SEACOOS Modeling Documentation
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C. Mooers, B. Weisberg, C. Werner

1. Regional nowcast/forecast system design

The coastal ocean of the southeast United States (U.S.) contains adjoining continental shelves of varying widths (Fig 1), being mainly broad on the West Florida Shelf [WFS] (100-150 km), narrow on the Southeast Florida Shelf (1-10 km) and gradually broadening and then narrowing in the South Atlantic Bight [SAB] (30-100 km). Here, the East Florida Shelf [EFS] sub-region covers the Southeast Florida Shelf and the southern third of the SAB; i.e., the Northeast Florida Shelf and the Carolina-Georgia Bight (CGB) sub-region cover the northern two thirds of the SAB. Because of its geographic location, the southeast U.S. experiences easterly waves and tropical cyclone passages in summer, and extratropical cyclone (e.g., Nor'easters) and cold front passages in winter. Such synoptic scale atmospheric disturbances over the CGB, EFS, and WFS sub-regions induce strong physical responses in the coastal ocean,

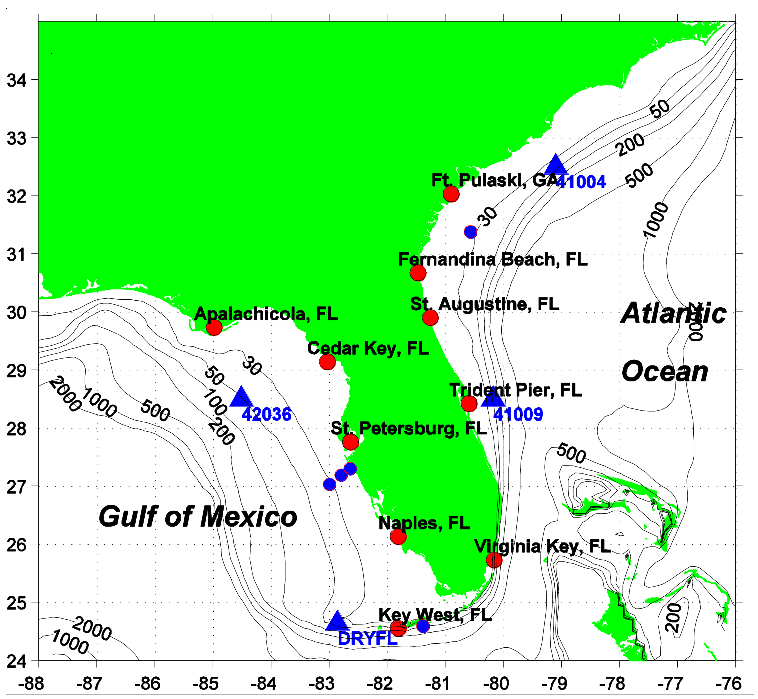

Figure 1. Bottom topography (depth in meters) and observation locations in the SEACOOS domain. Coastal tide gauges are denoted by red dots, NDBC buoys and a C-MAN station by blue triangles, and current meter moorings by circles.

including changes in sea level, across shelf and along shelf currents, coastal upwelling and downwelling, subtidal coastally-trapped waves, stratification, surface waves, and turbulent mixing. These responses to weather forcing often have significant socioeconomic effects through storm surges, rip currents, beach erosion, coastal upwelling/downwelling, nutrient transport, and related primary productivity including harmful algal blooms.

Due to the complexity of the coastal ocean, monitoring and predicting coastal ocean processes such as the aforementioned require a coastal ocean observing system that can incorporate both extensive *in-situ* (and satellite and coastal remote sensing) observations and numerical models. One such initiative is the Southeast Atlantic Coastal Ocean Observing System (SEACOOS), a partnership among the University of North Carolina-Chapel Hill (UNC), University of South Carolina (USC), Skidaway Institution of Oceanography (SkIO), University of Miami (UM), and University of South Florida (USF), that inclusively covers the coastal ocean off North Carolina, South Carolina, Georgia, and Florida. While all partners developed sustained observing programs (see SEACOOS Observing System Report); UNC, UM, and USF additionally ran sub-regional ocean circulation models in a continual, automated fashion (i.e., quasi-operationally) and provided an integrated product of surface fields and sea surface elevations.

The starting point for SEACOOS circulation modeling is the set of sub-regional models existing at UNC, UM, and USF, each being a three-dimensional, free-surface, primitive equation model, with high order turbulence closures, to study the tidal and sub-tidal structures of the sea level and currents of the sub-regions. The basis for separate models is historical, but it is also explained by the fact that the SEACOOS sub-regions (CGB, EFS, and WFS) are characterized by significantly different geometries, tidal regimes, and boundary current forcing that require focused attention. These sub-regions are as large or larger than other COOS regions, and hence, the computational requirements to individually model them with sufficient resolution are already challenging. At present, to cover the entire region with one high-resolution model may pose formidable computational demands if we are to meet the objective of real-time operational forecasts.

The entire SEACOOS region is linked by the advection of the Gulf of Mexico Loop Current (LC), Florida Current (FC), and Gulf Stream (GS) complex. The SAB from North Carolina to the Northeast Florida Shelf is narrow at Cape Hatteras, broad in the middle, and narrow at Cape Canaveral with varying impacts by the GS; the Southeast Florida Shelf is very narrow and always abutted by the FC; and the WFS is generally very wide and only occasionally impacted by the LC. The three sub-regions are affected by the synoptic scale weather systems that regularly transit the SEACOOS domain. The modeling efforts by UNC, UM and USF were initiated for specific sub-regional purposes and are evolutionary.

Short term: as a starting point, the sub-regional models aimed to address the following set of questions:

1. Can three separate sub-regional ocean models provide a coherent description of the coastal ocean circulation in the SEACOOS domain under relatively coherent and strong forcing from synoptic scale weather events?
2. To what degree do the sub-regional models reproduce in-situ observations?
3. What might be done to improve the models' fidelity?

Medium term: modeling is viewed as an essential component of an environmental information system and provides a means for dynamical interpolation of inevitably sparse and incomplete observations, fundamental to many research applications, and the basis for forecasts of coastal ocean conditions. Activities/deliverables include:

integration of oceanic and related observations in the SEACOOS region through state of the art regional circulation models;
implement modeling approaches that include biogeochemical and ecological quantities relevant to the SEACOOS domain;
couple the subregional models with basin scale models to capture longer-term and non-locally forced phenomena;
conduct validation and data assimilation experiments to examine model - data internal consistency;
establish, maintain, and upgrade the SEACOOS nowcast/forecast systems and its Web-based products;
aid in the design of the evolving and expanding observing system, run Observing System Simulation Experiments (OSSE);
further integrate with the observing system by conducting Coastal Ocean Data Assimilation Experiments (CODAE).

Longer term: development of application areas of particular interest to partners and stakeholders including, Spill Response (SR)/Search-and-Rescue (SAR)

Ecosystem Models

Wave Models

Sediment transport models

2. Experience with running subregional circulation modeling systems

The coastal ocean circulation models used in SEACOOS sub-regions are the Dartmouth College Ocean Model: QUODDY for CGB (at UNC), the Princeton Ocean Model: POM for EFS (at UM), and the Regional Ocean Modeling System (ROMS) for the WFS (at USF). The models are three-dimensional, hydrostatic, Boussinesq, fully nonlinear, and have a free surface. They integrate momentum, temperature and salinity, and two turbulence variables and both barotropic and baroclinic motions are resolved on tidal time scales. General terrain-following vertical coordinate system are used in each of the models, with non-uniform vertical discretization, allowing for tidal-time tracking of the free surface and resolution of surface and bottom boundary layers.

Domain-Wide Barotropic Applications. The SEACOOS regional modeling system routinely provides near-real-time daily barotropic nowcast and forecast fields (e.g., sea surface height and depth-averaged currents, drifter trajectories, etc.) from blended model output resulting from individual UNC, USF, and UM model implementations forced by imposed winds and tidal forcing. The model product is available daily on the website. A sample snapshot is provided in Figure (1). On a daily basis, scripts retrieve meteorological model files, manage the execution of the hydrodynamic models, post-process the output, and make available the output files (in a standardized netCDF formatted file) via local DODS servers. Next steps in the SEACOOS leading to the computation of baroclinic fields will require imposing heat fluxes, river discharge, and far-field (deep-ocean) effects on the nowcast/forecast system.

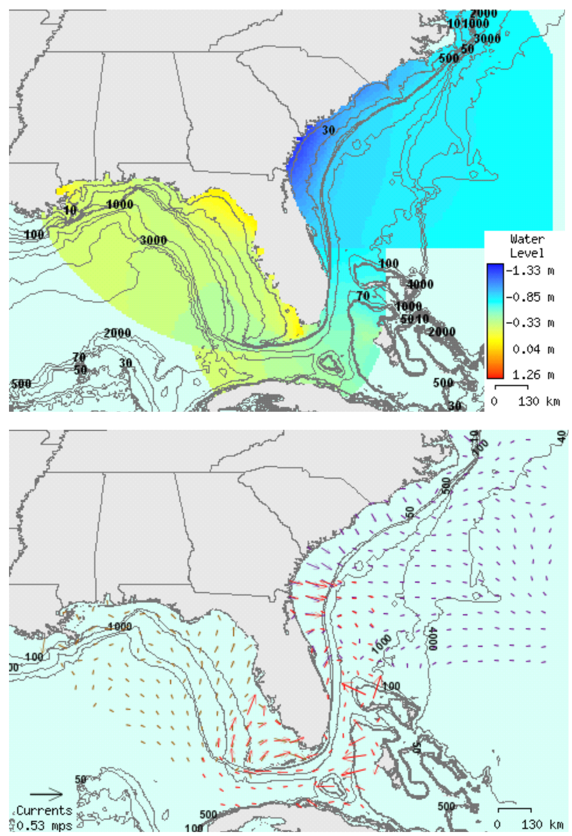

Figure 1. Sea surface elevation and depth averaged currents at an instant in time obtained by overlaying the USF, UM and UNC model solutions. Bottom depth contours in meters.

Within-region Applications. There is a need for the models developed within SEACOOS to address questions within particular regions, e.g., to answer questions pertaining to questions of relevance to local fisheries issues as related by larval transport (Figure 2), or

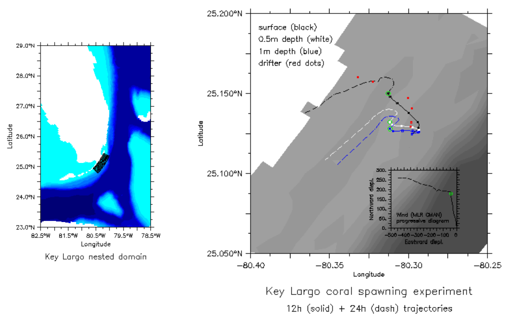

Figure 2. Larval dispersal model simulations (right panel) along the South Florida shelf coral reef systems (left panel, black rectangle) can provide information on the connectivity and retention of commercially or ecologically important species.

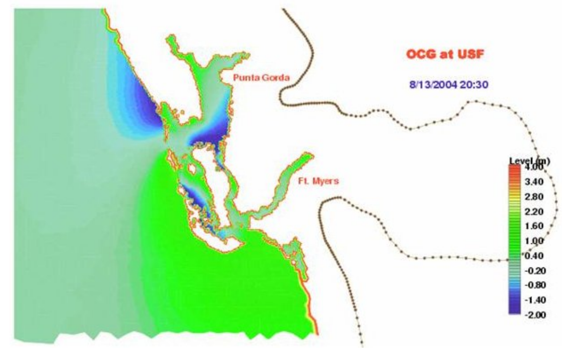

Figure 3. Model generated sea level in and near Tampa Bay in response to atmospheric forcing. The dotted line corresponds to the 8m above sea-level contour. Storm-surge models can be used to forecast inundations during severe storms.

possible flooding and storm surge effects (Figure 3). The approach taken is to downscale from the regional SEACOOS models developed by USF, UM and UNC.

Baroclinic applications. We have undertaken studies of the response of imposing heat fluxes and river discharge on the nowcast/forecast system (see Figure 4). In the SAB this has allowed the study of the formation of tidal fronts during summer, as well as the formation of low salinity fronts during wet seasons. The baroclinic version of EFS model has been used for model testing studies in a strictly simulation mode so far. Results for simulations of Florida Current frontal eddies on the EFS were validated against observed values (Fiechter and Mooers, 2004). On the WFS baroclinic hindcasts have been quantitatively gauged against data.

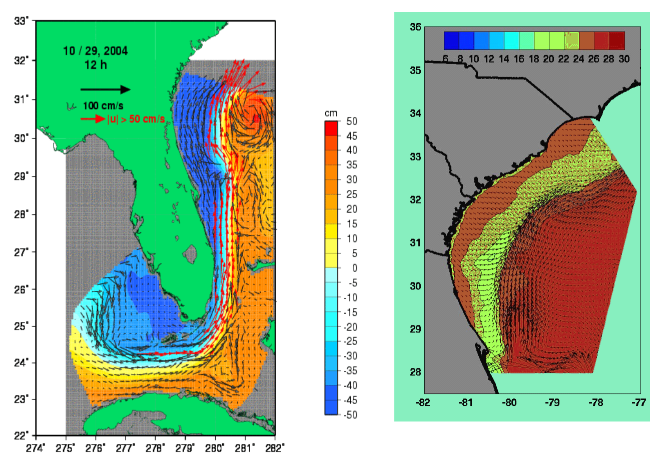

Figure 4. EFS and SAB baroclinic velocity field solutions. The EFS elevation and the SAB temperature fields are also shown.

Steps towards a baroclinic nowcast-forecast system. Inclusion of density components to the nowcast/forecast system requires inclusion of river discharge and atmospheric heat fluxes obtained from external sources, e.g., the NCEP operational model analysis and forecast fields. The more difficult problem, that of specifying the initial (background) density field, will initially be either climatological initial conditions of temperature and salinity, the use basin-scale ocean model forecasts of temperature and salinity structure, or some blending of these products as well as assimilation of observed data.

We have used optimal interpolation (O/I) techniques to composite SST fields from different satellites (using AVHRR, GOES, and TMI products) to quasi-operationally produce cloud-free daily images, and to composite surface wind fields from EDAS (model) and buoy and coastal observations for improved surface momentum flux forcing. The ocean model results from these O/I fields are demonstrably better than from the nominal EDAS fields alone. This quantitative finding underscores the importance of coastal ocean observing systems. These O/I techniques are incremental steps toward data assimilation.

Steps towards data-assimilation. We anticipate that sea level and ADCP data may be reliably available regionally for assimilation, and we will also consider assimilation of surface current data from HF radar. The latter is an open research topic requiring development of formal methods and forms part of a community-wide effort.

Ensemble solutions. Many forecasting modeling efforts issue forecasts based on "ensembles". For example, US hurricane forecasts, European storm surge forecasts, and the IPCC climate forecasts are based on ensembles of model runs. We are considering approaches where the three teams (UNC, UM, USF) use SEACOOS-wide models and work on the developing statistical measures of "forecasts" based on the three, now domain-wide, models. If we attempt this approach, we will be able to explore research areas in how we provide forecasts to the public. The ensemble three-model SEACOOS-wide domain approach is also advantageous in that:

the problem of dynamically linking all three sub-regions will be obviated;

we will still be able to focus/zoom in on our own sub-regions as needed through grid refinement and be responsive to the needs of the sub-region constituencies (e.g., the SAB estuaries, the Dry Tortugas and the Tampa Bay/Charlotte Harbor sites); and,

the implied "redundancy" of three model runs protects against failure of any one system, i.e., we will be more likely to provide continued forecast information to the SEACOOS user community.

3. Logistical issues

3.1 The fundamental needs for personnel,

3.2 Centralized and distributed National Backbone downloads,

3.3 Centralized and distributed computational facilities,

3.4 Data archival functions,

*3.5 Pathways to robustness***:** it is beneficial to have a distributed approach to running models, in general, and specifically during events (e.g., hurricanes) that result in down-time for one or more modeling sites simultaneously. The node that loses power misses runs but the rest of the solutions are available. The idea might be to duplicate runs for each domain creating multiple forecasts for each region. A consideration is that robustness should be achieved while minimizing the number of runs. However, the scale issue will remain, i.e., in the future we will need more resources, more resolution, and thus more run-time. One solution is to include a coarse resolution run at more than one site as a backup for failure.

A longer-term solution is that software will be able to address some of the issues using GRID computations and technologies. The most difficult problem and the one that needs to be resolved before pushing forward is security. The main conclusion is that robustness cannot be addressed locally; it has to be done somewhere else. Another advantage that grid approaches provide is that the source of, for instance, meteorological files might not matter (i.e., issues about file formats are taken care of somewhere else). We have considered the possibility of translating this to SEACOOS, even though it might be problematic: lack of files, network connection between groups, change of formats, etc. We need to better define robustness needs of the system. It is certain though that the solution to robustness must not be a duplication of the system, because even if it seems the obvious solution, it is not the most efficient way to do it. We need to better define robustness and look for single point failures, weak points and faults. The problem is that even people with a mandate of robustness, like the NWS, are not able to do it. It is clearly a very difficult problem that needs further study.

3.6 CONOPS (National Backbone assumptions, RCOOS operations, etc.)

Background. IOOS is developing in a multi-dimensional fashion. For example, it is the USA contribution to GOOS and, thus, the USA ocean contribution to GEOSS. IOOS is also developing on a multi-agency (primarily led by NOAA, NASA, and ONR), multi-disciplinary basis, with physical oceanography forming the foundation, and providing some of the motivation. There are global ocean and coastal ocean components to IOOS. There are also R&D and operational aspects to IOOS and broad participation by government, academia, and industry is intended. The coastal and global components differ in that more agencies are involved in the coastal ocean, the societal applications are broader, and there is a commitment to regionalization for the purposes of designing and operating flexible and adaptive coastal ocean observing systems. Interesting and important planning, R&D, and pre-operational steps have already been taken. However, a limiting or enabling factor has not yet been addressed: the determination of a "concept of operations" or "Who will be responsible for delivering ocean information services on a regular basis?" Until this question is resolved, it is difficult to design IOOS and the supporting R&D.

Discussion. Traditionally, federal agencies have had the responsibility of delivering operational environmental services to meet the Federal Government's responsibilities for protecting lives and property of the Nation and contributing to the 'common good'. Perhaps the classic example is NOAA's National Weather Service (NWS), which has origins dating back nearly 150 years. Today, NWS is a centralized organization with regional and local branches, ca. 5,000 employees, and an excellent reputation. However, when considering the capabilities of modern observational, computational, and information technology, a more distributed and even privatized approach is conceivable. On the other hand, NOAA's National Ocean Service (NOS) has only modest infrastructure (except for the National Water Level Observation Network, NWLON, and the Physical Oceanography Real Time System, PORTS) and would require significant expansion to fully undertake the coastal ocean component of IOOS. It also has no background in the global ocean component of IOOS, although it has growing expertise in estuarine prediction. Note, however, that NWS operates some of the key observing system elements in the coastal ocean (viz., the National Data Buoy Center (NDBC)'s meteorological buoys and coastal stations) and has ocean modeling groups at the National Centers for Environmental Prediction (NCEP). Hence, another option is to expand NCEP and other elements of NWS to take on operational IOOS tasks, *but that may be too much of a cultural stretch to be made by an organization of mainly meteorologists.* Of course, transfers of certain elements of NOS to NWS, or vice versa, are possible.

Additional national assets are the Naval Meteorology and Oceanography Command (CNMOC) with its two operational centers (NAVOCEANO and FNMOC), and the Naval Research Laboratory (NRL) that supports them with relevant R&D. The Navy is already running operational global ocean and coastal ocean models to meet its mission requirements. Though the civil and naval objectives are not identical, there is much in common, and each sector can learn valuable lessons through co-development and co-operations.

Some academic and private industry entities are technically capable of running *in situ* and satellite remote sensing observing systems, and others are technically capable of running numerical prediction systems and providing value-added services based on government – provided observations and model output. Much depends upon the economics of the situation and the financial resources committed by the Federal Government or some other group.

It is possible that the issues of the 'responsible party' and the 'performing party' could be separated. Until the market for coastal (and global) ocean environmental information products grows to make the private sector self-sustaining, the Federal Government must be the ‘responsible party’. The ‘performing party’ is another matter. However, for national security (and maybe other) reasons, and in order to be a ‘smart customer’, it would seem necessary for the Federal Government to maintain some in-house capability even if much effort is contracted.

Associated with the Regional Associations (RAs) of the Coastal – IOOS are Regional – COOSs (RCOOSs). The RAs and RCOOSs are to be tailored to the specific requirements of each region. The RCOOSs are to have operational as well as R&D roles. They will probably be comprised of academic and/or private sector participants, perhaps under federal supervision, and they will need to be linked to national scale and basin/global scale systems for atmospheric and open boundary conditions, etc.

Recommendations. For the basin scale/global scale operational oceanography activities, and based on the experience gained in the ongoing, collaborative Global Ocean Data Assimilation Experiment (GODAE), the Navy and NOAA should form a Joint Operations Center (JOC) for planning and budgeting; coordinating global observing systems, global datasets, and global numerical predictions; and dissemination of numerical products.

The JOC should be interfaced to the RCOOSs for the two –way exchange of information.

The RCOOSs should carry out functions parallel to those of the JOC but on the regional scale, including stewardship activities for the “National Backbone” within their region and interactions with NWS Weather Forecast Offices (WFOs), etc. within their region. Also, the RCOOSs should be carefully crafted to promote growth in the value-added industry, and to be synergistically connected to the research enterprise for mutual benefit.

The JOC should be initiated through participation, together with the RCOOSs, in the prospective Coastal Ocean Data Assimilation Experiment (CODAE).

Ocean.US should facilitate the development of JOC and RCOOSs along these lines and promote the conduct of CODAE.

4. Technical issues identified for future consideration

Maintaining a quasi-operational system. The implementation of the present quasi-operational system has involved the development of software to acquire and process the NCEP 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. Occasional network transfer delays can disrupt the daily operational model system cycle. While these delays may be local to a particular model group, this can delay the time at which all system model results are available for dissemination and further processing. A more robust method of acquiring the atmospheric forcing fields should be investigated, including possibly running a mesoscale atmospheric prediction model within the SEACOOS modeling groups. Long-term computing resource issues will need to be addressed, particularly when baroclinic versions of the operating models are implemented. These future systems will require increased storage and faster computational host machines.

Three sub-regional versus one domain-wide model. The three SEACOOS regions (the SAB, the EFS/FS and the WFS) are characterized by radically different geometries and forcings. The shelf region from northern Florida to North Carolina is affected by freshwater discharges nearshore, Gulf Stream forcing near the shelf edge, and is strongly wind-driven in the mid-shelf. Additionally, sounds and estuaries in Georgia and South Carolina require detailed geometric fidelity to capture the tidal/sea-level response along this coast. The Straits of Florida have a very narrow shelf and a steep continental slope. The flow in the Straits is dominated by the Florida Current and its variability, requiring explicit inclusion of the forcing by the offshore currents. The west Florida shelf is broad, and while strongly wind-forced, it also is affected by the variability of the Gulf of Mexico's Loop Current. Each of the modeling teams (UNC, UM and USF) has worked to capture the essential details of each region. The immediate 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. Alternatively, the development of a single SEACOOS-wide domain may be attractive for several reasons and is being discussed by the modeling teams. Among the desirable features are: the removal of boundary condition effects away from the local regions of interest and, if run simultaneously by the three teams (the meshes need not be the same with increased resolution varying according to the implementation), it would allow for model ensembles and other statistics to be estimated. Thus forecasts could be issued with a probability associated with to them. Additionally, in the event of any one model failing to complete, then 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 of the groups.

The challenge of representing dynamics on narrow shelves. While barotropic dynamics (tidal and wind-forced responses on the continental shelf) can capture coastal water level dynamics and provide relatively good skill for water levels on wide continental shelves, the same is not true for narrow shelf regions like the northern SAB/Hatteras, East Florida Shelf, and the Straits of Florida. The next versions of the SEACOOS NFS system will begin to incorporate regional-scale mass fields into the model dynamics – an upgrade that is expected to provide additional skill in water level forecasting. This is due to the strength of the mass field characteristics associated with these regions, as well as to the proximity of the baroclinic current to the coast.

Skill assessment. More rigorous skill assessment methods will also need to be addressed, particularly when observations become more routinely available. This includes examination of available depth-averaged velocity records and correlation of these errors with errors in the forecast wind fields. Additionally, we will need to develop methods for baroclinic model skill. A principal difficulty with the latter will be acquiring temperature and salinity information both to provide needed skill metrics and to guide the future development of data-assimilating SEACOOS modeling systems. Remotely sensed temperature, for example, provides good spatial coverage at the ocean surface for forecasting of surface temperature fronts. Subsurface measurements, however, are comparatively much sparser, and yet are needed for verification of3-dimensional model structure.

Initializing the mass field. 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 issue raises several important questions. How well do the basin-scale models represent the regional mass fields? How will the regional models assess the usefulness of the basin-scale products as initial conditions? Additionally, we will need to address the regions covered by each SEACOOS NFS model domain. The current "sub-regional" approach, whereby each modeling institution has implemented their model in their part of the SEACOOS domain, may need to be redesigned. One alternative approach is for each institution to implement their model over the entire SEACOOS region. This would certainly mean increased computational resource requirements for each group, but would facilitate model comparisons as well as move open-boundary zones farther away from our primary regions of interest. These are among the research questions that will need to be addressed in attaining this next level of modeling complexity.

Linking to offshore (basin-scale) models. The coastal ocean, in addition to being locally forced by winds, river discharge, heating and cooling, etc., is forced by the neighboring deep ocean and by shelf currents "upstream" of the model domain that flow into the region of interest (Fig. 5). To properly capture the fluxes of momentum, mass, as well as dissolved and particulate matter on and off the shelf regions, they need to be included as forcing functions, or boundary conditions to the regional models. In the SEACOOS region, several options and opportunities exist to begin to capture the links between the regional models and the adjacent waters. Some of these are:

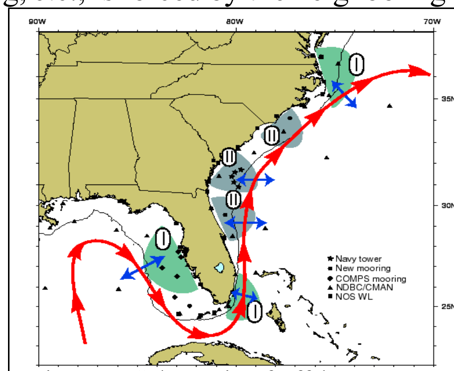

Figure 5. Schematic of offshore current along the SEACOOS shelf domain.

- *HYCOM* (http://hycom.rsmas.miami.edu/index.shtml): a multi-institutional developmental effort funded by the National Ocean Partnership Program (NOPP), as part of the U.S. Global Ocean Data Assimilation Experiment (GODAE). There exist SEACOOS collaborations with HYCOM (Hybrid Coordinate Ocean Model) whereby the 1/12° (on the order of 8kms) toward-operational HYCOM/GODAE North Atlantic model output are being examined and methods developed to downscale the model products into SEACOOS model domains. The frequency of availability of the HYCOM product is one week. This product will provide estimates of the regional hydrography as well as offshore sea surface height field due to the proximity of the deep ocean boundary current to the SEACOOS region continental shelf.

- *NCOM* (http://www7320.nrlssc.navy.mil/global_ncom/): the first American official operational global ocean prediction system operated by NAVOCEANO with 45 levels and 1/8th degree resolution (1/24th degree regional models will be made available in due course). The 1/8° global NCOM, the Naval Research Laboratory Coastal Ocean Model, is an operational product run daily by the Naval Oceanographic Office (NAVOCEANO) with atmospheric forcing from the Navy Operational Global Atmospheric Prediction System (NOGAPS) and assimilation of SST and satellite altimeter data obtained via the NAVOCEANO Altimeter Data Fusion Center. Just as for the HYCOM model results, the NCOM forecast fields will be among the basin-scale model products considered in the initialization and forcing of regional SEACOOS model solutions.
- *PROFS* (http://www.aos.princeton.edu/WWWPUBLIC/PROFS/): The *Princeton Regional Ocean Forecast System* is a hindcast, nowcast and forecast ocean model based on the Princeton Ocean Model (POM). Among PROFS's goals, of direct relevance to SEACOOS, is to develop and conduct high-resolution, accurate model simulations in coastal oceans and semi-enclosed seas Gulf of Mexico and Caribbean Sea under realistic ocean environments utilizing nested-grid techniques, data-assimilations and high-resolution atmospheric models.
- *NLOM* (http://www7320.nrlssc.navy.mil/global_nlom/): real-time nowcast/forecast results from the 1/16° and 1/32° global Naval Research Lab (NRL) Layered Ocean Models (NLOM). The 1/16° global NLOM is an operational product run daily by the Naval Oceanographic Office (NAVOCEANO) with atmospheric forcing from the Navy Operational Global Atmospheric Prediction System (NOGAPS) and assimilation of SST and satellite altimeter data obtained via the NAVOCEANO Altimeter Data Fusion Center.

- *ROFS* (http://polar.ncep.noaa.gov/cofs/): Regional Ocean Forecast System, a NOAA/NWS/NCEP operational system that generates daily nowcasts (i.e., analyses) and short-term (of the order of days) forecasts of ocean physical state variables for the coastal ocean of the United States eastern seaboard north of the Straits of Florida. ROFS is based on hydrodynamic, 3-D ocean circulation model (Princeton Ocean Model) which simulates of temperature, salinity, surface elevation, and currents for a region off the U.S. East Coast from ~30 to 47N and out to 50W. The model is driven at the ocean surface boundary by heat, moisture, and momentum fluxes provided by NCEP's Eta mesoscale atmospheric forecast model, and is driven along its open boundaries by tides and climatological estimates of temperature, salinity, and transport. The spatial resolution of the model varies from approximately 20km offshore to about 10km nearshore.

5. Future Science and Application Areas

Spill Response (SR)/Search-and-Rescue (SAR): Both the SR and SAR applications require information on particle trajectories, dispersal rates, and turbulent dispersion, together with error estimates. We have communicated with NOAA HAZMAT (SR) and USCG (SAR) for us to understand their needs and for them to understand our capabilities. In particular, we have conducted experiments with the USCG deploying groups of several their drifting buoys off Key West and tracking them downstream in and near the Florida Current and making comparisons to our model-predicted trajectories and dispersal rates.

Ecosystem Models: We are collaborating with colleagues of the National Marine Fisheries Service to study and quantify the transport of larvae of selected species on the SAB (see Lagrangian Modeling section of this report) shelf. This effort considers the model flow fields in relation to the design of Marine Protected Areas (MPAs). Additionally, exploratory studies have been carried out extending model solutions in the EFS to include a nutrient-phytoplankton-zooplankton-detritus (NPZD) ecosystem model, that has been partially validated through comparison of simulated phytoplankton fields to MODIS color imagery, representing chlorophyll-a concentrations (Fiechter and Mooers, resubmitted). Modeling efforts at USF are ongoing in the Monitoring and Event Response for Harmful Algal Blooms (MERHAB) and Ecology and Oceanography of Harmful Algal Blooms

(ECOHAB) programs. ECOHAB is focused on detection methodologies for HABs and their toxins, understanding of the causes and dynamics of HABs, developing forecasts of HAB growth, transport and toxicity, and predicting and ameliorating impacts on higher trophic levels and humans. One concern, in each of these case studies, is the difficulty in initializing and validating ecosystem models with appropriate observations. We need to continue to work with the Observational WG to address this. While satellite imagery might be the only data available at this point, in-water capabilities are essential.

Wave Models: Several approaches are available to model waves (high frequency, deep water gravity waves) including WAM and SWAN which are 3rd generation spectral wave prediction models that do not introduce assumptions on the spectral shape. Examples from the Global WW3 forecast can be found at https://www.fnmoc.navy.mil/PUBLIC/WAM/wam.html.

Although the agreement of most wave models with lab experiments is good, fundamental questions remain. For example, wave-current interactions, e.g., as can be expected between the Gulf Stream and waves traveling from the open ocean onto the shelf regions is not well understood. Going to 1km resolution has a big computational constraint that should be addressed before proceeding with making the wave model part of SEACOOS. Despite these issues, the message appears to be that the community can model waves "reasonably well'. One possibility being considered is, instead of running our own wave modeling system, 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. There is also a new opportunity of using the Mellor and Donelan (2006) coupled circulation and wave modeling approach.

Sediment transport models: Establishing wave modeling capabilities (directly within SEACOOS or indirectly through collaborative efforts) would improve estimates of bottom stress in the circulation models and allow for estimates of sediment transport. Regarding to the latter, it may be desirable to collaborate with USGS's efforts to establish a National Community Sediment Transport Model (NCSTM). A description of the effort is given in http://woodshole.er.usgs.gov/project-pages/sediment-transport/, which includes among its goals to advance instrumentation and data analysis techniques for making measurements to test and improve sediment-transport models, advance software analysis and visualization tools that support model applications, and apply sediment transport models to benefit regional studies – each of which is complementary to SEACOOS objectives and approaches.

7. References (the references to the PhD theses of Alfredo, Brian and Karen still need to be included)

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