, and two radar systems have been deployed to extend the existing Miami footprint northwards.
- Test and deploy suitable chemical & biological sensors: To date, the major hurdle in an interdisciplinary COOS has been the lack of automated, robust, *in situ* biogeochemical sensors that can be deployed for long periods without intensive maintenance. With technological advances, this is changing and sensors that meet the requirements of a COOS are being developed and gradually becoming available. As suitable sensors become available, they will be tested in areas that are already making physical and meteorological observations. If the assessment of performance is suitable, installations may begin in other such locations. As part of this Contract, a non-chemical nitrate sensor is being added to a location in North-West Florida where physical oceanographic and meteorological observations are on-going. A biological set of instruments were also deployed on the Central-East Florida Shelf.
- Continue deployment of multi-platform and interdisciplinary observing arrays: As biogeochemical sensors become viable (including passive and active acoustic arrays), planning and deployment of such sensors may begin in regions of interest, with co-located physical observations (currents, T/S). Additional types of platforms will also be deployed to complement stationary and remote observations. These include a combination of AUVs, gliders, vertical profilers, drifters, and routine ship-board observations. A workshop was funded through this contract to plan the Florida component of the Ocean Tracking Network, which will leverage $2M provided by sources outside Florida for acoustic sensors to be deployed in a line from Florida to Cuba. The OTN workshop, convened at Mote Marine Laboratory, provides information on interested parties, discuss funding for tags, discuss a work-plan, and the scientific outcomes of such an acoustic line. Deployment will being in 2010.
- Provide high-resolution satellite information and develop near-shore satellite capabilities: Satellite observations provide real-time, high-resolution synoptic views of the surface circulation, temperatures, Chlorophyll, CDOM and winds. In addition to providing information for fisheries and related applications, these data are used for data assimilation into some models, and validation for others, both of which are a critical aspect of developing operational models. Plans include additional research to improve these products and to develop new ones particularly for the near-shore and estuarine (e.g. Apalachicola Bay) ecosystems. Also required are preparations to:

incorporate the next generation of U.S. satellite data (NPOES and GOES_R); use other new data soon to become available (e.g. MERIS); and, plan for potential future reductions in some satellite data capabilities. Contract funds were used to provide daily high-resolution satellite maps and movies of SST, surface circulation, Chl and CDOM for all regions around Florida.

- Sustain all assets: This is the highest priority for observations, data management, and models. In some cases, the observations may not yet meet the requirements of a robust and automated system because of insufficient sensor technologies, but there are some long-term (including multi-decadal) routine monitoring efforts in coastal ocean waters (e.g. Florida Bay and the Florida Keys) that need to be sustained because of the value of such long data sets in identifying ecosystem change. Such monitoring efforts will be considered on a case-by-case basis and will have to address the needs of another COOS component, such as data of importance to model development. Plans will be developed and eventually implemented to make those monitoring efforts automated using an assortment of platforms and sensors.

2.3.2 Data Management

- Provide accessibility to archived data: Some data are not yet accessible to those who require them. Some of the data cover many years and would provide information to understand the long-term environmental variability. They are also useful in model development, for verifying hindcast model results and for data assimilation. Therefore, making this data accessible would be of benefit to similar regional and state data management goals as well as the general public.
- Continue to participate in regional and state data management activities: Data Management activities will be done in conjunction with the Regional Association DMAC programs and the work currently being undertaken by the state via the FWRMC and the FOCC sponsored IDM.
- Provide easy accessibility to FLCOOS data and data products: Between the 18 members of Florida COOS, there are a number of COOS-related observations and model output already available (Section 2.1), but no single location exists for access of this information. This will aid the state IDM efforts. This was also mentioned in a preliminary informal survey of end-users, who requested easy access to Florida-specific COOS data and model results, especially real-time information for immediate use. To address this issue, funds from this Contract were applied towards collating and providing easy access to COOS information from Florida COOS Consortium Members. The results from this effort are now available via the FLCOOS website: www.marine.usf.edu/flcoos.

2.3.3 Models

- Continue to plan, support and develop scientifically justifiable models from large-scale to shelf, coastal and estuarine-scale: Sections 2.1.3 and 2.2.3 outlined existing models, and the need for a number of different coupled models to perform ensemble averages and provide forecasts of physical, chemical and biological parameters. All models used need to be published in peer-reviewed journals as a commonly accepted metric for scientific validation of the model. Future planning efforts will include a workshop to discuss the best scientific approach for model development, including new and interdisciplinary models, and ensemble modeling. Contract funds were used in two modeling projects. One was to develop a large-scale coupled ocean-atmosphere model to cover all of Florida’s ocean environment. The second was to develop a high-resolution model for north-east Florida, to include the estuaries along that coast.
- Continue to support and adapt scientifically robust models for specific applications: Once a basic circulation model for any domain has been peer-reviewed, further coupling to an ecosystem model or adaptation to provide improved understanding and forecasting for specific applications, such as water quality or larval transport, will be implemented.

References

Florida Coastal Monitoring Interagency Technical Advisory Group, A Framework for Coastal Water-Resource Monitoring in Florida, DRAFT, December 21, 2006.

Florida COOS Caucus, White Paper: A Florida Coastal Ocean Observing System (Florida COOS), January 2006. Available at: http://marine.usf.edu/flcoos/about-us.php

Kildow, J., Facts and Figures: Florida's Ocean and Coastal Economies, Phase II Report. National Ocean Economics Program, June 2008. Available at:
http://www.floridaoceanscouncil.org/economies_report.htm

Paduan, J. J. O'Donnell, A. Allen, P.M. Kosro, S. Glenn, M. Bushnell, D. Musgrave, N. Shay, L. Washburn, M. Kuther, 2004. Surface Current Mapping in U.S. Coastal Waters: Implementation of a National System. Ocean.US, Arlington, VA., 22p.

Virmani, J. I., An Overview of Florida COOS Consortium Activities (Sept 06 – May 07) and a Strategic Plan for FLCOOS Deployment, Maintenance and Associated Research, Final Report, FWC DO 338153 (USF No. 47 10 1044 00), June 2007 (a). Available at: http://marine.usf.edu/flcoos/about-us.php

Virmani, J. I., An Implementation Plan for Florida's Coastal Ocean Observing System That Would Complement State Monitoring Efforts, Final Report, DEP No. RM063 (USF No. 47 10 1058 00), October 2007 (b). Available at: http://marine.usf.edu/flcoos/about-us.php

Virmani, J. I., and E. D. Estevez, Bio-sensing in Ocean Observations Workshop Report, Sarasota, Florida, June 18-20, 2007. Available at: http://marine.usf.edu/flcoos/about-us.php

Wolfe, S. H., An Inventory of Hydrodynamic, Water-Quality, and Ecosystem Models of Florida Coastal and Ocean Waters. January 21, 2007 (a).

Wolfe, S. H., Florida Oceans and Coastal Resources Council Science Research Overview: Full Set of Research Components. March 26, 2007 (b).

U.S. Census Bureau, National Survey of Fishing, Hunting and Wildlife-Associated Recreation Report, 2007.

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