A Northeast Atmosphere-Ocean Model System

R. Beardsley (WHOI); C. Chen and G. Cowles (University of Massachusetts – Dartmouth);B. Colle (Stony Brook University);
J. Edson (University of Connecticut); D. Haidvogel and J. Wilkin (Rutgers University)

SMAST-UMASSD

I. Introduction

In response to the spring 2005 NSF ORION Ocean Observatory Initiative (OOI) request for assistance, we submitted a detailed conceptual proposal for a Northeast regional state-of-the-art coupled Atmosphere/Ocean Model System (NEAOMS) for the Gulf of Maine/Mid-Atlantic Bight region (Scotian Shelf - Cape Hatteras) to study the coupled atmosphere-ocean behavior under a variety of conditions.

Our primary scientific goal is to use NEAOMS and the unique suite of new marine boundary layer and ocean measurements being proposed for the Northeast as part of the ORION OOI and IOOS efforts plus the suite of existing high-quality in-situ data being collected to develop a much deeper and quantitative (predictive) understanding of the physical processes governing strong winter storms (especially "Nor'easters" and hurricanes) and the response of the coastal ocean to such strong surface forcing. Our secondary scientific goal is to provide accurate high-resolution hindcasts and forecasts of the marine surface weather and coastal ocean physical state via the web for broad research, education, and public use.

This poster presents a brief description of NEAOMS, its core components, the proposed structure of data and model centers, and estimates of the computing and data storage resources that would be needed in the model center. Hopefully these infrastructure estimates will help guide discussion about the level of computing and storage resources needed to construct an operational model center for the Northeast.

II. NEAOMS

NEAOMS will feature four core models: (a) the next-generation community Weather Research and Forecast (WRF) model, (b) the Rutgers Regional Ocean Model (ROMS) and UMass-D Finite-Volume Coastal Ocean Circulation Model (FVCOM), and (c) the community surface wave model SWAN (Fig. 1). WRF will forecast the marine weather and produce the surface forcing that in part forces the ocean models (ROMS, FVCOM, and SWAN), with feedback to WRF as the ocean modifies the ocean surface temperature, air-sea fluxes, and atmospheric marine boundary layer. The core models exist (WRF, ROMS, and FVCOM are in intensive use in the region) but need integration and some improvement in model parameterizations and data assimilation methods for accurate near-real-time forecast and hindcast operations.

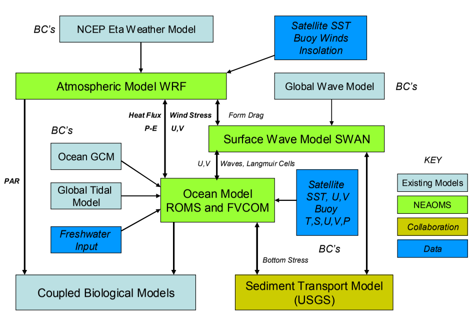

Fig. 1 NEAOMS Structure

Atmospheric Component

We propose to implement the Weather Research and Forecast (WRF) Modeling System as the high-resolution mesoscale atmospheric model in NEAOMS. WRF is a fully compressible nonhydrostatic finite-volume model designed for simulation with a horizontal resolution of 1–10 km. Although still in development, WRF builds upon the strengths of MM5 and provides a framework that takes advantage of recent advances: (a) WRF's governing equations are written in flux form to ensure conservation of mass, dry entropy, and scalars; (b) WRF uses an Arakawa C grid to gain better accuracy in simulations with higher resolution; and (c) WRF is coded in modular form, with separate modules for the different physical processes. We plan to improve WRF's usefulness over the Northeast coastal ocean through the following modifications: (a) assimilation of all available regional land and buoy wind data; (b) use of satellite and ocean model data to improve the SST boundary condition; (c) inclusion of advanced air–sea flux bulk formula (e.g., the COARE 3.0 algorithm, Fairall et al., 2003); and (d) addition of a wave boundary layer (WBL) module to include the effect of waves on vertical exchange when WRF is coupled to SWAN.

Ocean Component

We chose to feature ***two*** ocean circulation models in NEAOMS - the Rutgers Regional Ocean Model System (ROMS) and the UMass-D Finite-Volume Coastal Ocean Model (FVCOM) – for the following reasons (Fig. 2). First, both models feature the same basic physics and turbulent mixing options, the terrain-following sigma coordinate, either grid nesting (ROMS) or an unstructured grid (FVCOM) to improve horizontal spatial resolution where needed, excellent local and global conservation of momentum and scalars, data assimilation, and advanced coding optimized to run efficiently on multi-processor computers. Second, both models converge to the same solutions as spatial resolution is increased. Third, both models are in intensive use in NSF and other funded studies in the Northeast and have talented development/user groups dedicated to critical and impartial model evaluation versus data, model improvement, and the use of these models to address critical research and applied problems. Fourth, either model can be used to provide initial and boundary conditions to the other model, thus making it feasible for different users to choose either model for their specific application. Last, both ROMS and FVCOM groups are working hard on determining the best approaches to specifying the "upstream" and open ocean boundary conditions required for the NEAOMS domain.

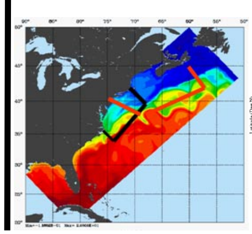

Fig. 2A ROMS Northeast Northwest Atlantic (NENA) model domain and nested ROMS MAB (black) and FVCOM GOM (red) domains.

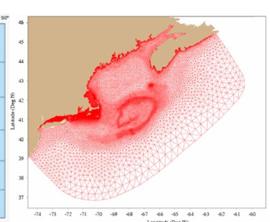

Fig. 2B The unstructured grid of GoM/GB FVCOM, with current horizontal resolution of 0.5-1.0 km on GB and 0.5 km near the coast.

SWAN

The surface wave model SWAN is optimized for use in coastal applications through the inclusion of a depth-induced wave breaking and three-wave interaction in the source/sink term for wave growth, and can be nested with the global wave model WAM to provide its boundary conditions. Proposed improvements to SWAN include (a) convert SWAN into a finite-volume model version with an unstructured grid so that it can run on both ROMS and FVCOM grids; (b) develop a source term formulation for SWAN that is consistent with the flux parameterizations used in WRF; (c) develop modules for WRF to simulate the effect of waves on vertical exchange; (d) include in ROMS and FVCOM the influence of surface wave energy dissipation (computed in SWAN) on the turbulent kinetic energy distribution and mixing in the upper ocean; and (e) use ROMS and FVCOM to provide the surface currents required by SWAN to accurately simulate wave propagation and wave–current interactions.

III. NEAOMS Data and Model Centers

NEAOMS will feature a distributed data center concept with a single central model center (Fig. 3) to (a) efficiently collect the data required to run and evaluate the NEOAMS coupled core models, (b) prepare these data for use in model forecast and hindcast operations, (c) run the model forecasts and hindcasts, (d) serve the model results, and (e) store and archive the model input/output/working/restart files. The function and infrastructure requirements of the data and model centers are described next.

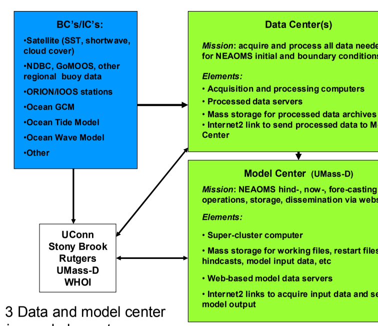

Fig. 3 Data and model center mission and elements

Data Centers

Data Center (PI)	Data
Stony Brook (Colle)	NCEP, NDBC, ORION, IOOS and other surface weather and wave data required to initialize and run WRF with assimilation
UConn (Edson)	ORION, IOOS, and other data involving in-situ direct measurements of air-sea fluxes and MABL structure
Rutgers (Haidvogel/ Wilkins)	ORION, IOOS, NEOS surface radar, and other oceanographic data needed to initialize and run (with assimilation) the ROMS/FVCOM models and the basin-scale GCM model data needed to specify the ocean open BC's
UMass-D (Chen/Cowles)	Satellite data (e.g., SST, insolation) and other data that need human processing and evaluation before operational use
WHOI (Beardsley)	ORION, IOOS, Canadian, and other oceanographic data needed for evaluation of model hindcasts and scientific study

Model Center

The model center will function as a model development, validation and operation unit to (a) integrate the observational data into the coupled model systems for both hindcast, assimilation, and forecast operations; (b) disseminate model results via the web; (c) store and archive all model input data, restart files, hindcasts; (d) help guide the design of the optimal adaptive observational network; (e) provide a center for training students and postdoctoral researchers in both atmospheric and oceanic modeling. This model center will be built on the existing coastal ocean modeling laboratory at UMass-D, which will be equipped with a high-performance 256-processor Linux cluster this August. This new computer will be sufficient for hindcast and forecast operations for the GoM region (e.g., a 1-yr model run with data assimilation and the existing GOM/GB FVCOM grid (Fig. 2B) should take less than 1-day clock time), but additional equipment must be added to extend the modeling effort to cover the entire Northeast coastal region with the proposed NEAOMS.

To estimate hardware requirements, we envision two distinct scenarios: (a) 3-day forecast to be completed in a period of four hours, and (b) 7-day hindcast to capture a specific event (e.g. the passage of a Nor'easter). The hindcasts will be used for parameterization evaluations and will include data assimilation. A wall clock time of two days is chosen for these hindcasts because it represents the practical limit for repetitive calculations. The required number of processors reflects current generation commodity chips such as the Intel Xeon EM64T family. Estimated computing and disk space requirements are shown in the following tables.

3-Day Forecast: Computing Requirements

Model	Grid Size (Horiz)	Grid Size (Vert)	#Processors
FVCOM GOM/GB	100000 elements	31	8
FVCOM MAB	100000 elements	31	8
ROMS North Atlantic	1000000 nodes	31	12
WRF GOM/MAB	30000 nodes	31	48
Coupled Model			76

7-Day Hindcast: Computing Requirements

Model	Grid Size (Horiz)	Grid Size (Vert)	#Processors
FVCOM GOM/GB	100000 elements	31	8
FVCOM MAB	100000 elements	31	8
ROMS North Atlantic	1000000 nodes	31	4
WRF GOM/MAB	30000 nodes	31	10
Coupled Model			30

Storage Requirements for Forecast/Hindcast Simulations

Model	Hourly Output (MB)	Restart Data (MB)
FVCOM GOM/MB	60	600
FVCOM MAB	60	600
ROMS	350	1800
WRF	60	300
Total Daily	13000	3900

Based on model hardware requirements, 106 processors are required to run the forecast and hindcast simulation scenarios simultaneously. The total daily archived output is roughly 17 gigabytes. In order to meet these requirements while maintaining an allowable margin for potential increase in model size, the model center would need to contain at least 64 dual processor servers connected by a high speed network such as Myrinet or Infiniband. A storage array containing 30 Terabytes of usable space would allow the storage of three full years of hourly forecast output in addition to several datasets from hindcast experiments. This data would be served to scientists at other institutions by a DODS/OPeNDAP server through UMass-D's Internet2 connection. A 200 gigabyte tape drive system would be used to archive older datasets.