SEACOOS Implementation Plan

Draft

v2.5 12/23/04

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0. Preamble

At the time of writing of this document support for and development of ocean observing systems in the United States is uncertain:

The US Commission on Ocean Policy final report has been released but as yet there has been no response from the Administration;

OceanUS has held its first IOOS Implementation conference but the initial Development Plan is not finalized, hence the national backbone is not yet defined;

RA formation has been initiated around the country but none yet exist;

An ORION program office has been funded but there has been no call for proposals for infrastructure.

SEACOOS, initiated in 2002, has begun to define how a regional coastal ocean observing system, or RCOOS, associated with each RA, might best be developed. In an effort to help initiate an open dialogue on how best to create RCOOSs in the US we here present our view of how this should be accomplished.

We recognize that the regional coastal ocean observing system (RCOOS) for the Southeast has yet to be formally organized. Though SEACOOS views itself as a pilot program to help define the SE RCOOS, we recognize that it can not be assumed that SEACOOS will become the RCOOS. It may be most appropriate for SEACOOS to consider itself as a candidate R&D branch of the SE RCOOS; how the operational needs of the RCOOS will be met is as yet largely unresolved. Nevertheless we here put forward our vision of how the SE RCOOS should begin.

I. General principles

This Implementation Plan defines guidelines for the development and staged implementation of SEACOOS. It builds on the SEACOOS Strategic Plan, which summarizes the vision and mission for the program and describes its functional subsystems (observing, modeling, information management, and outreach and education). A central theme of the Implementation Plan is that the transition of various SEACOOS observing and modeling efforts into the pilot and pre-operational programs of a regional system should follow a process in which the design and purpose are scientifically defensible and in which the subsystems act in a coordinated fashion. This Implementation Plan seeks to prioritize tasks and develop a timeline for the system build-out to 2012 (10 years from the beginning of the program).

To promote readability a number of the Implementation Plan concepts are presented as appendices. These include a discussion of regional coastal ocean observing system (RCOOS) design (Appendix 1) and the roles of various sectors (academic, private, and government) in creating and maintaining a RCOOS (Appendix 2). A generic development process is presented in Appendix 3, and our philosophy of prioritization is given in Appendix 4.

It is important to acknowledge that development of a RCOOS must be coordinated with larger scale national and international oceanographic efforts (IOOS, GOOS/GEOS and ORION), with subregional and local programs, and with governance and user engagement activities in the SE region. The latter are being coordinated by the Southeast Coastal Ocean Observations Regional Association (SECOORA), a program intended to guide the formation of a Regional Association that is ultimately certified by OceanUS. The observing system priorities in the Southeast US will ultimately be identified by SECOORA through engagement of potential users of the information.

Here, we present the SEACOOS vision for developing a regional coastal ocean observing system (RCOOS) for the SE U.S., and identify applications that are feasible to pursue in the near-term.

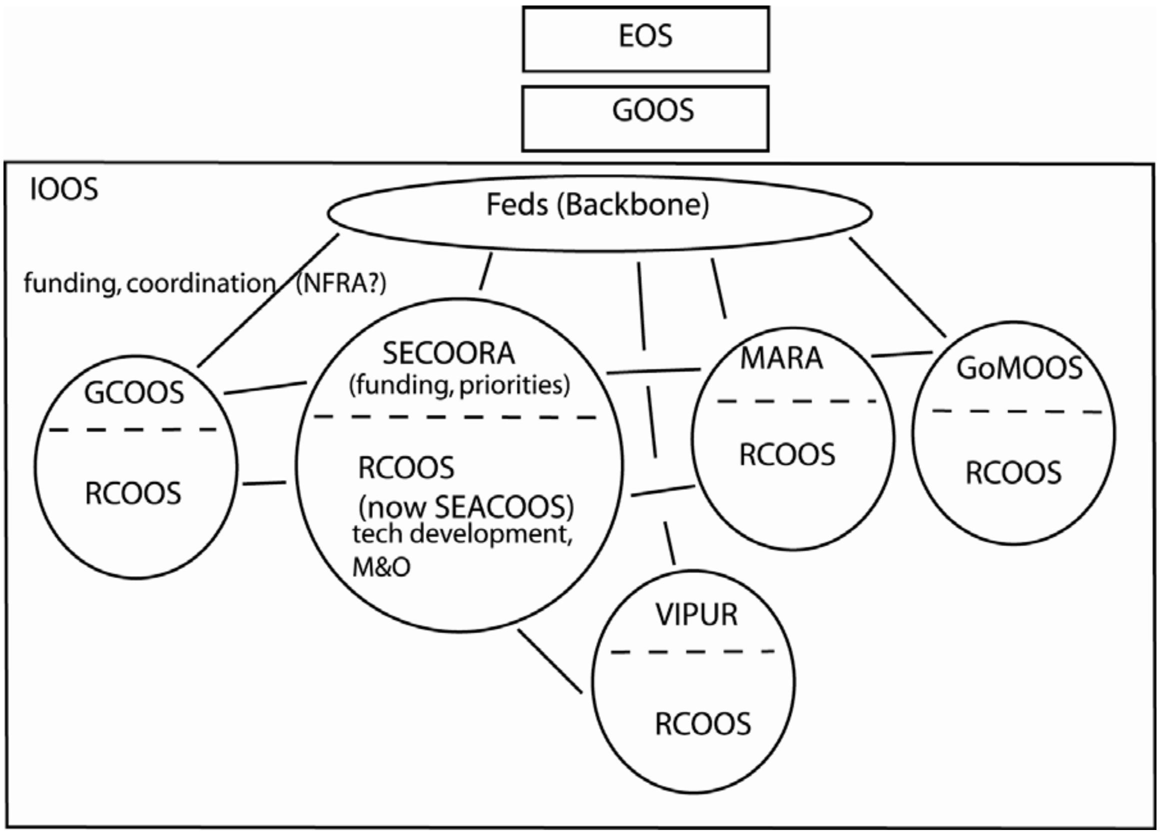

Figure 1 - Schematic representation of the elements at play in IOOS that must be coordinated.

I.1 Combining a systems approach with focus on specific applications

SEACOOS advocates a systems approach to construction of a RCOOS, one that considers a scientific rationale for the required observing and modeling elements. However, to ensure that the system is relevant to a broad range of societal issues also requires attention to specific applications, and engagement of relevant user groups, during the development process. Herein, we describe a timeline for the creation of a regional coastal ocean observation and prediction system with phased development of specific applications, consistent with this approach.

The RCOOS development can be considered from different organizational frameworks, depending upon functional or structural perspectives. First, as a scientific information system, the RCOOS is being developed to investigate a range of topics within three broad **components**, or process categories (below). Second, in terms of functional organization, the system is composed of four **subsystems** (observing, modeling, information management, education and extension). Finally, in terms of societal goals, the system can be approached through the **thematic issues** and specific applications described in the OceanUS IOOS Implementation Plan.

Structures

Organizational	***Process Components***	***Thematic***
		climate variability
Observing	Physical state	marine operations
Information Management	Biogeochem & ecosystem	national security
		sustainable resources
Modeling	Socio-economic	marine ecosystems
Extension & Education		natural hazards
		public health

I.2 A coastal ocean observation and prediction system for the Southeastern United States

The ultimate goal of the national Integrated Ocean Observing System (IOOS) is a sustained "system of systems" for observations and forecasts that collects and disseminates much of the environmental information necessary to address scientific and societal issues in the global and coastal oceans. Once established it will require continual evaluation and upgrades. Here we discuss steps to put into place an initial implementation that provides a framework to begin to address the many issues confronted by society in coastal areas. (The design of the system, driven by the geography, oceanography, and history of observing in the Southeast, is discussed in detail in Appendix 1). One of the cross-cutting themes emphasized in the report of the U.S. Commission on Ocean Policy (USCOP) is the need for ecosystems-based management of coastal resources. This requires an interdisciplinary, science-based approach. In this sense, we define three major scientific components that will guide the development of the RCOOS in the SE:

- Physical state estimation (includes ocean and atmosphere);
- Biogeochemical and ecosystem processes;
- The scientific basis for addressing socio-economic issues.

Each of the components is described in detail in Section III below.

I.3 Applications

A large number of societal issues can be addressed with information from the RCOOS. The range of applications poses a significant challenge to developing a RCOOS – that of defining priorities. This must be based on balancing regional needs and feasibility, and can be viewed as a negotiation between users and implementers. Presented below is the SEACOOS vision, which is intended to provide scientific direction for the development of the RCOOS (see also Appendix 4, Prioritization).

The **components** of the coastal ocean observing and prediction system comprise logical units of activity that include numerous inter-related elements and which should be developed in a coordinated fashion. A relationship exists between each **component** and the **coastal themes** identified in the OceanUS documentation that can be addressed using the information generated by the system. Such relationships are complex and multifaceted, but should help define those thematic issues which can be addressed in the short term versus the long term.

Each **component** can also be used to address a suite of scientific problems, many of which are relevant to ensuring the accuracy and adequacy of the COOS to address societal themes. Key scientific problems will be identified to study during the development of each subsystem and provide a context for objective evaluation of the subsystem's adequacy. Establishing the best overlay of **components**, coastal themes, and scientific processes to study is challenging but vital, and is one of the main purposes of this document.

I.4 The Role of Experiments in RCOOS Development

Adequacy of the RCOOS to address specific societal and scientific issues is best accomplished through experiments. Coastal Ocean Data Assimilation Experiments (CODAE) can be used to quantify errors of prediction systems and assess the adequacy of observational coverage to address specific applications. The CODAEs closely parallel similar systems testing planned for the Global Ocean Observing System. Experiments also have an important role in developmental stages of the systems to identify "best practices". The vitality of the RCOOS will be enhanced by regular testing, experimentation and analysis and argues for a strong research and development component to the RCOOS and regular CODAEs.

I.5 RCOOS as information aggregator/distributor

Along with enhancing regional observing and modeling capabilities, SEACOOS holds that a fundamental role of a RCOOS is that of aggregating and disseminating information. The RCOOS should act as the middleman in information exchange, by coordinating information merger from providers within the region, and serving as a clearing house for the aggregated information. These essential activities mandate a robust, regionally coordinated information management **subsystem**.

I.6 Extension and Education and feedback process

A central tenant of IOOS is that the observing system will be relevant to societal needs. This requires engagement of users. For this reason SEACOOS has initiated an extension and education **subsystem**. User engagement is clearest when focused on specific applications, hence the need for clear identification of applications, and user groups, in the timeline for construction of a RCOOS. We note that the extension effort should and will migrate to the Regional Association, and the timing of this transition will depend upon the establishment of a broad, diverse, interactive, and effective user community, and the resources necessary to support its activities.

Initial characterizations of user groups indicate that a useful distinction between super-users, those user groups accustomed to with large amounts of data and who often are product generators, and more casual users who typically require information products tailored to their specific needs. It is vital to engage a broad range of user groups as quickly as possible to ensure that SECOORA and its RCOOS have a vocal constituency willing to advocate for its funding. Confronted with how to begin this process, we have decided that our best chance of quick engagement is through super-users. The super-users require minimal ongoing support, can utilize aggregated information products for the region in their most basic form, and have established user groups they already serve.

I.7 Prioritization

A great challenge for developing observation systems is achieving a balance between needs and capabilities. A thorough needs assessment for our region is a vast undertaking and not deemed the responsibility of SEACOOS; rather, we will work with SECOORA to develop the ultimate system for prioritizing observing system investment as the IOOS becomes a reality. In the meantime, we make the following observations:

a) The physical structure of the ocean and its circulation are required to address most near real-time coastal ocean information needs. This is borne out in the findings of a number of workshops on this subject. We can therefore justify the need for accurate prediction of sea level, currents, temperature, salinity, waves, winds, and atmospheric heat and water flux as part of the observing system.

b) There exist tested autonomous sensing systems readily available for observing most of the primary physical variables. The feasibility is high to transition these techniques to pre-operations because of their long history of use in research (or existing operational) systems.

c) Ocean circulation, surface gravity wave, and atmospheric circulation models exist and are of sufficient maturity to be formally tested against observations and operating in real-time to produce forecasts of these fields.

d) These fields provide critical information on chemical, biological and geological processes in the coastal ocean and applications within each of these disciplines can be developed through intelligent use of this component of the ecosystem observation and prediction system.

We therefore are pursuing an aggressive campaign to augment the existing observing systems and modeling system elements to provide regional physical state estimation.

II. Building the System

A ten-year build out plan

We identify three phases of development: phase 1 (short-term, FY03-05); phase 2 (mid-range, FY05-FY07) and phase 3 (long-range, FY08-FY12). For each phase targeted applications and user groups, broad areas of implementation for the system as a whole, and details of how each working group will contribute to the development are identified. Obviously it will be important to fund, from the beginning, efforts that support applications in each of the phases, but funding dedicated to a specific application is expected to peak during its phase.

The rate as which the RCOOS can grow to support multiple applications is largely determined by the rate of funding. Based on the current rate of funding (roughly $5 million/yr to SEACOOS and roughly $12 million to active SE observing programs/year total) we estimate the progression given below. Decreased funding will result in slower development and increased funding will support more rapid growth. We also re-emphasize that the applications to be developed are simply initial implementations, sufficient to conduct a first round of CODAEs to assess system errors and base system revisions upon.

Targeted Applications and user groups

II.1 Phase I (to August 2005):

We identify two primary targeted applications, and associated user groups, for which SEACOOS has unique information available at present. These two applications are considered high priorities because of region-wide significance and because of feasibility (see also Appendix 4).

1. Use of circulation fields and Lagrangian drifter trajectories to support search and rescue, and spill response; also essential to nowcasts and forecasts of pollutant dispersal, HABs, etc.
    Identified users: Coast Guard, NOAA HAZMAT, NWS Weather forecast offices, State and Federal emergency managers

2. Fisheries oceanography – emphasizing particle trajectories to assess regional "connectivity" and fisheries recruitment.
    Identified users: Southeast_Fisheries Science Center/NMFS, South Atlantic Fisheries Management Council, Gray's Reef National Marine Sanctuary/NOS, Florida Keys National Marine Sanctuary/NOS, Fish and Wildlife Resources Institute/FL, South Carolina Department of Natural Resources, Beaufort Marine Laboratory/NOS.

Both of these applications rely on the presence of accurate, real-time representations of ocean circulation. Estimating the physical state of the coastal ocean is thus the initial focus for development of the coastal ocean information system presented below. This continues the

SEACOOS approach toward establishing region-wide sustained observing and modeling of the coastal ocean by building out from existing system elements.

II.2 Phase II (to August 2007):

Beginning with Phase 2, SEACOOS will enhance nearshore and inshore capabilities by adding two more targeted applications. These are also chosen because of feasibility, but are delayed until Phase 2 because of the significant development efforts required.

3. Storm surge/inundation – assist in providing high-resolution estimates of surge heights and inundation areas.
   Identified users: NWS/weather forecasting offices (WFOs), Emergency Management groups (Federal, State, and County).
   Major development requirement: high resolution topography onshore and high resolution bathymetry in the nearshore/inshore regions.

4. Surface Waves – to better represent rip currents, bed stress and sediment transport, and to provide validation for wave forecast models.
   Identified users: NWS/WFOs, state resource managers.

   Major development requirement: regional directional wave measurement program.

During Phase II we will also emphasize implementing an information archiving and retrieval plan, and a quality assurance/quality control protocol, as a necessary step towards a sustained system.

II.3 Phase III (2007-2012)

Given the rapid and accelerating pace of development of IOOS, RAs and RCOOSs, we feel it is premature to identify specific applications for the longer term time frame at present. We advocate a general emphasis on making routine chemical, biological and geological measurements, growth of the system inshore, and continued development of linkages to specific user groups to foster specific applications. We also anticipate that future evolution of SEACOOS will be addressing the emerging priorities of information needs for ecosystem based management, which was recently recommended in the Report of the US Commission on Ocean Policy.

	Applications	User-groups	Variables
Phase I	Search and Rescue, spill response, HABs	USCG, NOAA HAZMAT	Currents, winds, water temp, waves
	Fisheries	SAFMC, xNMS, FMRI, SC DNR, etc	Salinity, species and abundance, etc.
	Storm surge	NWS WFOs, state EM	Water levels, Inundation maps
Phase II	Rips and sediment transport	State CZM, NWS WFOs	Directional waves, sediment concentration

III. Components of the regional information system

III.1 Physical state estimation

Characterizing and forecasting the circulation of the ocean and atmosphere, and the interaction between them, is a fundamental objective of SEACOOS. This includes the surface gravity waves of the ocean. Well-constrained error estimates for state variables will be necessary for applications to societal issues. To meet the observational requirements, a wide variety of observing platforms are required, along with considerable enhancement of present spatial coverage. Similarly, to date no one model system has been used to represent the full physical system. Instead, a number of models are used that are then coupled, either through simple, one-way linkages or through more sophisticated two-way couplings. The following summarizes requirements for estimation of various components of the physical system in the coastal ocean, and outlines the phased approach to be followed in development of SEACOOS capabilities in these areas.

a) ***Ocean circulation*** – requires observations and models of sea level, currents, temperature and salinity, and of conditions on the boundary of the ocean - winds, heat flux and fresh water flux (from the atmosphere and from river discharge). Good quality bathymetry is also important, and mixing rates (diapycnal and isopycnal) are also critical.

Here, we distinguish plans to address two aspects of ocean circulation: barotropic and baroclinic dynamics.

Barotropic dynamics –includes the surface elevation and depth-averaged current response of the ocean to forcing by tides, winds and atmospheric pressure. Reasonably mature measurement and modeling systems exist for this sub-component. Thus, these capabilities have been implemented first. Working group sections provide further information on the barotropic components of the observation and modeling systems. Overall development plans are:

Phase I – *By the end of project year 3 (fall 2005),* an initial set of coastal ocean barotropic dynamics models should be implemented and an initial assessment against existing observations completed.

We consider this a fundamental sub-component of the observing system that should be established before moving on to other elements. Knowledge of sea level variations brought about by the tides and winds, and the associated currents, will lay the foundation for the rest of the observing system.
Phase II – *Beginning in fall 2005,* coastal ocean barotropic modeling will be transitioned to pre-operational status. This should include regular distribution of information to super-users and feedback on system changes/improvements. Given adequate funding, this phase may include expanding existing models and/or pursuing further coupling with other models into the nearshore/inshore areas. Such pilot modes will explore nesting/coupling options.
Phase III – Transition to an operational coastal barotropic modeling system and by 2012 have pilot and pre-operational barotropic dynamics modeling from the EEZ to the head of tide throughout much of the region.

Baroclinic dynamics – includes the effects of variations in seawater density on the pressure field. This requires accurate representation of the three-dimensional temperature and salinity fields throughout the region. Regular observations of these fields in three-dimensions are not presently being obtained. Achieving this capability represents a significant challenge. Representation of baroclinic dynamics also requires coupling to representations of the adjacent open ocean. Development efforts are detailed in the working group section, but overall development plans are:

Phase I – *By fall 2005*, aggregate the available temperature and salinity observations throughout the region and initiate pilot programs to enhance three-dimensional coverage. An initial baroclinic dynamics modeling effort (one that includes the effects of seawater density on the pressure field) will have been implemented. The importance of the density field in determining the circulation is highly variable in space and time throughout the SEACOOS domain. Thus, an observational program sufficient to resolve this variability is expected to take a number of years to develop.

Phase II – will continue pilot efforts in observing and modeling, culminating in an initial evaluation of adequacy of the assembled components.
Phase III – *In fall 2007,* the transition of temperature measurements and model hindcast studies to a pre-operational status will begin. This can build on existing "super-user" collaborations. Initiation of pre-operational salinity (and hence density) observations and forecast modeling will begin in out-years (2008-2010).

b) ***Marine atmosphere*** *-* The marine atmosphere plays a critical role in forcing motion in the coastal ocean and must thus be accurately represented if a valid ocean forecast is to be obtained. Observations in the marine atmospheric boundary layer are very sparse in comparison to those over land. An initial SEACOOS focus has been to assemble regional wind observations to assess the validity of existing model capabilities, and to support further development of barotropic and baroclinic circulation and surface wave models. Accurate models of the baroclinically driven flow field will also require observations of the net heat flux and fresh water flux (most often estimated indirectly from sea temperature, air temperature and humidity, rainfall, wind stress and short- and long-wave radiation).

Phase I: *By August 2005*, assess the accuracy of the NCEP wind field against aggregated wind observations. Begin aggregation of heat flux observations in support of baroclinic modeling effort.

Phase II: Assemble the existing fresh water flux observations, including river gauging stations, and any visibility observations. Continue transition of wind observations to pre-operational program (this has already been initiated through our provision of wind observations to NDBC). Continue to assess accuracy of existing meteorological models (NCEP in particular), and also consider partnerships with other groups running nested regional scale model efforts (e.g. the NSF LEAD program).

Phase III: Transition wind observations to operations and initiate pre-operational programs for observed heat flux, fresh water flux, and visibility. A choice of the marine meteorological model should be made, and a timeline for transition to pre-operational and operational status will be outlined (if not already accomplished).

c) ***Surface waves*** – requires observations of winds, currents, directional wave spectra, and bathymetry. Of particular importance to the southeast is the role of surface waves in re-shaping the coastline, which requires repeated high-resolution bathymetric surveys in the nearshore. This may be an opportunity to leverage an effort to obtain improved bathymetry.

Phase I: *By fall 2005*, an observational inter-comparison study will be completed to clarify which directional wave measurement technologies are best suited to be transitioned to pre-operational efforts.

Phase II: Based on the results of the inter-comparison study, we will define and implement a regional wave measurement strategy for the SE US to be completed by the end of Phase II (fall 2007). Partnering with federal and state agencies invested in this topic is essential (e.g. USACE, USGS, NOAA). This will include an evaluation of existing wave models and a decision on developing a modeling subsystem for our region.

Phase III: Transition of the observing and modeling elements to a pre-operational status is planned for the first few years of Phase III.

d) ***Optics*** – Light propagation in the ocean plays a critical role in biology and photochemistry. Radiation measurements are also essential to refined heat budgets and is the basis for estimates of many other variables (e.g., all remotely sensed ocean color products; in situ and remote estimates of turbidity and particle concentrations). Accurate modeling of the light field requires observations of incoming light field and in-situ properties. Linking the observed and modeled light fields to regional assessments of primary productivity and biogeochemical processes (e.g., cross-shelf transport, sediment resuspension and transport) requires coupling to the physical circulation.

Phase II: (*beginning in fall 2005)* Initiate aggregation of in-situ and remotely sensed observations of attenuation, turbidity, PAR, and other optical properties relevant to accurate heat budgets, and to support of development of regional modeling of primary production and biogeochemical exchange processes. As appropriate, a modeling effort may begin in Phase II.

Phase III: Initial evaluation of optical modeling will begin 1-2 years after the pilot program has begun, and development of coupled physical-bio-optical models will be explored.

III.2 Biogeochemical and ecological processes.

Building on the initial SEACOOS effort in fisheries oceanography, information on physical conditions will provide the organizing framework around which SEACOOS capabilities to address regional biogeochemical and ecological processes will be developed. This will include *in situ* and remote observations as well as modeling approaches. While there is considerable interest in further development of *in situ* sensors for chemical and biological properties, what is presently available for sustained field deployments is limited. For some sensors that are commercially available (e.g., for nutrients), unit costs and maintenance requirements can limit their application. Satellite remote sensing, and ocean color in particular, can provide information on a number of key biological and optical properties on a regional scale, and how the variability in these properties is coupled to physical processes. Given the challenges for algorithm development and validation in what are often optically complex coastal waters, evaluation of various products for specific applications will be required. Partnerships with other programs will likely be required for regional (and seasonal) remote sensing algorithm development and validation.

For the foreseeable future, direct sampling and field experiments will continue to be required to obtain estimates of key biogeochemical/ecological variables and rate processes (i.e., ship-based studies, short-term moorings). Thus, in the Phase II and Phase III time frames, one of the key contributions from the SEACOOS information system will be to provide a strong context of physical observations and models for focused biogeochemical/ecological process studies in the SE region.

Phase I: For *in situ* observations, a limited set of optical/bio-optical sensors have been deployed in a number of locations in the SEACOOS domain. Evaluating and improving strategies to minimize bio-fouling and reduce maintenance requirement is a key near-term objective for these in situ sensors. New configurations from manufacturers with integrated anti-fouling mechanisms will be tested. Satellite remote sensing products will be evaluated for applications in specific biogeochemical and ecological contexts.

Phase II: The infrastructure to support sustained field tests of new sensor systems will continue to be developed. The initial basis for sub-regional, coupled physical-biological models will be developed through the pilot efforts on baroclinic dynamics (above). Specific processes will be targeted for focused effort within SEACOOS, based on evaluation of the status of observation and modeling capabilities (e.g., HABs, cross-shelf exchange processes, sediment resuspension events).

Phase III: The observational, modeling and data management infrastructure for coupling biogeochemical and ecological models to physical models over a range of time and space scales will be developed. Based on interactions with user groups, targeted applications for these components of the SEACOOS information system will be pursued.

III.3 Socio-economic applications.

Recognizing and quantifying the role of humans in the coastal ecosystem has been called for in the report of the U.S. Commission on Ocean Policy. Management agencies have long recognized this need and have considerable information on land use, population distributions, etc. They should be encouraged to make their databases publicly available through regional COOS programs as a first step in filling this information void. SEACOOS has supported an economic study but has not made further concerted effort in this direction, since other IOOS-related studies have been initiated.

The development of SEACOOS is intended to be consistent with addressing the broad socio-economic areas (thematic issues) described in the IOOS Implementation plan developed by OceanUS. The thematic issues that are initially emphasized will be those identified through the interactions with key user groups (already initiated). It is envisioned that this engagement of users will be coordinated through the Regional Association (SECOORA).

Phase I: Continue SEACOOS engagement with regional "super-user" groups (such as those concerned with marine weather, hazardous materials responses, coastal emergency management, regional fisheries management). Assist SECOORA in its initial organizational efforts.

Phase II: Through the efforts of SECOORA to engage various user groups, target socio-economic issues in the SE region to which the scientific information provided by SEACOOS can be effectively applied.

Phase III: Further develop the regional capability to address the IOOS thematic issues in coordination with the national program.

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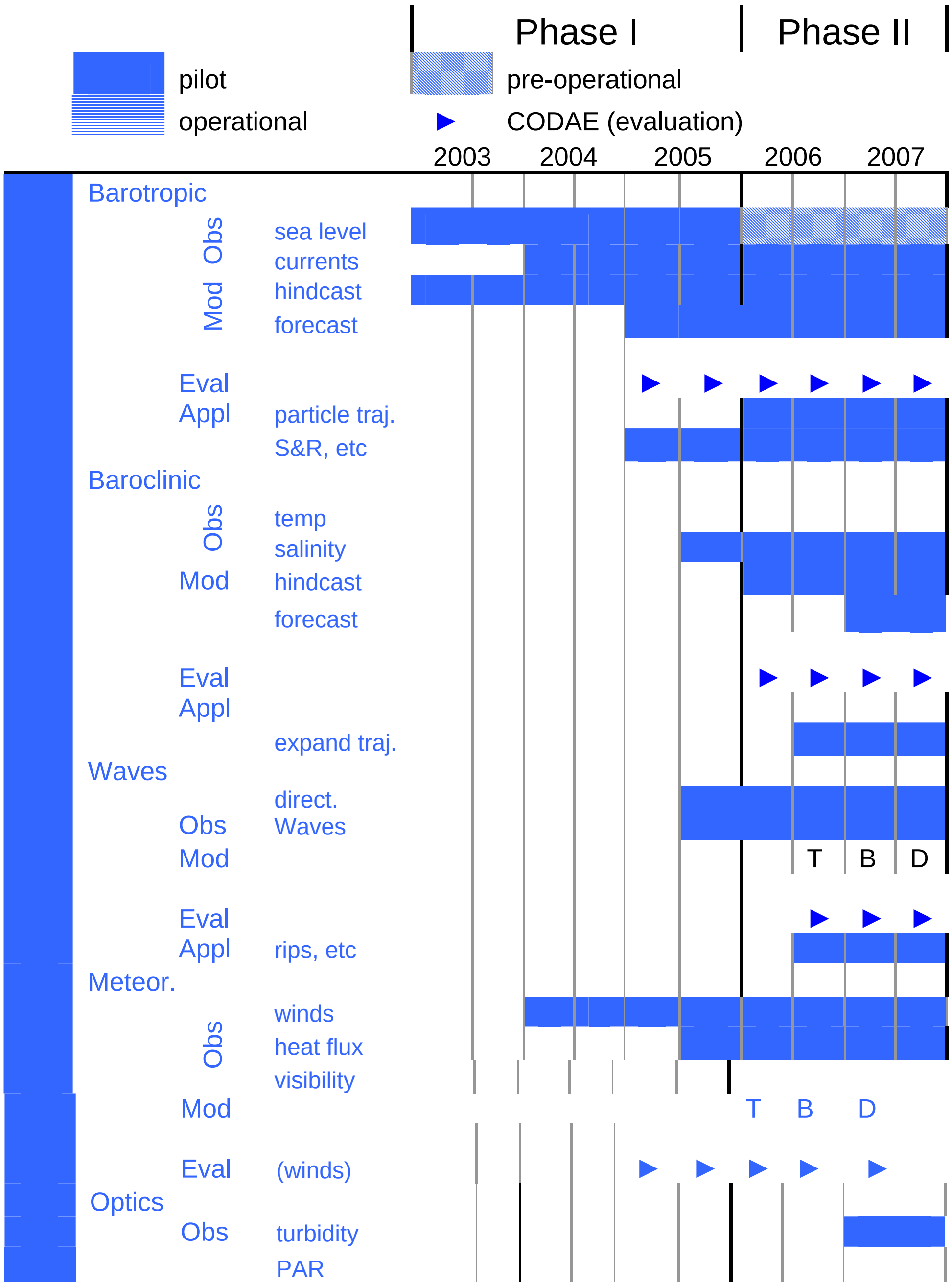
Phase I
Phase II
pilot
operational
pre-operational
CODAE (evaluation)
2003
2004
2005
2006
2007
Barotropic
Obs
Mod
sea level
currents
hindcast
forecast
Eval
Appl
particle traj.
S&R, etc
Baroclinic
Obs
temp
salinity
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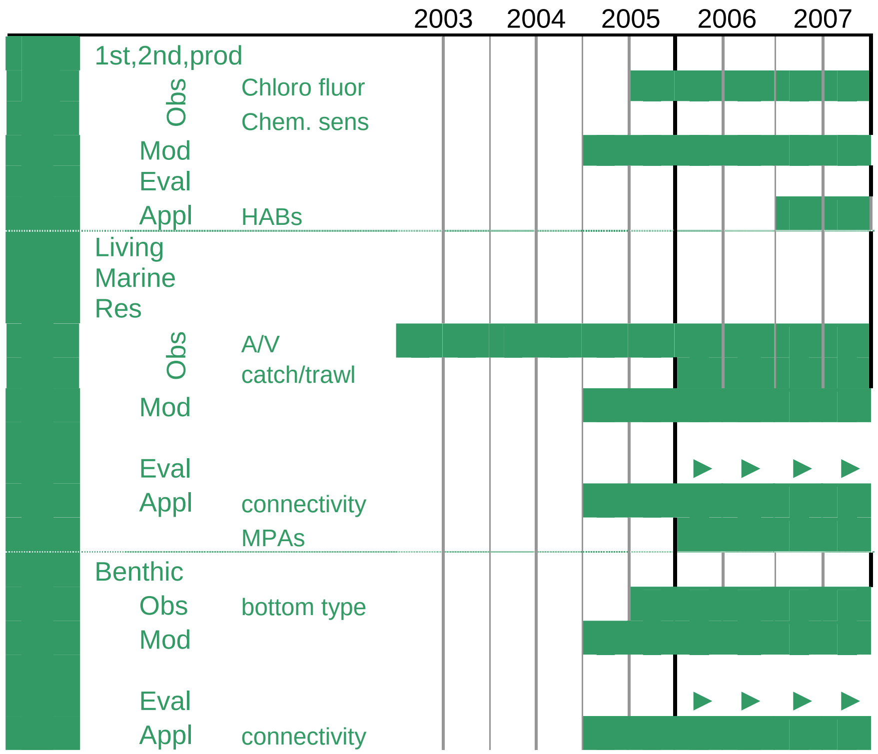

The Gantt charts above portray the timing of major activities over the next few years. Variables of particular interest are listed, as are start times for various modeling activities and possible evaluation activities (e.g. CODAE).

Observing WG Implementation Plan

Phase I

1. Establish an inventory of the regional observing assets; to ensure that this inventory remains up to date, and is coordinated with the efforts of Federal Affiliates and other sub-regional programs, construct a dynamic, web-accessible database; coordinate with Federal Affiliates to define the maintenance and operations costs for various components of the existing observing system; quantify the "leveraging" contributed by the SEACOOS partners.
2. Improve the reliability of the existing observations and their delivery to users.
3. Develop circulation descriptions based on existing SEACOOS data with applications to S&R and fisheries oceanography. Work with MWG to define where additional observations are needed to support ocean circulation models. Develop Lagrangian capabilities.
4. Actively engage fisheries councils to find common interests. Do advance legwork for either: 1) Fisheries Oceanography as an organizing theme for Spring SEACOOS WS; or 2) a separate symposium with the Fisheries community. Work with Fisheries community to promote broader use of the existing observations, to identify priorities for additional observations relating to management needs (e.g., where and when additional data are needed; what needs to be measured?), and to assess how these can be efficiently obtained.
5. Develop additional "value-added" products with existing observations (science-based products, e.g., winds, SST, ocean color products, surface currents, heat flux, etc.).
6. Interact with Federal Affiliates on technical issues. Provide test beds for technical evaluations of emerging remote and *in situ* technologies, including observational infrastructure (e.g., deployment packages, power and communications systems) as well as sensors.
7. Perform the analyses required to improve the observing system design (interactively with MWG) and to develop products for broader applications (interactively with E&E WG and IM WG).
8. Initiate a collaborative regional surface wave program. Coordinate with affiliates, starting with a regional workshop at the Field Research Facility (USACE). Conduct a collaborative field experiment in the domain covered by the WERA system to evaluate in situ and remote technologies for estimating the directional wave field.

Phase II

Many of the Phase I activities listed above are not tasks that can be brought to a clearly defined end point. Thus, much of the Phase I effort will be ongoing in the Phase II time frame (such as continued technical evaluations, etc.). However, as part of the second phase of the SEACOOS Implementation, these activities will be expanded to include additional areas of targeted effort.

Surface waves pilot project.

The surface wave program for SEACOOS is at an early stage. An initial community discussion was held as one of the break-out sessions of the Spring 2004 SEACOOS workshop, and directional wave observational capabilities in SEACOOS have been added in 2004. Establishing the design and best practices for a surface wave program (observations and models) will require both scientific analyses and coordination with other groups. This is an area of interest to several agencies, and interactions will need to be developed through the planning process. In addition to the planned

SEACOOS surface wave experiment, interactions with federal agencies and other interested parties has been initiated. A regional surface wave workshop has been proposed for 2005, and the initial efforts to form a regional "wave group" are being pursued. Various observational technologies will continue to be evaluated and the design for SEACOOS wave "test-beds" will be developed. Priority locations for deployment of surface wave observing assets (e.g., areas where coastal erosion or rip currents are critical issues; observations needed for model validation, etc.) will be assessed in this process.

Storm surge/inundation.
Given the extensive low-lying coastal areas in the Southeast, observations and forecasts of coastal storm surge and storm-related inundation are critical to public safety and economic issues such as risk assessment for coastal development. Thus, it is essential that SEACOOS efforts in this area are effectively coordinated with other regional programs and the potential users of this information are engaged in the development process. Additions of relevant real-time observations by SEACOOS (e.g., winds, water level, waves, currents) will need to be coordinated with the data assimilation and model validation needs of the SEACOOS MWG and other regional modeling programs (such as SURA SCOOP). Similarly, the dissemination of information to various user groups (such as State- and County-level Emergency Response personnel) will require engagement through the SEACOOS E&EWG and product delivery through the SEACOOS Information Management system.

Information Management WG Implementation Plan

The Information Management (IM) System supports all SEACOOS activities in cross-cutting ways. Thus, specific tasks to advance IM contributions are likely to support multiple applications. Nevertheless, some IM areas of focus relating to the three principal process areas are outlined below:

The Three Principal Areas:
Physical State: Four applications have been identified, and will be addressed in two phases (Phase 1: circulation fields, fisheries oceanography; Phase 2: storm surge, surface waves). Regardless of the process area, specific IM application development will be largely based on event based products that will be identified in coordination with the Obs, Modeling, and E&E WGs. These “events” can be ongoing processes, such as the wind field and sea surface temperature products that have been developed, or may be based on episodic events, such a cold water upwelling or hypoxic events.

Biogeochemical/ecological Processes: Two major areas of activity will relate to the requirement for dealing with additional large volumes of complex heterogeneous data.

- Processes and protocols will be required to be able to integrate SEACOOS observing data, which is largely offshore, with the large assemblage of nearshore and estuarine data that have been collected through other programs (e.g. NERRS, EPA). Such nearshore data are typically delayed mode, often lack standards-compliant metadata, and are likely to represent a range of formats and vocabularies. The development of mechanisms to integrate these data can be formidable, but the potential benefits are enormous.

- Incorporation of biological and chemical data into the IM data management structure. The problems associated with incorporation of these data are identified above. Appropriate standards must be identified and agreed upon, and then applied to the appropriate data bases.

Socio-economic applications: The IM supports this component largely through the development of user-targeted products, e.g. storm surge forecasting models. Other contributions include:

- Workforce training and student training and education both through inclusion in IM activities and by developing educational tools;
- Technology transfer, through the development and optimization of computer software development and application to IOOS activities;
- Contribution to the establishment of a truly operational and reliable IOOS through development of the necessary IM processes and infrastructure.
- Development of an IM system that can include and integrate demographic and economic data.

Additional cross-cutting and overarching activities include:

- Establishment of an “In-reach (iterative) process” that assumes full communication with the other WGs in SEACOOS;
- Identification of the requirements needed to achieve appropriate redundancy in the IM system, followed by their implementation;
- Determination of the appropriate archiving processes, archive locations, and the infrastructure required, followed by implementation of the resultant plan;
- Establishment, in coordination with appropriate partners (e.g. SURA SCOOP) of the appropriate metadata, data, and protocol standards, followed by their implementation;
- Coordination with SECOORA and with other RAs, federal agencies, and relevant national organizations to ensure cross-fertilization of knowledge gained and sharing of IM products.

Modeling WG Implementation Plan

Phase I

Develop skill assessment. The current implementation of the SEACOOS Nowcast Forecast System (NFS) is barotropic, with imposed wind stress and tidal elevations. We have focused to date on tidal and sub-tidal (40 hr) low pass filtered coastal water level skill at selected locations, with extensions to include spatial assessment of the observations as more data become available. We will also quantify the spatial and temporal errors in the NCEP EDAS/ETA wind fields used to drive the NFS.

Implementation of strategies for baroclinic modeling and offshore forcing. In addition to properly imposing the forcings by river discharges and atmospheric heat flux, a primary difficulty in including baroclinic dynamics is the specification of accurate and realistic initial conditions for a particular forecast. One possible method for such initialization is by one-way nesting of regional-scale baroclinic models to basin-scale models. This will require assessing how well the basin-scale models represent the regional mass fields and/or how the regional models respond to the basin-scale products as initial conditions.

Assess the regional modeling approach. The SAB, the EFS/FS and the WFS are characterized by radically different geometries and forcings. Next steps include consideration of how best to link model results of the individual study domains and provide a single integrated description of the circulation in the SEACOOS region. Linking the three domains dynamically is not straightforward. The development of a single SEACOOS-wide domain may be attractive for several reasons and will be considered. Implementation of common model domains would allow for model ensembles and other statistics to be estimated. Thus forecasts would be issued with a probability associated with to them. Additionally, in the event on a model failing to complete, there would be in effect a two model back-up built into the system. The downside is the cost associated with a larger model domain maintained by each group.

Phase II

Ecosystem models. We plan to study and quantify the transport of larvae of selected species in the SEACOOS domain. This effort considers the model flow fields in relation to the design of Marine Protected Areas (MPAs). Additionally, we anticipate our modeling studies to consider nutrient-phytoplankton-zooplankton-detritus (NPZD) formulations, which will require close communication with the Observational WG to make use of available data for validation and initialization purposes.

Wave models. Inclusion of (high frequency) wave models may improve estimates of bottom friction and sediment transport. Several approaches are available. One approach is that used by the Army Corps of Engineers wherein a 3rd generation wave model is used (no spectral *a priori* expectations) based on WAM (see http://frf.usace.army.mil/wis/). Although the agreement with lab experiments is good, fundamental research questions remain. For example, the Gulf Stream on the waves traveling from the open ocean onto the shelf regions is not well understood. One possibility to be explored is that instead of running a wave modeling system within SEACOOS, to download wave modeling products the same way we are downloading the atmospheric forcing. The SEACOOS niche might be to provide a higher resolution wave product with a complementary observing system.

Data assimilation. We will begin to examine the possibility of data assimilation into the SEA-COOS modeling sub-regions as real-time data (e.g., sea level, ADCP and HF Radar) become routinely available.

Execute an initial SE CODAE. While a few demonstrations have been made with the coupling of global ocean to coastal ocean prediction systems, a broad spectrum of science questions and implementation issues must be addressed to move forward with more capable global and coastal ocean information systems that can be applied to an expanding set of user needs, which will increase the demand for operational oceanography. Both the global and coastal ocean communities recognize that it is now an urgent requirement to begin to design and conduct a Coastal Ocean Data Assimilation Experiment (CODAE) as a series of experiments in a variety of regimes which we intend to help develop.

Ensuring Robustness & Grid Technologies. In a nowcast-forecast operational system, it is beneficial to have a distributed approach to running models, in general, and specifically during instances (e.g., the recent hurricanes) that can result in down-time for one or more modeling sites simultaneously. A consideration is that robustness should be achieved while minimizing the number of runs (and associated costs). One solution is to include a coarse resolution run at more than one site as a backup for failure. The goal (in collaboration with SURA-SCOOP) is that Grid computations and grid technologies will be able to address some of the robustness issues.

Portability of the operational system. The implementation of the present operational system has involved the development of software to acquire and process atmospheric products, prepare the models for execution, and post-process the system outputs. However, once in operational mode and with demonstrated skill, groups that have more experience with operational system requirements might better handle maintenance of these systems. It is thus critical to develop and provide documentation of this system to facilitate migration of technology to other groups.

Extension & Education WG Implementation Plan

The Extension and Education Working Group provides leadership within SEACOOS for outreach to users of coastal ocean observing system (COOS) data and data applications. Extension activities focus on adult learners who would use the transfer of COOS data as a decision support tool for public service (weather forecasting, coastal management, security, public safety) and commerce. Extension skills interpret language of science for non-science users of COOS information and facilitate interaction among science information users and scientists. Education interprets science information for formal K-12 educational system, college-level educators and educators at “free choice” institutions, including museums and aquaria. The ability to provide an educational context for coastal ocean observing real-time or near real time data, use of technology, career opportunities can align with state and national science education standards. It can provide incentives for students to continue their education, choose ocean science degrees or become involved with ocean stewardship. Education efforts typically involve workshops, development of curricular materials and lessons, and a network of engaged teachers. Extension and Education both function to increase awareness of coastal ocean information from the observing network system.

Extension interprets research results that have matured sufficiently to be developed into applications for users. Extension is both responsive and opportunistic. It must respond flexibly to scientific advances and to the unanticipated needs of users. This response, by necessity, may include the revision, or even abandonment, of previously determined objectives.

Education is also responsive and opportunistic. A new challenge for education is the integration of ocean observing data into curricular materials. A major task is to develop priorities based-on which elements of SEACOOS research are best suited for formal/"free choice" education transfer.

Extension & Education Program Framework

The Extension and Education Working Group has created a program framework with four major elements: 1) Facilitating PI/user interaction; 2) Increasing public awareness of the uses and benefits of SEACOOS data and applications; 3) Working with PIs to enhance and maintain internal mechanisms for the development of Extension and education programs; and 4) Initiating the process of transition from SEACOOS to SECOORA Extension and education.

1) Facilitating PI/User Interaction

a. Region-wide. Working with SEACOOS PI s and targeted users on region-wide SEACOOS science applications. Consistent with the overall SEACOOS Implementation Plan, E&E work in this area in phase 1 will focus on scientist "super-users" within management agencies. Planned activities include:

1. Follow-up on targeted "super-user" meetings held in Fall 2004 related to marine weather, HazMat, fisheries and habitat.
2. Continue to facilitate targeted meetings between SEACOOS PIs and "super-users" on topics which may include harmful algal bloom detection and management, and sea turtle research.
3. Represent E&E on SEACOOS cross-cutting thematic working groups, including:

   Fisheries Oceanography – Fishery science and management applications.
   Waves – Rip current, sedimentation and other shoreline processes applications.
   Circulation – Search and Rescue and HazMat applications.

b. Sub-Regional Systems. In phase one, (prior to the transition to SECOORA) the E&E WG will work to create and maintain communications and collaborative linkages among SEACOOS and sub-system extension and education program activity and work with SEACOOS (and other sub-regional system) PI s and targeted users on sub-regional COOS science applications. Planned activities include:

1. E&E WG members in each state will take primary responsibility for developing communications and interactive E&E program links with the SEACOOS sub-systems and others in the region.

   NC – NC COOS, CORMP
   SC – CAROCOOPS
   GA – SABSOON
   FL – COMPS, EFSIS, PORTS
2. E&E products of sub-system interactions will be reported-on and submitted to SEACOOS/SECOORA for possible region-wide application.

c. Business & Industry. Prior to the formal transition to SECOORA, the E&E WG will work with SECOORA, SEACOOS PI s and targeted users in business and industry on regional and sub-regional SEACOOS science applications. Planned activities include:

1. Following-up on previous user characterization efforts, the E&E WG will facilitate PI/private sector user interactions for the purpose of developing pilot projects, which could lead to the commercialization, within the private sector, of SEACOOS data application products. Planned activities include:
1. Private sector users will be identified for participation in targeted user/PI exploratory meetings.
2. Appropriate pilot projects will be identified.
3. If necessary, external funding for pilot projects will be sought through sources including Sea Grant Industrial Fellowships, SBIR, and STTR.

d. K-16 Education. E & E WG targets educators in both formal and informal or "free choice" institutional situations and draws information from regional and sub-regional SEACOOS science. Planned activities include:

1. Develop regional awareness of SEACOOS and its potential usefulness to educators.
2. Develop and deliver programs designed to make use of COOS information in formal educational settings with teachers and pre-college students, and eventually to undergraduate faculty and students.
3. Develop and implement strategies to reach educational audiences including web sites, DVDs, workshops, conferences, newsletters and ocean awareness days (SEPORTs).

2) Public Awareness. Introducing the general public and potential users of SEACOOS data (presently not primarily targeted) is an important element in the development of SEACOOS. Public awareness activities communicate basic COOS concepts, establish the relevance of ocean observations for user groups and enumerate societal benefits of SEACOOS and COOS in general. E&E WG members will engage in communications activities intended to achieve these goals. Planned activities include:

1. The development and distribution of electronic and printed interpretative and educational materials, including web sites, DVDs, newsletters, interpretive signs, kiosk and other displays, brochures, Power Point slide programs, media interviews, etc.
2. These materials will be delivered via the Internet, at public gatherings, at SEACOOS observing installations (public piers), HF radar sites, etc.

3) SEACOOS Internal Program Development (In-reach). E&E WG members will attend to the group processes which keep any organization functioning optimally. Planned activities include:

1. Facilitate information flow among the E&E and other WGs, with special emphasis on interaction with the IM WG on the planning, delivery and evaluation of IM products.
2. Establish and maintain working relationships with SEACOOS PIs.
3. Participate in PIC and website development processes,

4. Serve on SEACOOS committees, e.g. thematic working groups.
5. Participate in biannual SEACOOS workshops.
6. Attend E&E WG meetings and contribute to program planning and reporting.

4) Transitioning to SECOORA. Planning and implementing the transition from SEACOOS to SECOORA E&E. Planned activities include:

1. Participate in SECOORA organizational and other activities, including the SECOORA summit.
2. Work with SECOORA staff to establish E&E linkages with non-SEACOOS observing systems and users in the private sector.

Appendix 1 - Design

The design of the observing system is driven by the geography and oceanography of the region, the history of observing, and the key elements that need to be included. The oceanography of the Southeast is first reviewed.

1.1 Oceanography of SE

Regional response of the coastal ocean to physical forcing - Cyclones and the synoptic scale atmospheric forcing over the South Atlantic Bight (SAB), East Florida Shelf (EFS) and West Florida Shelf (WFS) sub-regions of SEACOOS often excite a strong physical response in the coastal ocean. The response includes sea level changes, cross-shelf and along-shelf currents (including near-inertial motions), changes in stratification due to advection and turbulent mixing, and changes in the surface wave field. The response impacts cross-shelf exchange of water and tracers, sediment resuspension and transport, nutrient availability, optical properties, drift trajectories, and productivity levels. With the exception of the tide in parts of the SEACOOS domain, the oceanic response to atmospheric forcing is often the most energetic signal in observations and therefore readily measured. Integrated over seasons, the coastal ocean response induced by atmospheric forcing plays a defining role in the seasonal variability on the shelf and controls the residence times of particles in shelf waters.

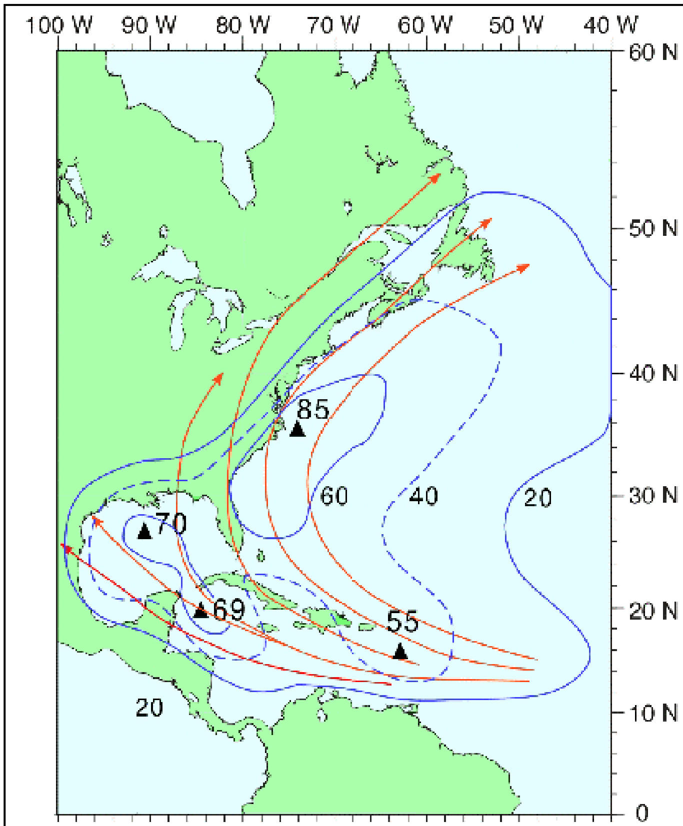

Figure 2. Shown are tropical cyclone tracks and number of occurrences (blue contours) over a 103-year period from Neumann (1993). The numbers represent the occurrences of a hurricane within a 140 km radius of that point.

The southeast United States is especially susceptible to both tropical and extra-tropical cyclones and winter storms such as Nor'easters and cold-air outbreaks (see 1989 JGR special issue on Genesis of Atmospheric Lows Experiment). Neumann (1993) quantified the mean direction of the tropical cyclone (TC) tracks from 1886-1989 (103 years) as shown in Fig 1. Generally, if storms do not recurve east of 60°W, they will landfall along the US coastline. The number of TCs ranged from 70 in the Gulf of Mexico to a maximum of 85 off Cape Hatteras, North Carolina. Given the high probability of landfall and the broad coastal plains characteristic of the SEACOOS domain, with its vast areas of low-lying land, accurate prediction of the oceanic interaction with, and response to, tropical storms is vital to enable a timely response to this form of natural hazard.

Two other physical mechanisms that force large net displacement and control water mass properties of shelf waters are buoyancy input from river discharge (and groundwater) and influence of boundary currents at the shelf margins (i.e. the Loop Current/Florida Current/Gulf Stream (LC/FC/GS) complex). Buoyancy-driven coastal currents originate in the nearshore region, are characterized by variability on small (O10 km) spatial scales, and produce strong cross-shore variability in vertical structure (e.g. Garvine, 1999). In much of the Southeast, the inner shelf is also strongly influenced by surface gravity waves. Measurements to quantify processes on the inner shelf can be difficult because of the shallow depths and wave-driven currents, and expensive because of the small scales of variability that must be resolved. We therefore choose to emphasize the circulation response to atmospheric forcing, with a secondary emphasis on boundary current interactions at the shelf margins, in our initial effort. Later development of SEACOOS will incorporate studies of the inner shelf.

Current understanding of regional physical oceanography - Continental shelves are buffer regions between the coast and the deep-ocean. There, land drainage-derived and ocean waters mix to determine the material properties of the coastal ocean. By material properties we refer to any conservative or non-conservative state variables such as sea level, velocity, temperature, salinity, and nutrients. The overarching question regarding the variations in these and other coastal zone water properties is the relative importance between local and deep-ocean forcing. Here we define local forcing as the shelf-wide inputs of momentum (by winds and pressure) and buoyancy (by surface heat flux, evaporation minus precipitation, and river inflows). Similarly, deep-ocean forcing is defined as the momentum and buoyancy input at the shelf break by boundary currents, eddies, and tides. Along with these dynamically active forcing functions are the fluxes of dynamically passive materials (nutrients, plankton, fish larvae, etc.).

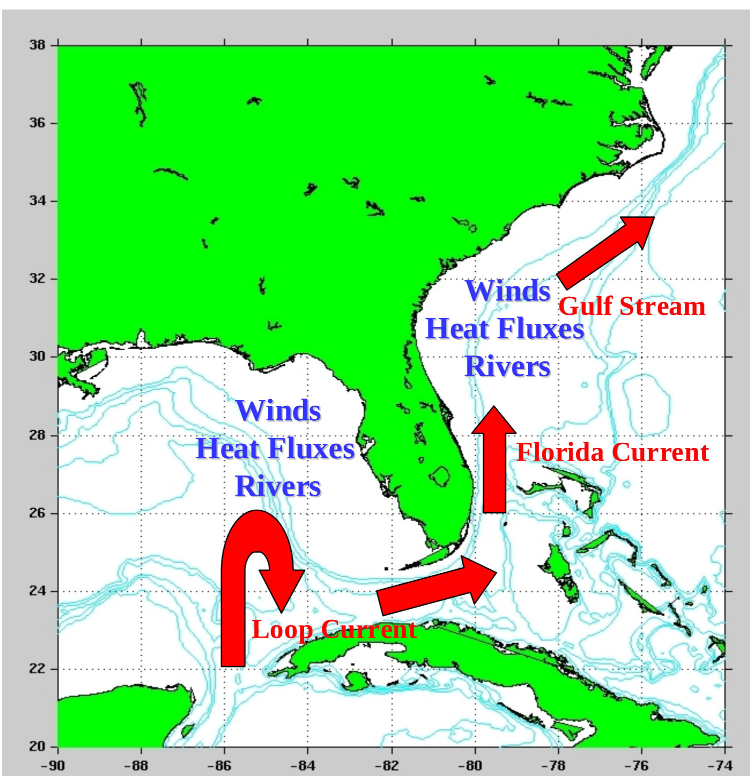

Figure 3. The coastal waters of the SEACOOS domain are linked by the Loop Current/Florida Current/Gulf Stream complex. Shelf waters respond strongly to atmospheric forcing by winds and air-sea fluxes and are also influenced by inputs from the Mississippi River and rivers of Appalachian origin.

A conceptual picture of these processes is shown in Figure 3 in our domain of concern.   The SEACOOS domain extends from the FL/AL border and the influence of the Mississippi River in the southwest to north of Cape Hatteras in the northeast. While the Florida peninsula may appear to divide the SEACOOS domain into two separate regions geographically, this is not the case oceanographically. Water properties within the SEACOOS domain are influenced by the Mississippi River, which drains the U.S. heartland, and by the rivers of Appalachian origin. Water properties are linked in the SEACOOS domain by the LC/FC/GS complex, that enters the Gulf of Mexico through the Yucatan Strait, flows around Florida through the Straits of Florida, follows the topography along the eastern seaboard, and separates from the coast at Cape Hatteras. The subregions are also linked atmospherically by regional-scale extra-tropical and tropical weather systems as noted above. This oceanographic linkage also influences the SEACOOS region's climate. Surface winds are derived from atmospheric pressure gradients and are influenced directly and indirectly by sea surface temperatures (SST). Except in summer, SEACOOS domain SST gradients are determined by the temperature contrasts between the relatively warm waters of the LC/FC/GS complex and cooler waters of the continental shelf. Moreover, the LC/FL/GS complex, especially in winter, is the Earth's region of maximum latent (and sensible) heat exchange between the ocean and the atmosphere. Winter storms that originate over the Gulf of Mexico are a major moisture source for the U.S. heartland and Nor'easters gain explosive intensity off the SAB coastline usually over these warm ocean waters (see the GALE special volume of JGR, 1989). Along with such extra-tropical weather in fall through spring, tropical weather systems in summer are also fueled by the relatively warm waters of the LC/FC/GS complex (Marks et al., 1998).

These regional linkages through rivers, western boundary currents, and weather patterns are further manifested by their local and deep-ocean forcing contributions to the continental shelf. The shelf has a broad variation in geometry that makes the SEACOOS region a natural laboratory for comparative studies on shelf dynamics and ecology. With the exception of DeSoto Canyon on the Florida Panhandle coast, the WFS is broad and gently sloping. This is in stark contrast to the very narrow EFS. Moving northward the shelf widens beyond Cape Canaveral to a secondary maximum off Georgia (Blake Plateau) and remains of moderate width along the SAB until narrowing off Cape Hatteras. These variations in the shelf width underscore the relative importance of deep-ocean versus local forcing along the length of the domain. Albeit overly simplified, the direct influence by western boundary current and eddy interactions is most pronounced where the shelf is narrowest, whereas local effects are most pronounced where the shelf is widest.

On the WFS we find that the interactions between local and deep-ocean forcing are complex. Because of rotational constraints, the Loop Current (LC) cannot simply override the shelf. Instead, LC interactions with the shelf topography cause material isopleths to rise up along the shelf break, and this makes it easier for local upwelling-favorable winds to bring cold, nutrient rich water of deep-ocean origin onto the shelf. Given that perturbations propagate cyclonically along the shelf break (Paluszkiewicz *et al.*, 1983; Vukovich and Maul, 1985), boundary current interactions do not have to occur locally to affect local material isopleth heights. Hetland et al. (1999) hypothesized that LC interactions occurring just west of the Dry Tortugas can affect currents over the entire WFS since isobaths converge there allowing the LC to contact shallow isobaths. Weisberg and He (2002) confirm this hypothesis and further explore the baroclinic consequences due to upwelling. Frictional effects of the surface and bottom Ekman layers are essential in overcoming the rotational constraint and permitting cross-shelf transport. The bottom Ekman layer is one of the primary conduits for cross-shelf transport (Weisberg et al., 2001), a consequence of both local and deep-ocean forcing.

The WFS and the EFS circulation processes are linked through the kinematics and dynamics of the LC and FC as part of seasonal to annual variations. Lee et al. (1992) found a gyre circulation along the inshore edge of the FC with scales of O(100 km) and a seasonal signal modulating biological activity along the reef tract of the Florida Keys. Surface wind variations between winter and summer seasons have a pronounced impact on the coastal ocean currents, including flow reverals associated with wind-driven coastal upwelling and downwelling events.

Frontal eddies and submesoscale vortices have been observed along the inner edge of the Florida Current (Lee and Mayer, 1977). Surface currents within a submesoscale vortex rotated cyclonically with the largest currents at a radius of about 1 km from the center. Over a period of about four hours, the vortex moved through the domain at an estimated translation speed of 30 cm s^{-1}, which is similar to spin-off eddies and submesoscale vortices observed by coastal HF radar-derived surface currents (Shay *et al.* 1998a). Horizontal current shears between the FC and the coastal current are quite large, which is a condition favorable for instabilities that could lead to the formation of the submesoscale eddies observed. Undoubtedly, these submesoscale eddies are a major source of mixing and dispersal on the EFS which must be characterized.

The shelf widens towards the SAB where the Blake Plateau separates the deep ocean from the coastal regime. The SAB shelf has been characterized as consisting of three shelf zones, or coastal ocean regimes (e.g., Atkinson et al., 1983; Lee et al., 1989): an inner shelf regime (<20 m depth) influenced by river discharge, often vertically stratified, and with a weak but persistent southward baroclinic flow; mid-shelf (20-40 m depth), being largely wind-forced, thermally stratified in spring and summer, and well-mixed in fall and winter; and outer shelf (>40 m to the shelf break), strongly influenced by the Gulf Stream and often stratified. The largest tides in the SEACOOS domain occur in the SAB, and exceed a 3m range on spring tides near Savannah, GA (Redfield, 1958). Tidal currents are the dominant source of current variance and at mid-shelf exhibit a pronounced sensitivity to seasonal stratification that likely impacts vertical mixing rates (Muglia et al, in prep). Over the shelf margin, cyclonic, cold-core eddies and meanders form along the onshore edge of the Gulf Stream between the Straits of Florida and about 30°N and again between 32°N and 34°N in regions favorable to barolinic instability. This brings cooler nutrient-rich waters onto the shelf, strongly influencing phytoplankton production (e.g., Lee et al. 1991). The onshore penetration of eddies depends on shelf hydrography, which is largely determined by seasonal atmospheric and hydrographic conditions (Weber and Blanton, 1980; Atkinson et al., 1983). The aperiodic meandering of the Gulf Stream necessitates time series observations to understand variability on the SAB shelf.

Further downstream, as the boundary current approaches Cape Hatteras, its net transport increases due to inflow from recirculation patterns to form the GS core where it separates from the coast (Johns et al., 1995). An important component to this flow is a southward-flowing current from the North Atlantic along the shelf and slope regions. Cooler, fresher water (more buoyant) associated with both coastally trapped, buoyant outflows from estuaries and rivers and this slope current interacts with warm, higher salinity tropical water to form filaments, rips, and eddies in the oceanic flows (Marmorino and Trump, 1994). In this domain, coastal surface current patterns from HF radar reveal a complex time-space continuum of flows across the North Carolina shelf including 3 to 7 day intrusions of the GS's North Wall. This is also a region of extra-tropical cyclogenesis during the winter months, which can form the Nor'easters that impact the weather in the MAB (Austin and Lentz, 1999).

1.2 Implications for system layout

The physical setting within the SEACOOS domain suggests overall design considerations for the observing system. There clearly is a need for ocean-side boundary conditions. This is particularly challenging for the SEACOOS domain because of the presence of the Loop Current - Florida Current - Gulf Stream system. Known variations in cross and along shelf transports dictate regular monitoring at the shelf-break, mid-shelf, inner shelf at a minimum; and the complex inshore waters, which support strong spatial gradients and are highly structured, will require significant investment to do well.

The monitoring will be accomplished through a combination of fixed and moving in-situ and remote sensing platforms. Fixed in-situ sampling platforms are expected to be the principal observing tool in the system's first implementation, and ideally the spacing between platforms is set by correlation scales of the dominant processes. To take advantage of existing infrastructure, however, SEACOOS has begun with an initial set of fixed platforms determined by the history of observing in the Southeast.

1.3 History of Observing in the Southeast– initial conditions for SEACOOS

SEACOOS began as a collaboration between existing subregional efforts and components of federal observing systems, each with its own design rationale. Though not ideal, this sets the starting point (initial conditions) for the system.

Main federal assets include the NDBC CMAN and buoy systems, the NOS NWLON, and USGS water resources monitoring network. The NDBC network provides relatively sparse but region-wide spatial coverage. Specific locations have been based on political priorities in some cases, and the positioning is driven by atmospheric criteria, not oceanographic. Each measures a number of meteorological parameters (wind speed and direction, air temperature and humidity, barometric pressure) with some measuring water temperature and scalar surface waves.

Figure 4 - Location of NOAA real-time coastal ocean asset locations

The NOS NWLON also provides sparse but region-wide coverage. Major ports are a focus of the network. All sites provide referenced water level measurements, and many include ancillary observations of some meteorological and/or oceanographic variables. Spacing is non-uniform and measurements in NE Florida as especially sparse.

USGS?

COMPS was initiated in 1997 with State of Florida support, and has since been maintained through a combination of research programs. The present state (as of September 2003) of the USF-maintained COMPS in-situ array is shown in Figure 5. Along with eight coastal stations for winds and sea level primarily we have six surface buoys that telemeter data in real time via GOES satellite and four either subsurface buoys or bottom mounted installations that record oceanographic data internally.

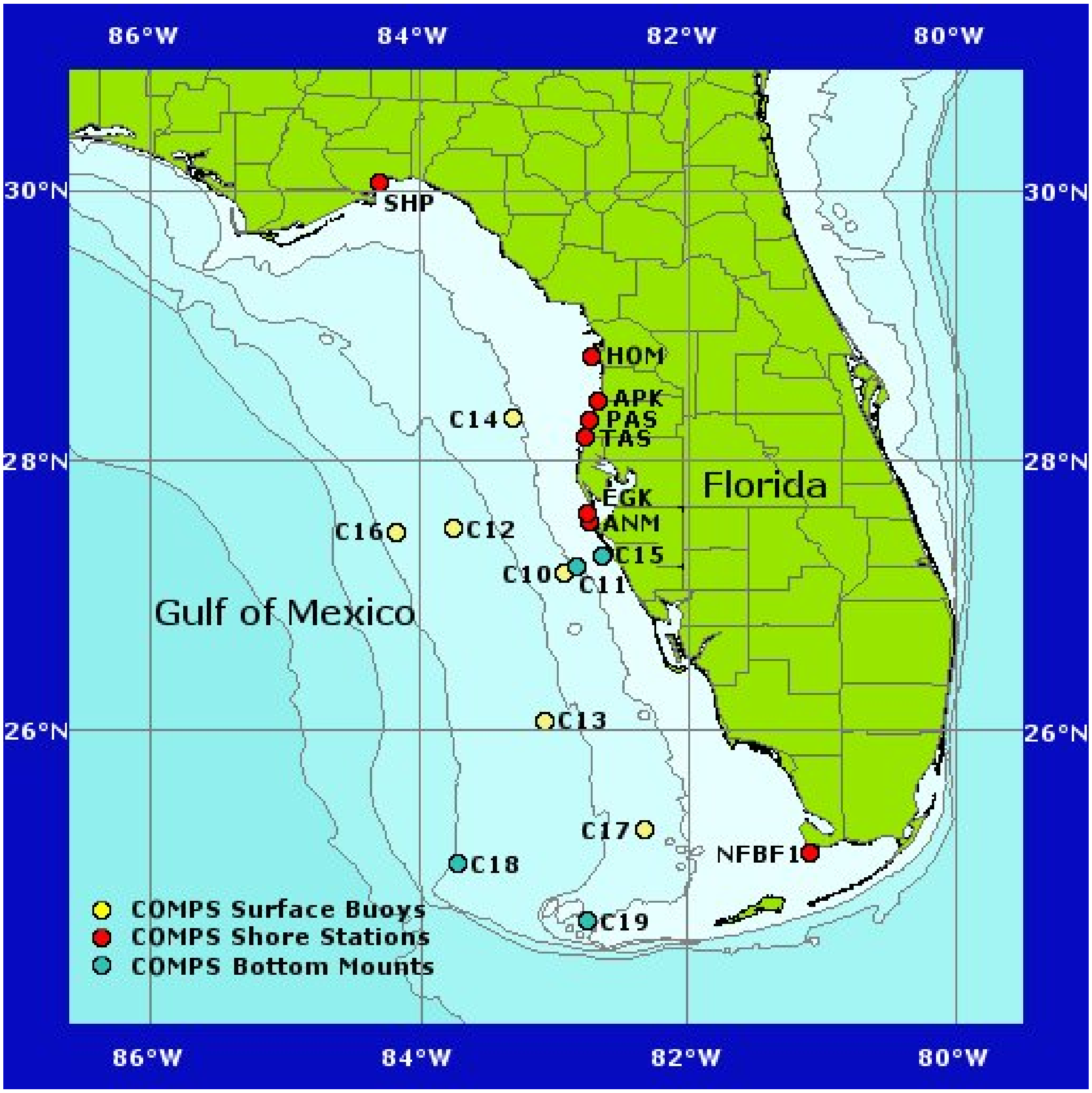

Figure 5 - locations of COMPS observing platforms

SABSOON began in 1998 as a NOPP-funded observatory effort. It was specifically designed to instrument the Navy towers off Georgia, and the engineering effort has remained focused on these systems. The facility is viewed as a high-end testbed because of the availability of high bandwidth communications and relatively large power supply.

Figure 6 - locations of SEACOOS partner fixed platform locations (need to update!)

1.4 Coupling of the Coastal Ocean to the Earth Observing System

It is critical to recognize that the ocean, atmosphere, watersheds, and seafloor are linked. Though we historically have treated these components as independent, they influence each other in significant ways. The nature of the interactions between components vary from simple, largely one-way influences (e.g., the impact of watersheds on coastal waters) to complicated two-way coupling (e.g., the influence of the winds on the surface wave field and the wave fields impact on friction in the marine boundary layer). We must strive to build a fully coupled Earth Observing System over time, recognizing that this is a goal which will take many years to realize.

1.5 Key elements

The observing system must include the ability to map ocean fields in three dimensions through time. This requires a combination of the synoptic view afforded by remotely sensed imagery, continuous in-situ observations, and numerical models to objectively fill the gaps between sparse interior observations. Nested models can be used to provide enhanced resolution in highly structured areas such as many nearshore and inshore areas, and where there are abrupt changes in topography. And, a robust information management/data management system is required to collate, exchange, display and archive the observations and model out generated.

1.6 Growth of the system to include the near-shore coastal zone

As an operational philosophy, SEACOOS considers it appropriate that the initial implementation first to links the coastal ocean regionally. The coastal ocean provides a principal connection between various inshore waters, is the vital outer boundary condition for inshore models, and lies at the interface between terrestrial and open ocean sources of materials. There are also a limited number of information providers in the coastal ocean, and pragmatically there are a manageable number of groups to coordinate as an initial organizational effort. It is considered straightforward to couple to the offshore, basin scale observing system, and this is occurring naturally as the system develops.

A concerted effort will be required to develop inshore capabilities. Adequate representation of the highly structured inshore environment is expected to require a much greater investment in infrastructure, and at present is beyond the scope of SEACOOS resources. However, there exist other inshore monitoring programs, e.g. the National Estuarine Research Reserve System, which may be adapted and enhanced to facilitate aggregation of data with SEACOOS, thus leveraging both systems for a more comprehensive coastal perspective.

1.7 Evolving scales of interest/responsibility

One of the uncertainties we now face is defining the spatial scale at which the observing system effort becomes a local responsibility. At present, SEACOOS does not have the resources to ensure adequate instrumentation and modeling for the extensive estuaries of the SE and the large number of individual beach communities in the region. It is not clear if and when, SEACOOS will be able to do so. Hence, there needs to be an agreement on the scales which the initial implementation will resolve.

Appendix 2

2.1 Roles within the evolving Regional Association

SEACOOS, as a largely academic consortium, views itself at present as having a science advisory role to the nascent Regional Association, SECOORA. The region needs scientific advice on many facets of the RCOOS, and SEACOOS has the capabilities to act in this fashion. This must include regular and ongoing evaluation of the system's ability to accurately answer specific scientific and user needs. Academia also has along history of Research & Development (R&D) activity and can also bring this expertise to the RA. Less clear is the role of SEACOOS in the routine operations and maintenance of the observing system, i.e. outside the obvious role of system evaluation.

A tremendous challenge faced in all applied science programs is the transition of skills and tools from research to operations. OceanUS has provided a framework for transitioning, which we adopt and refine for our purposes.

2.2 Definitions of research, pilot, and pre-operational projects and operational systems

An RCOOS will evolve over time as the breadth of topics it addresses increase, and technology advances, and as funding permits. Technologies and capabilities deemed appropriate as observing system elements, be they observational, data management, or modeling in focus, will necessarily transition from R&D to operational as they mature. The selection of elements will be an ongoing and iterative process, but we identify several stages of the transition process:

Research projects involve the exploratory development of new techniques and the application of new technologies to enable new understanding. These are vital elements to growth and evolution of the system.

Pilot projects repeatedly test promising techniques in the range of conditions present in the region. The intent is to identify strengths and weaknesses of the technique in an operational setting, and implement modifications as needed. Researchers should play a leading role in pilot projects but ideally will coordinate and work with system operators.

Pre-operational projects effect the transition from research to operations. Techniques are incorporated into the operational system to ensure that: the new technique does not compromise the existing operational system; that it significantly improves/advances existing capabilities (e.g. more cost effective); and that system operators have all necessary information to maintain the new technology. Operators should have the primary responsibility for these projects.

Operational systems are ones that are routine and sustained, and provide a regular stream of data or data products that satisfy an identified need. Clearly defined funding streams and budgets for all elements of the operational system are required. There shall be defined plans for maintenance and repairs of systems when problems occur.

2.3 Sectors

To be vital, Regional Coastal Ocean Observing Systems require the active participation of academia, government and industry. We view these three sectors has having largely complementary roles in the RCOOS, with some areas of collaborative and synergistic effort. Roles are most readily defined for a mature system; the challenge is in building towards this goal.

Academia: in the mature system the academic research community will play the central role in evaluation and evolution of the observing system. Academics will play a quasi- operational role during the developmental stages of a COOS when various components are being developed and tested for operational compliance. Their products are typically free and open and neither industrially nor militarily proprietary in a direct sense.

Industry: in the mature system the private sector will be one of the operators of the system or system components, infrastructure providers (of both goods, e.g., instrumentation, and services, e.g., information management), retailers of tailored products, and consumers of aggregated information (for internal consumption or to be repackaged for re-sale). Industry operators can be engaged as observing components successfully complete initial pilot studies, or collaborative pilot projects may be established to address specific development needs. The development of tools and applications, typical value-added products, will be done by both SEACOOS and the private sector. Recognition of the kinds of products appropriate for public access (SEACOOS products) will be achieved through ongoing and collaborative discussions among the sectors concerned.

Government: in the mature system, government will be a primary funding source, operator, user, and product provider, with an emphasis placed on health, environmental management, safety and emergency issues. There is a natural tension between government and industry roles in operation of the system, though on a regional scale, no one state government, nor the federal government, should have a controlling influence.

Appendix 3 - Development process

For a given observing subsystem, for which no operational capabilities now exist, an initial development process will be followed that entails:

Establishment of need: the system should satisfy an identified information requirement.

Assessment of existing capabilities is an involved process that will be tailored to each subsystem but at a minimum will:

1. develop an inventory of existing relevant measurements from all sources willing to contribute (federal assets, in particular, elements of the national backbone in the region, regional, subregional and state assets, and local assets);
2. aggregate the observations from the region;
3. engage users to establish best methods of information delivery;
4. make merged observations available via the portal;
5. inventory operational modeling capabilities;
6. assess model skill against existing observations;
7. display model output via the portal if appropriate; and
8. evaluate the accuracy and coverage of the measurements in the context of observing system needs (i.e., quality measurements where needed).

Responses/actions:
1) If observations are sufficient, of adequate quality, and verify that model accuracy is appropriate, display and distribution of the results is appropriate as an initial implementation.

2) If observations are insufficient to adequately evaluate existing modeling systems (if the model systems exists), initiate a regional enhancement. A decision on the nature of the enhancement is the responsibility of the observing working group. Use of testbed facilities to identify technologies best suited to enter pilot projects is highly recommended.

3) Initiate a modeling effort if the existing modeling capabilities are inadequate or do not exist. A decision on the nature of the enhancement is the responsibility of the modeling working group.

4) If sensing systems and/or modeling systems are not robust enough to enter a pilot program, SEACOOS will seek to initiate a research effort to identify and implement the needed systems. It is expected that these systems will either be approved for use in a pilot program or discontinued. It is essential that this process be integrated with the efforts of ORION (and NSF) and build from and/or take advantage of on-going testbed efforts, like ACT.

Development programs (cases 2-4): Once a program has been approved as a pilot, a process is needed to transition it to pre-operational status. This should involve mechanisms to provide continuous surveillance of products to identify failures if warranted/needed by the Regional Association.

Coastal Ocean Data Assimilation Experiments (CODAE): once a subsystem of observations and modeling is assembled and preliminary tests are complete, a CODAE should be conducted to provide a comprehensive test and evaluation of the system. This type of evaluation will occur for each subsystem after an initial pilot project and will be repeated as systems mature and evolve.

Appendix 4

4.1 Prioritization

A great challenge for developing observation systems is achieving a balance between needs and capabilities. We typically need information of a specific nature, e.g., predictions of the distributions of target fish species, concentration and spatial distribution over time of a harmful algal bloom, etc. This must be weighed against the ability of the oceanographic community to observe and/or model the required information. It is important to recognize that it is not practical for SEACOOS to approach all coastal issues at once. For example, some systems are needed to address multiple issues and our scientific understanding is advanced enough to intelligently develop a robust information system, whereas in other cases specialized systems are required to address a particular issue. We therefore must prioritize our development by balancing needs, practical abilities, and scientific input.

A thorough needs assessment for our region is a vast undertaking and not deemed the responsibility of SEACOOS; rather, we will work with SECOORA to develop the ultimate system for prioritizing observing system investment as the IOOS becomes a reality. In the meantime, we make the following observations:

a) The physical structure of the ocean and its circulation are required to address most near real-time coastal ocean information needs. This is borne out in the findings of a number of workshops on this subject. We can therefore justify the need for accurate prediction of sea level, currents, temperature, salinity, waves, winds, and atmospheric heat and water flux as part of the observing system.

b) There exist tested autonomous sensing systems readily available for observing most of the primary physical variables. The feasibility is high to transition these techniques to pre-operations because of their long history of use in research (or existing operational) systems.

c) Ocean circulation, surface gravity wave, and atmospheric circulation models exist and are of sufficient maturity to be formally tested against observations and operating in real-time to produce forecasts of these fields.

d) These fields provide critical information on chemical, biological and geological processes in the coastal ocean and applications within each of these disciplines can be developed through intelligent use of this component of the ecosystem observation and prediction system.

We therefore are pursuing an aggressive campaign to augment the existing observing systems and modeling system elements to provide regional physical state estimation. Details are provided in section III.

Because of the breadth of themes to be addressed with COOS, we must observe a great many other variables if the observing system is to satisfy most anticipated needs. Prioritization of these additional measurements is not a simple matter. As part of the Airlie House workshop [REFERENCE] the importance of variables was ranked according to their importance in addressing multiple themes (over 40 themes were identified). Which variables occur most often is not obvious, and the table of rankings can be surprising. Ideally a similar exercise will be repeated in coordination with SECOORA for our region to tailor the table to our regional needs. It is important to recognize that some of these variables will be highly correlated and may not require intensive monitoring.

Nevertheless, other factors become important in defining which variable or system should be given priority. An assessment of feasibility and impact of existing measurement systems is needed. For variables of similar value in addressing multiple needs, preference for initiation of pilot studies will be given to measurement systems with the greatest feasibility and impact. For variables without adequate observing systems consideration will be given to initiating a research effort.

4.2 User groups

Preliminary work by the E&E working group has made it clear that there are at least three classes of users: those who are accustomed to working with data streams and who are typically data product providers, such as the weather service, fisheries managers, and commercial shipping; more casual users of coastal ocean information, who typically are consumers of tailored data products that do not assume a high level of familiarity with oceanography or the coastal ocean; and the formal education community. We refer to the former as super-users, to distinguish them from other user groups, because they often have a voracious appetite for data and are savvy enough to utilize essentially raw observations and/or model output in the immediate future for practical applications.

It is vital to engage a broad range of user groups as quickly as possible to ensure that SECOORA and its RCOOS have a vocal constituency willing to advocate for its funding. Confronted with how to begin this process, we have decided that our best chance of quick engagement is through super-users. The super-users require minimal ongoing support, can utilize aggregated information products for the region in their most basic form, and have established user groups they already serve.

4.3 Link to national backbone and other RCOOS

As the IOOS is initially implemented, it is vital that its essential components, the national backbone and the RCOOSs, develop and maintain a high level of interoperability. For data and information flow, sets of standards must be established that enable data sharing among all components, and a common set of tools and applications will be needed to enable seamless data discovery, archiving, and transfer. This work has begun with the OceanUS DMAC plan and must continue. SECOORA and SEACOOS must make sure they are active participants in this process.

There must also be coordination on governance issues. Many federal agencies, regional councils, private industries and user groups have boundaries that do not align with those of the nascent regional associations. Our approach to these entities should promote ease of interaction. For some groups, affiliation with the National Federation of Regional Associations (NFRA) will be the most sensible form of coordination. How these organizational issues should be resolved is not obvious at present but they are essential to address in the near-term.