THE CAROLINAS COASTAL OCEAN OBSERVING AND PREDICTION SYSTEM (CARO-COOPS)

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SEMI-ANNUAL PROGRESS REPORT
June 1, 2003 – November 30, 2003

1. 0 Progress to Date

This report outlines accomplishments and progress towards stated objectives during the first 6 months of project year two. There have also been several adjustments in objectives, due to delays in deployment and unexpected shiptime and water level station installation and maintenance expenses. These changes are explained in section 2.5. Program progress is described in Sections 2 through 5. The original proposal Timeline is illustrated in Section 6, and the status of specific objectives as outlined in the original proposal Timeline is described in Section 7.

2.0 The Observing Subsystem

The Caro-COOPS observational network was originally conceived of and designed from two perspectives: one, what is understood of the marine meteorological and physical oceanographic processes affecting the marine and atmospheric weather of the system over all time scales; and two, what is the infrastructure necessary to measure the required oceanographic and meteorological parameters required for the predictive models and to transmit data in real-time to the communications network and data management subsystem. The major features of the array are as follows:

- The infrastructure consists of a mix of platforms and *in situ* sensors with real-time telemetry and is being developed in a manner that enhances and supplements existing in situ and remote coastal observing networks in the region, as appropriate.
- The sites for deployment have been determined on the basis of a) historical oceanographic and meteorological data on the hydrographic features, structures, and dynamics of the region; and b) the requirements for model development and definitive real-time validation of regional coastal ocean predictive skills.
- The initial set of measurements emphasizes those variables that are required for accurate and timely forecasts of coastal storms and flooding. A small biogeochemical component is included as an initial step towards linkage of physical processes with ecological response and to provide the foundation for future coupled forecasting.
- The system provides the spatial (horizontal and vertical) and temporal coverage that is necessary to detect changes on local to regional scales and to predict how larger scale changes are expressed at the local level.
- The system design is flexible such that it may be adapted to incorporate new information on the time-space scales of variability of important ocean processes and new technological capabilities and to meet new information needs of user groups.

2.1 Array Configuration

The operational area for the Caro-COOPS observing network extends from the coast of the Carolinas, offshore past the shelf break, which is located along the 100 m isobath, to depths up to

300 m. Here, the confluence of the tropical and sub-tropical oceanic, atmospheric and ecosystem domains influence a range of regionally based physical, biological, and geochemical phenomena.

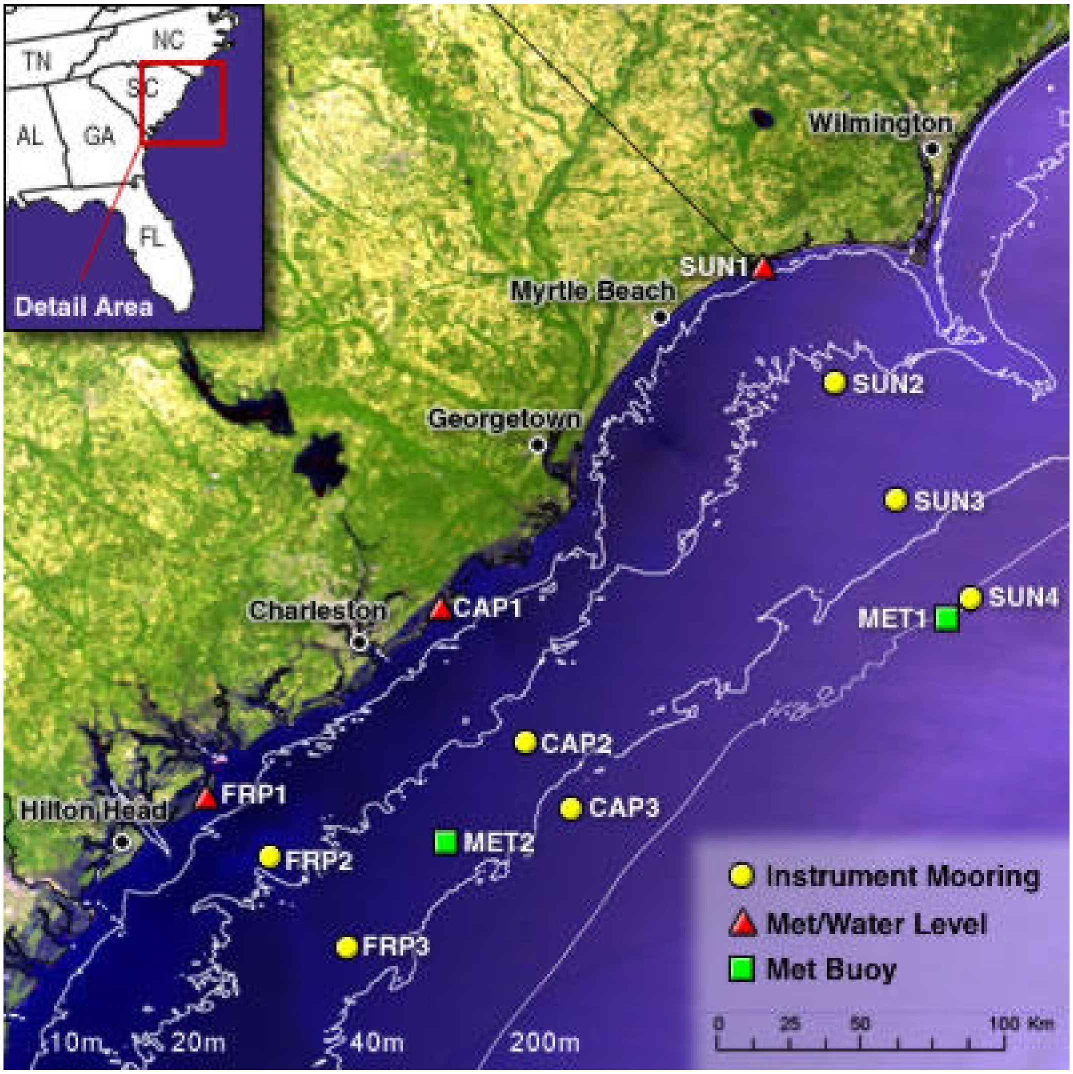

Figure 1. The Caro-COOPS (and CORMP overlap) Array, deployed in July/August 2003. Note the 3 cross-isobath "picket fences" extending out from Sunset Beach (SUN1-SUN4), Capers Island (CAP1-CAP3), and Fripp Island (FRP1-FRP3).

Monitoring and modeling are synergistic processes, and placement of the observation sites within this area and selection of the variables to be measured were based on the data requirements of the CEMEPS and on an understanding of observational sites critical for focusing on key oceanographic features and processes. Storm surge considerations in the initial demonstration project require both offshore and inshore observations to properly compute the spatial and temporal extent, structure, timing, and persistence of coastal and inland flooding, which ensues during the passage of a storm. For verification of predictive skills, one must validate the surge at the coast per se, the offshore ocean circulation, the spatial and temporal evolution of the wave-current fields, and the resulting inland inundation. In addition to reviewing the historical data, the

Caro-COOPS NCSU modeling group ran development models to give further input on the actual observing network design. Sites and instrumentation were chosen to establish upstream, downstream, and offshore volumetric fluxes through virtual picket fence boundaries, as well as input and output through the air/sea interface, for model validation.

The design of the observing system had to take into account logistical considerations, such as the availability of ships suitable for mooring deployment, and the practicalities of cost, since financial resources are limited. Thus, the initial phase consists of three cross-isobath "picket fences" of moorings, including a line beginning at Sunset Beach, NC and extending into Upper Long Bay, NC; a second line extending from Capers Island above Charleston Harbor, and a third line set north of Hilton Head Island, SC at Fripps Inlet (Figure 1). Conceptually, each line includes a shore-based water level / meteorological station (WLS) and offshore moorings located on the inner shelf (10 m isobath), mid-shelf (30 m), and upper slope (100+ m). The lines provide inputs and outputs for the model, i.e., along-isobath flow through cross-isobath lines. Also, meteorological buoys, placed within each of the two boxes formed by the mooring array, document air-sea interactions.

The design also underscores the goals to integrate Caro-COOPS within the overall framework of the US IOOS and to fill the large gaps that presently exist in the present federal and state observational networks in the Southeast US region. Currently, the NOAA National Data Buoy Center (NDBC) maintains four buoys off the NC/SC coast which provide hourly meteorological and sea state data. NDBC also has C-MAN meteorological observing systems at Duck, Diamond Shoals (off Cape Hatteras), Cape Lookout, and Frying Pan Shoals (off Cape Fear) in NC, and Folly Island in SC. Station data include barometric pressure, wind direction, speed and gust, and air temperature; the offshore C-MAN stations also measure and transmit hourly sea water temperature, sea level, and waves data. Caro-COOPS has also installed three water level and meteorological stations to augment the five long-term continuously operating National Water Level Observing Network (NWLON) water level stations in NC, and three stations in SC. The three Caro-COOPS stations doubled the number of sites between the Cape Fear River in NC and the mouth of the Savannah River in GA. The Caro-COOPS WLS were installed at historical NWLON sites, which will allow for the use of existing benchmarks for geo-leveling the Caro-COOPS stations. Caro-COOPS also will provide long-term time series of physical oceanographic data in support NOAA and South Carolina Department of Natural Resources (SC DNR) ship-based hydrographic and fisheries surveys.

The initial phase of the Caro-COOPS network also strengthens the complementary nature of the regional coastal ocean observing systems in the Southeast. The Caro-COOPS moorings in Upper Long Bay couple with moorings in Onslow Bay maintained by NCSU as part of UNCW's CORMP. Similarly, the Fripps Inlet line interfaces with the northern-most observing platforms of the South Atlantic Bight Synoptic Offshore Observational Network (SABSOON), operated by the Skidaway Institute of Oceanography.

As a final point, data from an *in situ* observing system is more powerful for ocean state estimation and ocean forecasts and prediction when integrated with remote sensing data from satellites and aircraft. Sea surface temperature satellite images (AVHRR) and high resolution (~1 km nadir) ocean color imagery from the NASA Sea-viewing Wide Field-of-view Sensor (SeaWiFS) for the Southeast region will be routinely collected as part of the Caro-COOPS observational system.

2. 2 Core Variables

The initial set of variables that must be measured and assimilated in real time include sea level, water temperature and salinity, vector currents, surface waves, air temperature, barometric pressure, and winds. In addition to these variables, the design includes measurements of chlorophyll fluorescence at all of the 30-m and 100+-m sites at 10 m below the surface, and dissolved inorganic nutrients (NO_3^- and Br^-) at 10 m depth at one of the deep water moorings. Details on measurements, instrumentation, and mooring locations are provided in Appendix 1.

2. 3 Implementation of the Observational Network

Deployment of the initial elements of the *in situ* observing subsystem was completed in August 2003, including:

- The Sunset Beach line, consisting of a WLS on the Sunset Beach Pier, moorings at 10 m and 30 m, and a deep water mooring at 225 m depth to monitor the inshore edge of the Gulf Stream;
- The Charleston Harbor line, consisting of a WLS on south Capers Island and moorings at 10m and 30m;
- The Fripps Inlet line, which includes a WLS on the Hunting Island SC State Park Pier and moorings at 10m and 30m; and
- Two (2) meteorological buoys.

The positions of the main array are shown in Figure 1. Additionally, current meters were deployed at sites in the Wando, Cooper, and Ashley Rivers to determine if a two-layer current flow occurs in the river tributaries upstream of Charleston Harbor.

The suite of instrumentation (Appendix 1) includes bottom mounted, upward looking RD Instruments, Inc. Acoustic Doppler Current Profilers, up-fitted to measure waves, at all 10 m and 30 m mooring sites. A mix of Seabird Electronics, Inc. Microcat (salinity and temperature) and Seacat recorders (salinity, temperature, and pressure), interfaced with Chelsea Instruments Aquatracka III fluorometers, are attached to the taut wire moorings at the 30 m and deepwater sites. An MBARI-ISUS in situ nutrient analyzer was mounted on the outermost Sunset Beach line mooring. The meteorological buoys are the Aanderaa Coastal Monitoring Buoy CMB4280, which measures average and maximum (gusts) wind speed, wind direction, barometric pressure, relative humidity, solar and sky radiation, and air and water temperature.

The Caro-COOPS WLSs are Sutron Corporation NOS G3 Water Level Stations, equipped with primary and backup water level sensors and ancillary sensors to measure oceanographic and meteorological variables, in addition to water levels. Installation and operation of the Caro-COOPS stations meet NOAA standards, and the Caro-COOPS data are included in the national database.

The primary vessel for marine operations was the SC DNR *R/V Palmetto*, although the *R/V Cape Hatteras* was employed for the Sunset Beach line deployment (see also Section 2.5). Cruises are scheduled at approximately 6-month intervals for deploying, recovering, and servicing the Caro-COOPS moorings.

2. 4 Data Telemetry

All components of the observational array are outfitted for the real-time telemetry of data which represents a significant advancement in regional observation systems. Our team is currently investigating and addressing issues of data collection and telemetry which are unique to each of these system subtypes.

Our three pier-based water level stations represent a collaborative effort between Caro-COOPS and NOAA's National Water Level Observation Network (NWLON). Data collected at each of these stations are transmitted to the NWLON via the GOES satellite where the data undergo NWLON's quality assurance / quality control (QA/QC) process. QA/QC'd water level and meteorological data are then made available to Caro-COOPS. Currently two of the three water level stations are collecting and transmitting data, and we are working with NWLON to bring the station at Sunset Beach to operational status.

Our offshore ADCP moorings power on every six hours for 2.0 minutes to transmit data via the Iridium satellite system back to a receiving modem housed at the University of South Carolina. The Iridium system has the advantage that it provides two-way communications, as opposed to a one-way system, such as GOES or ARGOS. The opportunity to utilize the Iridium system is a result of collaborative efforts between Caro-COOPS, the Department of Defense, and the Southeast Atlantic Coastal Ocean Observing System (SEA-COOS) initiative.

As is to be encountered with the deployment of sophisticated data collection and transmission systems in the harsh oceanic environment, our Caro-COOPS offshore observational array has experienced both success and problems with data collection and transmission. Although the Iridium system is designed to provide for pole-to-pole, round-the-clock coverage we have experienced dropouts and missed connections sporadically. Although it is difficult this early in our project to explain the reasons for these interruptions in data flow, the geometry of the Iridium satellite constellation and/or remote unit geography may be contributing factors. As compared to wired and wireless data transmission rates, the Iridium data transmission rates are low with an effective baud rate of 2400 and a working baud rate usually lower. For real-time data transmission, low data transmission rates limit the amount of information transfer over a given period of time thereby limiting the complexity and density of the instrumentation on our buoy systems. The limited baud rate also affects the type of real-time data that can be transmitted; for example, wave height and other wave products are too large (in file size) and cannot be transmitted. We anticipate that this data transfer rate can be increased via improvements in data telemetry rates and and/or improvements in compression processes within the dataloggers.

Another issue that we are dealing with on the ADCP moorings is clock drift on the Zeno datalogger. This drift is approximately one second per day. To address this issue we are working on an automated procedure that utilizes the two-way communication capabilities of the Iridium system to correct the datalogger clock drift.

Currently three of our deployed buoyed systems are fully operational in terms of the collection and transmission of data. Observational data received from the ADCP moorings along the Sunset Beach line are flat-lining at erroneous values for several observations following the passage of Hurricane Isabel suggesting the early fall storm may have damaged the instrumentation along this line. This will be rectified during our scheduled turnaround in late January.

For the two offshore meteorological packages, collected data are transmitted via the Orbcomm satellite system and the data are forwarded to us via e-mail. Following initial deployment this summer, both meteorological stations were operationally collecting and transmitting data. Since early September though, neither of the meteorological buoys have been operational, and we plan to rectify this by installing the meteorological instrumentation on our mooring design.

The first opportunity to service the buoys is scheduled for January/February 2004 during which time we will be able to address issues that can only be addressed on location. Planned servicing currently includes increasing from 2.0 minutes to 2.5 or 3.0 minutes the amount of time allocated for communications and data telemetry, thereby easing some of the latency effects during data transmission.

2.5 Modifications in the Array Implementation

Some modifications have been made in our plans for implementation of the array this project year. To a large extent, these modifications were made necessary by unavoidable delays in the initial deployment and some unanticipated substantial extra costs. One major cost was ship time on the *R/V Hatteras*. When we were due to deploy the moorings in the summer, the *R/V Palmetto*, which we had planned to use, developed a mechanical problem and was unavailable. We judged it was essential that we deployed as soon as possible and before the hurricane season, so we decided to use the *R/V Hatteras*, which was available but more costly. In the meantime, the costs for the *R/V Palmetto* have also increased, so ship time will be an increasing burden on the budget. The other major additional cost was required for installation and maintenance of the three new coastal water level stations. These costs were not apparent in our initial discussions with CO-OPS, but they are clearly a necessary element of implementing the NWLON component. We have also realized the need to support more technician time for the moorings and water level stations; these increases are in the NCSU budget. To offset these additional costs, we have made the followed changes: deferred installation of the water level station at Riseley Pier, deferred implementation of the two 200-m moorings, and made a small reduction in time for one research associate at USC. We will also defer the summer turn around and maintenance of moorings until July, i.e. the next project year. Funds for the SC DNR subcontract will also be reduced because of the reduction in time required for the *R/V Palmetto*. These budget changes are provided in Appendix 2.

3.0 The Data Communications and Information Management Subsystem

The Data Communications and Information Management subsystem comprises three primary components: (1) the reception, management and transfer of observation data, (2) delivery of quality controlled data, metadata and data products to a Web-based data and information portal providing access to a broad user base, and (3) design of user-friendly tools and information products for model output. A comprehensive plan has been implemented for data input and output, data archival, data documentation, and data and product dissemination that includes the following components:

- Offshore and shore-based data collection with near real-time data transmission via the low-orbit Iridium satellite cellular communications system, the Orbcomm low-orbit satellite communication system, and NOAA’s Geostationary Operational Environmental Satellites (GOES).
- Data collection from federal agencies to facilitate data parameterization for modeling and product generation.
- Archival within a relational database management system for near-real time display and permanent storage in the netCDF file format.
- Access to data via Distributed Oceanographic Data System (DODS) / OPenDAP.
- Access to data and derived products will be available to the public and research community via a Web-based data and information portal.

- Enhanced Federal Geographic Data Committee (FGDC) metadata development, search and query utilities.
- Management tools allowing users to generate GIS-based products over the Internet.

3.1 Maintain and Enhance Techniques for Data Assimilation, Processing and Product Output

Our approach for data assimilation, processing, and product output is centered on the use of relational databases as a normalizing intermediary between diverse dataset types and formats from which we can build immediate analysis products with a focus on near real-time data. We are cognizant of, and compliant with, the recommendations emerging from the IOOS DMAC, while also working to address anticipated needs and those encountered within the Caro-COOPS operation. We are also working closely with SEA-COOS, CORMP, and the Gulf of Maine Ocean Observing System (GoMOOS) to ensure an infrastructure that accommodates a broad and diverse set of data bases. Multiple data types are currently being stored in the Caro-COOPS relational database including near real-time data from our observational array (termed *primary data*), and relevant data obtained from Federal and state websites, existing geologic and historical publications, and academic institutions (termed *ancillary data*; Figs. 2a,b).

As an example, "screen scraping" techniques are used to capture Caro-COOPS water level data from the NWLON website and imported into our database using developed program scripts.

We are also utilizing Geographic Information System (GIS) technology to import geographically-referenced datasets into our database. Other tools and tables are being developed to accommodate new datasets from users where the data format is unique but needs to be described and linked to our existing database and tools. It is important to assimilate and provide information in a variety of formats, such as column oriented text, netCDF, HDF and XML using data conventions or standards to help facilitate our needs and the needs of the modeling groups we interact with where possible. NetCDF file conventions are being detailed to support model input interpolation by describing in detail the resolution and availability of data in regards to both temporal and spatial domains.

3.2 Enrich Existing Models with Higher Quality and/or Additional Inputs and Products

The current storm inundation modeling efforts of Caro-COOPS using the CEMEPS have been based on 3-arc-second Digital Elevation Models (DEM) available from National Geophysical Data Center (NGDC). This is a 90m x 90m model grid. We plan to increase the spatial resolution of the model input and output to increase the accuracy of the model and result in a better visual output/product. Current efforts focus on the development of a 30m x 30m model grid for the Charleston, SC area. We are also exploring the possibility of accessing a higher resolution data set for Beaufort County, SC through a contact at the US Army Corps of Engineers (CoE). The CoE, Charleston District has produced a high-resolution model grid generated from LIDAR and merged this with high-resolution bathymetric data for Beaufort County modeling efforts.

The use of OpenGIS Consortium (OGC) Web Mapping Service (WMS) standards are also being explored to determine potential benefits to providing an easy way to exchange map-based information between community GIS systems. This effort is integrated with SEA-COOS activities.

Figure 2a. Current Caro-COOPS Primary Data.

NWLON water level stations (3)
- Water level
- Water temperature
- Air pressure
- Air temperature
- Wind speed/gust/direction

10m stations (3)

PCAT (bottom)
- Temperature
- Salinity
- Conductivity
- Pressure

ADCP (bottom, 10 bins with current and direction)

30m stations (3)

FCAT (top)
- Temperature
- Salinity
- Conductivity
- Pressure
- Voltage

PCAT (bottom)
- Temperature
- Salinity
- Conductivity
- Pressure

ADCP (bottom, 10 bins with current and direction)

200m station (1)

FCAT (top)
- Temperature
- Salinity
- Conductivity
- Pressure
- Voltage

ADCP (top, 10 bins with current and direction)

NUTS

UCAT
- Temperature
- Conductivity
- Pressure

Meteorological stations (2)
- Wind speed/gust/direction
- Air temperature
- Air pressure
- Relative humidity
- Solar radiation
- Water temperature at 1m
- Water temperature at 4m

Figure 2b. Examples of Caro-COOPS-Associated Ancillary Data

Bathymetry / topography
NGDC DEM
River discharge
USGS
Winds
NOAA National Hurricane Center
NOAA National Weather Service
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3.3 Maintain and Enhance QA/QC Procedures

The operational extent and diversity of the Caro-COOPS observation network has resulted in a challenging environment for Quality Assurance/Quality Control (QA/QC). There is a diverse and wide-ranging scale of QA/QC categories/types identified as relevant to Caro-COOPS data:

1. QA/QC that is performed on the data as they are collected by the instruments.
2. QA/QC documentation that details an instrument calibration and maintenance procedures.
3. Organizational QA/QC: the process where the National Water Level Observation Network (NWLON) returns the water level/meteorological data from Sunset Beach Pier, NC, Capers Island, SC and Fripp Inlet, SC data to Caro-COOPS with the data already processed for QA/QC by NWLON.
4. Regional QA/QC: the process by which data is assessed by examining the measured parameter range against the known or expected environmental range for a geographic region in which the instrument is deployed.
5. Feedback QA/QC: the process by which data is assessed based on the previous running history of the deployed instrumentation and known ranges for the measured parameters.
6. Instrumentation QA/QC: the process where the instrument itself may filter collected data or provide acceptable or recommended ranges for collected data.

Caro-COOPS QA/QC efforts will focus on QA/QC down to the "Instrumentation QA/QC" level. Our current QA/QC efforts are utilizing range limits as outlined in #6 above. The Caro-COOPS QA/QC procedure is a step process whereby parameters are checked and then flagged when outside of acceptable range limits or are missing. We are currently developing a step process for automated QA/QC measurements similar in scope and function as those of the NOAA National Data Buoy Center (NDBC). The automated QA/QC will be initiated following data download from the Iridium satellite and e-mailed data downloads from Orbcomm and is planned to entail the following step process:

1. Raw data are checked for errors as a result of truncated or other transmission errors.
2. Range checks will compare a measurement with a pre-established upper and lower limit.
3. Time continuity will track the change over time of a particular variable.

The use of flags will be continually updated and initiated in Caro-COOPS QA/QC procedures. Currently we are investigating the use multiple flag types to document erroneous measurements during the automated QA/QC processes. Following the guidelines as specified by the NDBC, a "hard flag" will indicate that the data are highly suspect and should be removed from the data record, while a "soft flag" will indicate that the data are suspect and should be reviewed. Initial "raw" data are never deleted from the system.

3.4 Enhance Data Documentation Tools and Techniques

Caro-COOPS is currently developing a metadata editing tool set to be incorporated with a data upload "wizard". Although the data upload wizard is not particularly suited for automated data collection operations, the use of such a tool is being designed to meet the needs of in situ data collections. This tool will initially be a Web-enabled metadata editor based on the model developed by Cast-Net (www.cast-net.org), a multi-state initiative spear-headed by USC and funded by NSF and the Southeastern Universities Research Association (SURA). It will be a key component to all Caro-COOPS data management activities as it will allow for the development of FGDC-compliant metadata records central to data management initiatives. This metadata editor will optimize data documentation entry efforts by enabling users to generate and use their own specific templates. Development of the metadata editor is ongoing and we expect a beta product in the next few months. When sufficiently developed, the tool will be made generally available to the data management community.

The importance of metadata development within Caro-COOPS cannot be overstated as metadata will be a key component for the information management subsystem. Metadata will form the foundation of all data management activities and will be integrated with all scientific data sets. Our current efforts are focused on the assimilation of various metadata standards including: (1) Federal Geographic Data Committee approved Content Standard for Digital Geospatial Metadata (FGDC-STD-001-1998) (CSDGM) that is the primary standard for the description of spatial data and is federally mandated, (2) Ecological Metadata language (EML), and (3) SensorML. Each one of these metadata standards will facilitate program documentation and data discovery in addition to increasing administrative efficiency. The key operational areas that will be supported by these metadata standards include observational data (both current buoy and future in situ and remotely sensed collections), instrumentation, methods, and QA/QC.

We have also been providing assistance to CORMP with their data management needs. Members of our staff have visited UNC-W, met with their data producers, and provided advice and guidance on procedures and processes. We also plan to manage their real time data streams within the Caro-COOPS data management system.

3.5 Develop Products and Web Access for the User Community

The model outputs described in Section 2.2.1.2 have been used to develop a demonstration version of an interactive flooding risk assessment system. Our initial goal is to produce user-friendly tools that are designed for optimal use by emergency response managers.

The demonstration version (www.carocoops.org/documents/presentations/surge_demo_files/frame.htm) was presented to emergency management officials in Charleston County, SC in July 2003 to gain preliminary feedback regarding the system's design and potential value; meetings are also planned to develop partnerships with state-level emergency management officials.

The Caro-COOPS website (www.carocoops.org) is the centralized presence or hub for accessing Caro-COOPS data, metadata and developed products. The website was first established during Year 1 of the project. It was considerably expanded and updated in mid-December, and access to real time data was "switched on" for those sites providing reliable data. The Caro-COOPS website provides information concerning the design of the observational array, instrumentation, demonstration products (e.g. the integrated storm surge model demonstration), and news and updates. IOOS-supported data access tools such as DODS and the Live Access Server (LAS), as well as mapping software have been implemented within the Caro-COOPS website. The site also provides an opportunity for interested parties to subscribe to a dedicated Caro-COOPS e-mail list.

4.0 The Modeling and Applications Subsystem

The coastal atmospheric and oceanic modeling group at NCSU has developed an adaptable Coastal and Estuarine Marine and Environment Prediction System (CEMEPS), which is being used as the backbone model for Caro-COOPS. The architecture of the CEMEPS consists of the optimal mix (yet to be determined) of data acquisition, data assimilation, numerical modeling, and application modules. The numerical modeling module contains a suite of interactively linked atmospheric, oceanic, estuary, and river model components.

The atmospheric component of CEMEPS currently includes the choice of: (1) the Advanced Regional Prediction System (ARPS, Xue et al., 1995), a mesoscale weather forecast model developed at the University of Oklahoma; (2) a dynamic or parametric hurricane model (such as the GFDL hurricane model and the Holland hurricane wind model, Holland, 1980); (3) real-time wind analysis; and (4) the optimal combination of real-time wind analysis and a parametric hurricane model. Additional mesoscale weather forecast models, including the NCEP Eta Model, the UO Advanced Regional Prediction Model (ARP), the PSU Mesoscale Model version 5 (MM5), and the Weather Research and Forecasting model (WRF), have been added to the choice of atmospheric models. NASA NSCAT winds and NOAA's NWS precipitation data will also be obtained and applied as forcing to the model. The complete atmospheric module provides wind and pressure forcing for the storm surge model and the wave model.

The oceanic modeling component is a coupled wave-current-tide simulation system, consisting principally of the Princeton University Ocean Model (POM) that is interactively coupled to a third generation wave model called WAM Cycle4 (Xie et al., 2001) and an inundation modeling program (Peng et al., 2002). A shallow water wave model using an improved coupling formulation developed by Guan et al. (2001) is being incorporated into the wave-current coupled modeling system for the entire coastal region of South Atlantic Bight. Tides are simulated via specified lateral boundary conditions that contain tidal information. Topex-Poseidon Altimeter data can also be ported into the model as appropriate. The output from the oceanic module includes a distribution map of storm surge elevation and inundation, surface and subsurface current fields, significant wave height and frequency fields, and tidal elevation and currents. These model data are provided as input to application modules.

4.1 Validation of the Model Offshore Component

An essential requirement is validation of the offshore component of the model, including the current and wave fields at the locations and depths of our observations throughout the array under different forcing conditions. Simultaneously, we will calculate volumetric fluxes between the coastal water level stations, the 10 m moorings, and the 30 m moorings. These calculations are complicated by the variations in the alignment of the local topography, i.e., the bathymetry and the coastline. Because coastal flows are predominantly alongshore, if the assumption of what is truly alongshore or "parabathic," and what is truly offshore or "diabathic," is incorrect by only several degrees, it can result in miscalculations of on vs. an offshore flow or vice-versa. This mistake is sufficient to produce faulty model calculations, problematic model validations, and most seriously, incorrect model initializations. This is also critical to the validation of the wave field output in general and the shallow water wave field in particular. The solution is to ensure that we have the highest resolution bathymetric and topographic data sets and that we perform very careful kinematical descriptor analyses of the data collected at the various observational sites to determine the principal axes of flow at each and every site.

4.2 Storm Surge Validation

The CEMEPS modeling system has been configured for the offshore region of the Caro-COOPS study domain with a uniform grid size of 2km. Model validation began with the hind-casting of the offshore storm surge produced by Hurricane Hugo, one of the strongest hurricanes to hit South Carolina. We have conducted comparisons between the observed peak surges at all offshore gauge locations within the Caro-COOPS domain vs. the model-predicted peak surges at these same locations. There is very close agreement between the model results and the observations. The volumetric flux equations have been set up in keeping with the previous work of Pietrafesa and colleagues in the Caro-COOPS domain and will be implemented during the latter half of this project year.

4.3 Surface Wave Validation Using Existing Models

We have configured both the U.S. Navy's Shallow Wave Action or SWAN (Version III) model with the NOAA WaveWatch (Version III) model for the Caro-COOPS study region and validated both models separately against wave data collected at regional to local NOAA meteorological buoys during the passages of several historical hurricanes (namely, Fran, 1996, Bonnie, 1998, Floyd 1999 and Isabel, 2003). The NOAA WaveWatch III model is shown to work well in waters deeper than ~ 40 meters, while the Navy's SWAN III model is shown to work well in waters of all depths, particularly those in waters less than ~ 30 meters in depth. However, while WaveWatch is not very computationally demanding, SWAN is. Given that much of the Caro-COOPS continental margin region is shallow (< 40m), SWAN must be utilized along with WaveWatch for proper modeling of the wave field.

4.4 Coastal, Estuary, Harbor, and Inland Model Validation

A nested CEMEPS modeling system was configured to include both the offshore and estuary regions of the Charleston Harbor domain with a uniform grid size of 2km for the offshore domain, 300m in the near-shore zone and 80-m grid size within the harbor. Model validation began with the hind-casting of the coupled coastal, estuary, harbor storm surges produced by Hurricane Hugo. and model simulated results show good comparisons with observed peak surges at all gauge locations within the Charleston Harbor domain. There is especially close agreement between the model results and the observations in the outer portions of the harbor with agreement becoming attenuated towards the zones of connection between the harbor and the river tributaries, the Ashley, Cooper and Wando. To address the interactions of the harbor with the rivers, the rivers have been instrumented with near surface and near bottom doublets of current meters. These data have been collected every 20 minutes for 9 months to date and are being processed for evaluation. The responses of the three rivers separately and collectively to a variety of atmospheric wind, pressure, and precipitation events will be determined and then the river effects will be introduced to the harbor model in an interactively coupled manner. Thus it is anticipated that the agreement between the model output and the observed surges will be improved. Validation has also been carried out on the areas of flooding caused by Hurricane Hugo. Again, the inundation comparisons are expected to improve once the effects of the rivers and precipitation have been accounted for.

We were provided with a valuable opportunity to test the nested storm surge modeling system with the approach of Hurricane Isabel in September 2003. The system was used, in real time, during the passage of Isabel for the North Carolina coastal region, lower Virginia, and the Pamlico-Albemarle Sound system and showed significant advantages over the traditional two-dimensional storm surge model used by the NOAA National Weather Service's Meteorology Technology Development Lab and National Hurricane Center. The model output was included on the Ocean.US and NOAA Coastal Services Center web sites during and after the event.

The recruitment of a data assimilation post-doc at NCSU has been deferred until delivery of real time data is more consistent.

5.0 Demonstration Projects

5.1 Coastal and Inland Flooding Prediction

A major driving force for the development of Caro-COOPS is the generation of products that serve the user community. The first demonstration project we identified was the development of a real-time prognostic capability to predict coastal flooding during the passages of high-energy atmospheric events such as Tropical Cyclones (TCs) and Extra-Tropical Cyclones (ETCs).

Preliminary validation of the modeling system for the Charleston Harbor region has been conducted. A real-time prognostic capability to predict coastal flooding has been established for Tropical Cyclones and Extra-Tropical Cyclones for the Charleston Harbor region at high spatial resolution (80-m grid) and for the entire Caro-Coops region at 2-km grid resolution.

In addition to building the real-time capability, three demonstration projects have been completed and are described in the following sections.

5.1.1 Hurricane Hugo Hindcast

The hurricane struck the South Carolina coast to the north of Charleston over the period September 20-23, 1989 and caused not only considerable wind but also massive water damage to the city and surrounding areas. As proposed, for computational efficiency, and for much greater accuracy but also for GIS overlays, we have developed a nested model architecture. An animation of the offshore surge and an animation of the surge in Charleston Harbor proper and adjacent areas have also been developed. Our CEMEPS model output can be compared to that of the NOAA/NWS SLOSH model and shows the superior guidance that CEMEPS provides over SLOSH. Greater spatial resolution and temporal accuracy is demonstrated allowing for more accurate advanced warnings of the timing and levels of surge and flood inundation as well as flood retreat. This capability will enable WFO forecasters and emergency managers to have much more detailed, precise, and advanced warnings than they do from present intra-agency sources. Our goal is to provide the tools to enable better planning and phasing of flood related evacuation and save time, personal property, and most importantly, lives.

5.1.2 Hurricane Hugo GIS application

An example of the utility of the CEMEPS model inundation output is the overlay of model output on a rectified aerial photograph of the Charleston downtown area. This merging has been depicted in an animation. The accuracy of the model inundation is yet to be determined because of issues related to properly merging the model output with GIS, but any discrepancies between the model overlay and the GIS map will be resolved. This product demonstrates the utility and promise of this advanced operational forecast tool. (See also Section 3.5).

5.1.3 Hurricane Isabel Predictions

Isabel approached the middle portion of the US Eastern Seaboard 17-19 September, 2003. Isabel achieved Category 5 status while in the central SE Atlantic but declined in intensity beginning on 14 September. By the time that the eye made landfall at ~ 1:00 PM on the 18th, at Ocracoke, NC, the event had downgraded significantly to a Category 2 to 1. While Isabel was not an especially wet event, with precipitation estimates of 1-7 inches, it caused significant storm surge flooding. At the request of the NWS Raleigh and Morehead Forecast Offices, the NCSU CEMEPS team began participating in the forecast activities of Hurricane Isabel on September 12. A special website (http://dell01-112res3.meas.ncsu.edu/CFDL/) for Isabel was setup and made available to the NWS Forecast Offices on Monday September 15. This site was then linked with USC Caro-COOPS, Ocean.US, and NOAA Coastal Services Center web sites for greater community dissemination. Ensemble simulations began on Saturday September 13. The results from the ensemble simulations, including a map of flooding probability in the Pamlico-Albemarle Sound system and storm surge animation for the official forecast track, were posted on the websites on Monday September 15, four days prior to the storm making landfall. When the track and intensity of the storm became better defined, the model was run again with both ensemble forecasts and deterministic forecasts. The forecasts were updated twice a day and put on the websites for general access. Initial feedback from NWS WFO forecasters indicate that the products provided by the model were very accurate and added considerable value to the suite of forecast guidance products available to them routinely.

5.2 Fisheries Resource Management

The Caro-COOPS team has targeted fisheries resources as the subject area for the next product development. Our approach is to work with the fisheries community to identify priority needs that can be addressed by Caro-COOPS. Our intention is to work interactively with a representative group from the community to identify specific products that can be developed from the Caro-COOPS program output. The identification of these specific objectives, in turn, will influence future planning for the observation array and model development, as well as identification of potential linkages and partners. We have already been working with the South Carolina Department of Natural Resources and discussing ways in which Caro-COOPS can augment their ongoing fisheries research and monitoring efforts, with a view towards developing collaborative work within the Caro-COOPS framework.

As part of the effort to take the information being derived from the Caro-COOPS array and create useful information products for the fisheries community, Caro-COOPS hosted a workshop on October 2-3, 2003, in Charleston, S.C. (see Appendix 3 for agenda). Attending the workshop were a wide variety of representatives from the fisheries industry, fisheries experts, and resource managers from the South Atlantic area. Attending also were the principals and scientific and technical staff from the Caro- COOPS project and collaborators with expertise particularly relevant to fisheries. In addition to those attending, some additional interviews have been scheduled to meet with segments of the fisheries industry which could not send participants to the workshop.

The purpose of the meeting was to brief the fisheries community participants (including recreational, commercial and environmental interests) regarding the kinds of information and data available from the Caro-COOPS array, and hear directly from them specific recommendations as to: (l.) What might be of importance to their community, whether currently available from the Caro-COOPS array or potentially available in the future; (2) What format is most useful to provide such information; and (3) What communication means should be used to make the information or data available. The meeting was designed to be an informal but highly focused think-tank exercise and was facilitated by Deborah J. Stirling and Dr. John Mark Dean, with additional support from Dr. Earle Buckley.

Section 6

Original Caro-COOPS Timeline-Year 2

TASK	J03	J03	A03	S03	O03	N03	D03	J04	F04	M04	A04	M04
Observational Sub-System												
Order 2nd Year Equipment	■	■	■	■	■	■	■					
Construct ADCP Housings	■	■	■	■								
Order Mooring Supplies	■	■										
Hire New Marine Tech	■											
Arrange Ship Schedule	■					■						
Establish Real Time Capability	■	■	■	■								
Ocean.US Iridium Trials	■	■	■	■	■	■	■	■	■	■	■	■
Experimental Real Time							■	■	■	■	■	■
Mooring Deployment/Recovery	■					■	■				■	■
Install Charleston Harbor Stations	■											
Install/Service Coastal Met Stations	■					■	■				■	■
Install/Service Water Level Stations	■					■	■				■	■
Real Time Coastal Met/WL Data	■	■	■	■	■	■	■	■	■	■	■	■
Satellite SST and Color	■	■	■	■	■	■	■	■	■	■	■	■
Begin Climate Variation detection										■	■	■
Seasonal Cruises	■					■	■				■	■
Data Communications and Management Sub-System												
Troubleshoot On-line Data Streams	■	■	■									
Produce Merged Data Sets	■	■										
Automation/Streamlining of Data	■	■	■	■	■	■						
Produce Specific User Products					■	■	■	■	■	■	■	■
Enhance Model Outputs								■	■	■	■	■
Improve QA/QC Procedures	■	■	■	■	■	■	■	■	■	■	■	■
Enhance/Expand VNIS	■	■	■	■	■	■						
Identify Outputs for Established Processes						■	■	■	■	■	■	■
Build Archival Tools	■	■	■	■								
Explore Additional Formats/Utilities	■	■	■	■	■	■	■	■	■	■	■	■
Modeling and Applications Subsystem												
Hire Data Assimilation Post-Doc	■											
Development CEMEPS Physics	■	■	■	■	■	■	■	■				

7.0 Status of Specific Tasks

Observational Subsystem

Task 1: Order 2nd year equipment-- ongoing
Task 2: Construct ADCP housings – ongoing
Task 3: Order mooring supplies – ongoing
Task 4: Hire new marine technician – deferred until January 2004
Task 5: Arrange ship schedule – completed for this project year
Task 6: Establish real time capability – done, but refinements ongoing
Task 7: Ocean.US iridium trials – ongoing
Task 8: Experimental real time – ongoing
Task 9: Mooring deployment/recovery – deployment completed; recovery planned for Jan-March 2004
Task 10: Install Charleston Harbor stations: completed
Task 11: Install/service coastal met stations: installation completed; maintenance ongoing
Task 12: Real time coastal met/WL data: completed and continuing
Task 13: Satellite SST and Color – ongoing
Task 14: Begin climate variation detection – planned for latter half of project year

Task 15: Seasonal cruises – deferred

Data Communications and Management Subsystem
Task 16: Troubleshoot on-line data streams – ongoing
Task 17: Produce merged data sets – ongoing
Task 18: Automation/streamlining of data – largely achieved, but ongoing
Task 19: Product specific user products – initiated; planned for 2nd half of project year
Task 20: Enhance model outputs – latter half of project year
Task 21: Improve QA/QC procedures – ongoing
Task 22: Enhance/Expand web site – 1st revision complete; ongoing
Task 23: Identify outputs for established processes – 2nd half of project year
Task 24: Build archival tools – initiated, but most effort will be in 2nd half of project year
Task 25: Explore additional formats/utilities – ongoing

Modeling and Applications Subsystem
Task 26: Hire data assimilation post-doc – deferred until 2nd half of project year
Task 27: Development of CEMEPS physics – ongoing
Task 28: Atmospheric and oceanic mesoscale environment modeling – ongoing
Task 29: Atmospheric and lateral boundary conditions
Task 30: Wave and tide boundary conditions – ongoing
Task 31: High-resolution modeling system for study region – done for Charleston Harbor; ongoing for other areas of focus
Task 32: Atmospheric and lateral boundary conditions – ongoing
Task 33: Wave and tide boundary conditions – ongoing
Task 34: Develop data inspection and display – planned for 2nd half of project year
Task 35: Deferred until year 3

Demonstration Project – Coastal and Inland Flooding Prediction
Task 36: Begin to validate storm surge and flooding model in Charleston Harbor – ongoing
Task 37: Begin to validate Hilton Head – planned for 2nd half of project year
Task 38: Begin to validate Myrtle Beach – planned for 2nd half of project year
Task 39: Begin to validate waves output -- planned for 2nd half of project year

Demonstration Project – Living Marine Resources Management
Task 40: Analyze available datasets – ongoing
Task 41: Users' thinktank – completed
Task 42: Develop workplan – deferred to 2nd half of project year

References

Holland, G.J. 1980. An analytic model of the wind and pressure profiles in hurricanes. Monthly Weather Review, 108, 1212-1218.

Peng, M.C., L. Xie, and L.J. Pietrafesa. 2002. A dynamically consistent and volume preserving wetting and drying scheme for coastal model applications. Submitted to J. Geophysical Research.

Xie, L., K. Wu, L.J. Pietrafesa, and C. Zhang, 2001: A numerical study of wave-current interaction through surface and bottom stresses: wind-driven circulation in the South Atlantic bight under uniform winds. J. Geophys. Res., 106, 16841-16855.

Appendix 1: Buoy Info Chart

SUN1 - Sunset Beach Pier

Station Location (Lat/Long)	Decimal Degrees: 33.86 N, 78.51 W Degrees, Min., Sec.: 33º 51' 36" N, 78º 30' 36" W
Observations	Water level, meteorological, currents
Data Collection Platforms	see below
Transmission and Receiving	GOES
Approximate Water Depth	NA

Data Collection Platforms:

NOS G3 Water Level Station with Backup Gauge	
Sensor	**Data Type**
(1) Submersible Pressure Transducer (2) Aquatrak Assembly (3) Accububble Bubbler	Water level
Water Temperature Sensor	Water Temp

Sutron Automated Weather Station	
Sensor	**Data Type**
Accubar Barometric Pressure Sensor	Barometric pressure
AT/RH Sensor	Air temperature, relative humidity
Wind Sensor Prop Vane	Wind speed, direction
Ultrasonic Wind Sensor	Wind speed, direction

SUN2 - Sunset Nearshore

Station Location (Lat/Long)	Decimal Degrees: 33.78 N, 78.48 W Degrees, Min., Sec.: 33° 46' 48" N, 78° 28' 48" W
Observations	Sea state
Data Collection Platform	see below
Data Format	Binary
Interval of Data Measurements and Updates	15 min. sampling
Transmission and Receiving	Iridium, 4 hr. interval
Approximate Water	10m

Data Collection Platform:

Bottom mounted inductively coupled to taut-wire mooring	
Sensor	**Data Type**
ADCP	Current speed and direction; Wave height, period, direction
Seacat + P (Paroscientific Digiquartz sensors)	Water level, Temperature, Salinity

Depth	

SUN3 - Sunset Mid-shelf

<table>
<tr><th>Station Location (Lat/Long)</th><td>Decimal Degrees: 33.34 N, 78.17 W
Degrees, Min., Sec.: 33° 20' 24" N, 78° 10' 12" W</td></tr>
<tr><th>Observations</th><td>Sea state, biological</td></tr>
<tr><th>Data Collection Platform</th><td>
<table>
<tr><th colspan="2">Bottom mounted inductively coupled to taut-wire mooring</th></tr>
<tr><th>Sensor</th><th>Data Type</th></tr>
<tr><td>ADCP</td><td>Current speed and direction; Wave height, period, direction</td></tr>
<tr><td>Seacat + P (Paroscientific Digiquartz sensors)</td><td>Water level, Temperature, Salinity</td></tr>
<tr><td>Seacat + FL (Chelsea Instruments Aquatracka III Fluorometer)</td><td>Temperature, Salinity, Chlorophyll</td></tr>
</table>
</td></tr>
<tr><th>Data Format</th><td>Binary</td></tr>
<tr><th>Interval of Data Measurements and Updates</th><td>15 min. sampling</td></tr>
<tr><th>Transmission and Receiving</th><td>Iridium, 4 hr. interval</td></tr>
<tr><th>Approximate Water Depth</th><td>30m</td></tr>
</table>

SUN4 - Sunset Outer Shelf

<table>
<tr><th>Station Location (Lat/Long)</th><td>Decimal Degrees: 33.78 N, 77.83 W
Degrees, Min., Sec.: 32° 51' N, 77° 50' W</td></tr>
<tr><th>Observations</th><td>Sea state, biological</td></tr>
<tr><th>Data Collection Platform</th><td>
<table>
<tr><th colspan="2">Inductively coupled to taut-wire mooring</th></tr>
<tr><th>Sensor</th><th>Data Type</th></tr>
<tr><td>ADCP</td><td>Current speed and direction; Wave height, period, direction</td></tr>
<tr><td>Microcat</td><td>Temperature, Salinity</td></tr>
<tr><td>Seacat + FL</td><td>Temperature, Salinity, Chlorophyll</td></tr>
</table>
</td></tr>
<tr><th>Interval of Data Measurements and Updates</th><td>15 min. sampling</td></tr>
<tr><th>Transmission and Receiving</th><td>Iridium, 4 hr. interval</td></tr>
<tr><th>Approximate Water Depth</th><td>200+m</td></tr>
</table>

MET1 - N. Charleston Met

<table>
<tr><th>Station Location (Lat/Long)</th><td>Decimal Degrees: 32.87 N, 77.83 W
Degrees, Min., Sec.: 32° 52' N, 77° 50' W</td></tr>
<tr><th>Observations</th><td>Meteorological, sea state</td></tr>
</table>

Data Collection Platform	**Aanderaa Coastal Monitoring Buoy CMB4280**	
	Sensor	**Data Type**
	Wind Speed Sensor 2740	Average &maximum (gusts) wind speed
	Wind Direction Sensor 3590	Wind direction
	Air Pressure Sensor 2810	Barometric pressure
	Relative Humidity Sensor 3445	Relative humidity
	Air Temperature Sensor 3455A	Air temperature
	Solar Radiation Sensor 2770	Solar and sky radiation
	Water temperature (2)	Water temp
Interval of Data Measurements and Updates	15 min. sampling	
Transmission and Receiving	Orbcomm, 1 hr. interval	
Approximate Water Depth	200m	

CAP1 - Capers Island

Station Location (Lat/Long)	Decimal Degrees: 32.68 N, 79.68 W Degrees, Min., Sec.: 32º 41' N, 79º 42' W	
Observations	Water level, meteorological, currents	
Data Collection Platforms	**NOS G3 Water Level Station with Backup Gauge**	
	Sensor	**Data Type**
	(1) Submersible Pressure Transducer (2) Aquatrak Assembly (3) Accububble Bubbler	Water level
	Water Temperature Sensor	Water Temp
	Sutron Automated Weather Station	
	Sensor	**Data Type**
	Accubar Barometric Pressure Sensor	Barometric pressure
	AT/RH Sensor	Air temperature, relative humidity
	Wind Sensor Prop Vane	Wind speed, direction
	Ultrasonic Wind Sensor	Wind speed, direction
Transmission and Receiving	GOES	
Approximate Water Depth	NA	

CAP2 - Capers Nearshore

Station Location	Decimal Degrees: 32.81 N, 79.63 W

(Lat/Long)	Degrees, Min., Sec.: 32° 48' 36" N, 79° 37' 48" W		
Observations	Sea state		
Data Collection Platform	**Bottom mounted inductively coupled to taunt-wire mooring**		
	Sensor	**Data Type**	
	ADCP	Current speed and direction; Wave height, period, direction	
	Seacat + P	Water level, temperature, salinity	
Data Format	Binary		
Interval of Data Measurements and Updates	15 min. sampling		
Transmission and Receiving	Iridium, 4 hr. interval		
Approximate Water Depth	10m		

CAP3 - Capers Mid-shelf

Station Location (Lat/Long)	Decimal Degrees: 32.52 N, 79.34 W Degrees, Min., Sec.: 32° 31' 12" N, 79° 20' 24" W	
Observations	Sea state	
Data Collection Platform	**Bottom mounted inductively coupled to taut-wire mooring**	
	Sensor	**Data Type**
	ADCP	Current speed and direction; Wave height, period, direction
	Seacat + P	Water level, temperature, salinity
	Seacat + FL	Temperature, Salinity, Chlorophyll
Data Format	Binary	
Interval of Data Measurements and Updates	15 min. sampling	
Transmission and Receiving	Iridium, 4 hr. interval	
Approximate Water Depth	30m	

MET2 - S. Charleston Met

Station Location (Lat/Long)	Decimal Degrees: 32.2 N, 79.67 W Degrees, Min., Sec.: 32° 12' N, 79° 40' 12" W	
Observations	Meteorological, sea state	
Data Collection Platform	**Aanderaa Coastal Monitoring Buoy CMB4280**	
	Sensor	**Data Type**
	Wind Speed Sensor 2740	Average and maximum (gusts) wind speed
	Relative Humidity Sensor 3445	Relative humidity

	Air Temperature Sensor 3455A	Air temperature
	Solar Radiation Sensor 2770	Solar and sky radiation
	Water temperature Sensors (2)	Water temp.
Interval of Data Measurements and Updates	15 min. sampling	
Transmission and Receiving	Orbcomm, 1 hr. interval	
Approximate Water Depth	30m	

FRP1 - Fripp Inlet

Station Location (Lat/Long)	Decimal Degrees: 32.45 N, 80.45 W Degrees, Min., Sec.: 32° 20' 24" N, 80° 27' 36" W
Observations	Water level, meteorological, currents
Data Collection Platforms	
Approximate Water Depth	NA

Data Collection Platforms:

NOS G3 Water Level Station with Backup Gauge	
Sensor	**Data Type**
(1) Submersible Pressure Transducer (2) Aquatrak Assembly (3) Accububble Bubbler	Water level
Water Temperature Sensor	Water Temp

Sutron Automated Weather Station	
Sensor	**Data Type**
Accubar Barometric Pressure Sensor	Barometric pressure
AT/RH Sensor	Air temperature, relative humidity
Wind Sensor Prop Vane	Wind speed, direction
Ultrasonic Wind Sensor	Wind speed, direction

FRP2 - Fripp Nearshore

Station Location (Lat/Long)	Decimal Degrees: 32.28 N, 80.41 W Degrees, Min., Sec.: 32° 16' 48" N, 80° 24' 36" W
Observations	Sea state
Data Collection Platform	
Data Format	Binary

Data Collection Platform:

Bottom mounted inductively coupled to taut-wire mooring	
Sensor	**Data Type**
ADCP	Current speed and direction; Wave height, period, direction
Seacat + P	Water level, temperature, salinity

Interval of Data Measurements and Updates	15 min. sampling
Transmission and Receiving	Iridium, 4 hr. interval
Approximate Water Depth	10m

FRP3 - Fripp Mid-shelf

<table>
<tr><th>Station Location (Lat/Long)</th><td>Decimal Degrees: 31.91 N, 80.03 W
Degrees, Min., Sec.: 31° 54' 36" N, 80° 01' 48" W</td></tr>
<tr><th>Observations</th><td>Sea state, biological</td></tr>
<tr><th>Data Collection Platform</th><td><table>
<tr><th colspan="2">Bottom mounted inductively coupled to taut-wire mooring</th></tr>
<tr><th>Sensor</th><th>Data Type</th></tr>
<tr><td>ADCP</td><td>Current speed and direction; Wave height, period, direction</td></tr>
<tr><td>Seacat + P</td><td>Water level, Temperature, Salinity</td></tr>
<tr><td>Seacat + FL</td><td>Temperature, Salinity, Chlorophyll</td></tr>
</table></td></tr>
<tr><th>Data Format</th><td>Binary</td></tr>
<tr><th>Interval of Data Measurements and Updates</th><td>15 min. sampling</td></tr>
<tr><th>Transmission and Receiving</th><td>Iridium, 4 hr. interval</td></tr>
<tr><th>Approximate Water Depth</th><td>30m</td></tr>
</table>

Appendix 2

Caro-COOPS budget for FY2004--Revised December, 2003

Cost category	Person-months (/yr)	Year 02	Total	Notes
SENIOR PERSONNEL				
Dr. Madilyn Fletcher	1.5	16,719		
Dr. Dwayne Porter	0.5	3,000		
Senior Systems Developer	12	70,710		
Systems Administrator	12	65,920		
Systems/Communications Engineer	3	15,827		
OTHER PERSONNEL				
Programmer/Developer (2)	24	120,000		
Research Associate (2)	20	83,332		Reduced 4 months
TOTAL SALARIES		375,508		
FRINGE BENEFITS		87817		
TOTAL SALARIES & FRINGE BENEFITS		463,325		
TRAVEL				
Domestic		27,000		
International		0		
TOTAL TRAVEL		27,000		
EQUIPMENT				
Mooring instrumentation		86,208		Reduced
Data management		20,200		
TOTAL EQUIPMENT		106,408		
SUPPLIES		45,759		
TOTAL SUPPLIES		45,759		
OTHER DIRECT COSTS				
Computer Services		11,000		
Communications costs		5,100		
Shiptime (RV Hatteras		36,000		New item
WLS installation & maintenance		61,500		New item
Subaward to NCSU		1,178,450		
Subaward to UNCW		74,000		
Subaward to SC DNR		82,000		Reduced
Subaward to Waterstone		20,000		
CO-OPS		72,000		
TOTAL OTHER DIRECT COSTS		1,540,050		
TOTAL DIRECT COSTS		2,182,542		

INDIRECT COSTS	301,358
Rate - 45.0%	
Basis - $669,684	
TOTAL DIRECT & INDIRECT COSTS	2,483,90 0
Amount withheld by NOAA for CO-OPS	72,000
Net amount awarded to USC	2,411,90 0

Table 3: NCSU Budget detail for 6/1/03-5/31/04

Cost category	Person-months(/yr)	Year 02	Subtotal		Notes
SENIOR PERSONNEL					
Pietrafesa	1	12,250	12,250		
Xie	1	8,000	8,000		
Morrison	1	9,250	9,250		
Buckley	8	9,625	77,000		
Dickey	1	10,000	10,000		
Kamykowski	1	0	0		
Demaster	0.25	3,500	3,500		
Miller	1	0	0		
Wolcott	0.5	0	0		
				120,000	
POST-DOCS					
Bao	12		48,000		
Peng	6		24,000		
TBD	12		48,000		
Guan	6		24,000		
				144,000	
TECHNICIANS					
Epps	7		30,000		
Gabriel	3		16,000		
Stanfield	6		19978		Increased time/salary
Kinder	10		56,000		
Sweet	10		48,000		
TBD	5		20,811		New position
				190,789	
STUDENTS					
Liu1	12		20,000		
Yan	12		20,000		
Liu2	12		20,000		
				60,000	
TOTAL SALARIES					514,789
Fringe 23%(a+c)+14%(b)+10%					97,642

(d) TOTAL SALARIES & FRINGE				612,431
EQUIPMENT				136,697
SUPPLIES	Mooring hardware, $2K per mooring		24,000	
	Tide stations		$4,000	
	Met buoys	$800/buoy	2,400	
	Bottom ADCP	$1,500 each	$3,000	
	Pingers, additional weight		$5,000	
TOTAL SUPPLIES				$38,400
TRAVEL				
	Array installation/maintenance		$14,000	
	National workshops, meetings		4,000	
TOTAL TRAVEL				$18,000
OTHER	Shipping		20,000	
	Software licensing		5,000	
	Publications		4,000	
	Data Communications		3,000	
	Tuition @$5,012/student		15,036	
TOTAL OTHER COSTS				47,036
TOTAL DIRECT COSTS				852,564
INDIRECT COSTS 46.5% of $700,831				325,886
TOTAL PROJECT COSTS				1,178,450

Equipment costs

	Unit cost	Total
Upgrade WLR	9,000	27,000
10 m mooring	46,795	93,590
30 m mooring	62,115	62,115
30 m met stn	40,200	40,200
Total		222,905
NCSU share	$136,697	
USC share	$86,208	

Appendix 3

A Brainstorming Think -Tank for Caro-COOPS :
What do fishery resources users need to know? And how can Caro-COOPS be targeted to meet those needs?

October 2-3, 2003
Charleston, SC

Deb Stirling – Convenor and Chair
John Mark Dean - Recorder

1:30 PM Introductions

2:00 PM What is Caro-COOPS and why should I care?
Project Directors Len Pietrafesa and Madilyn Fletcher

2:45 PM Short question and answer period

3:00 PM Break

3:30 PM Development of topics for development- There are no bad ideas

4:30 PM Identification of priorities and small groups for topic development

5:45 PM Recess

6:00 PM Social

Dinner is on your own

Oct. 3

8:30 AM Small groups continue and develop a report

9:45 AM Break

10:15 AM Convene all groups and begin reports- Each group has 15 minutes for explanation of the topic, the approach, expected benefits, the user groups, and the priority, followed by 15-20 minutes of discussion.

11:45 AM Lunch in the restaurant

1:00 PM Continue reports

2:45 PM	Develop priority ranking of topics (Use the dot method and this will also constitute a break)
3:15 PM	Report on priorities recommended and revise with discussion
4:00 PM	Adjourn