Development of an Ocean Model for COAMPS

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LONG TERM GOALS

The long-term goal is to develop a fully-coupled, mesoscale, atmosphere-ocean prediction system that can be used over any given area of the world. This is to be accomplished by coupling a full-physics, mesoscale ocean model to a mesoscale atmospheric forecast model; developing, testing, and evaluating software for the necessary supporting infrastructure; and by leveraging related programs to develop an ocean data assimilation capability. This prediction system will be the cornerstone of a vertically integrated program such that it will be used for basic and applied research to study forecast problems in which coupling may be important and it will also be transitioned to operations to address those situations in which coupling is found to make a significant positive impact on mesoscale forecasts of the atmosphere and/or ocean.

OBJECTIVES

The main objectives of this project are to:

1. *Study the methodologies for coupling a mesoscale ocean model to a mesoscale atmospheric model.* This will include studies of issues that include, but are not limited to: one-way vs. two-way interaction, frequency of coupling, and the relative importance of air-ocean energy exchanges between the atmosphere and the ocean.

2. *Develop techniques to allow for a mesoscale ocean model to incorporate tendencies from a global ocean model.* The techniques that have been developed and used successfully to allow atmospheric global forecast tendencies to be used in atmospheric mesoscale models will be applied to the ocean models.

3. *Develop techniques to ensure that the coupled ocean-atmosphere system is relocatable to any region over the world.* Currently, the uniqueness and slope of the bathymetry for any given area; the availability of data, particularly synthetic observations; and the lack of a full-physics global model present the largest problems in relocating a mesoscale ocean model to any given location.

4. *Test and validate the coupled prediction system over a number of areas and over a variety of weather/ocean phenomena.* The purpose of this testing will be to establish under what conditions coupling is necessary, and whether the systems need to be loosely- or tightly-coupled.

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APPROACH

Our approach is to utilize existing atmosphere and ocean models as the basis for the goals and objectives of this project. The nonhydrostatic atmospheric model contained in the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) will be used to provide all atmospheric forcing to the ocean models. Two existing ocean models have been coupled to the atmospheric model in COAMPS. These are the Modular Ocean Model (MOM), and the Princeton Ocean Model (POM). The MOM and POM models represent the state of the art for mesoscale ocean models. MOM uses a z-coordinate in the vertical while POM uses a sigma vertical coordinate system. Both models are currently in use by many researchers around the world. The NRL Coastal Ocean Model (NCOM), currently being developed at NRL SSC as part of this joint program, is currently being coupled to the atmospheric model in COAMPS, and the effort involving MOM is being dropped. The NCOM uses a hybrid sigma/z vertical coordinate, and therefore, may be more appropriate in those locations where steep bathymetry poses a problem for the standard sigma coordinate, as in the POM. The POM will be used as a baseline for the initial NCOM forecasts, and we expect to transition completely to NCOM over time. The coupled work with POM is being performed by Dr. Paul May (contractor with Anteon), and the coupled work with MOM and NCOM is being performed by Dr. Xiaodong Hong, (post-doc at NRL MRY). Dr. Paul Martin (NRL SSC), the developer of NCOM, assists with the implementation and testing of this model. The development of the COAMPS atmospheric model is supported under the NRL MRY base program.

WORK COMPLETED

1. Code has been developed and tested that allows for the generation of a bathymetry field for any of 5 different grid projections (Mercator, Polar stereographic, Lambert Conformal, Spherical, and Cartesian) for any area over the world. Currently, this code utilizes a 5’ global bathymetry database.

2. A general coupling strategy has been developed that allows for each model to use it's own resolution and time step, and allows for an arbitrary coupling interval.

3. The following steps have been taken to couple ocean models to the COAMPS atmospheric model:
   a. The MOM has been coupled to the COAMPS atmospheric model and initial testing regarding the effects of coupling on tropical cyclone track and intensity forecasts has been performed.
   b. The original POM code has been modified for more general use (e.g., included the latest version of turbulence mixing, added code to allow for horizontally nested grids), and this version of POM has been coupled to COAMPS.
   c. NCOM has been delivered from NRL SSC to NRL MRY and is being coupled to the COAMPS atmospheric model.

RESULTS

A series of atmosphere-ocean coupled and uncoupled simulations have been performed for Hurricane Opal, using the atmospheric model from COAMPS and MOM. Both models used a spherical grid with 0.2 degree horizontal resolution. The initial conditions for MOM were generated by doing a 2-year global spin-up with MOM using climatological forcing. The resulting sea-surface-temperature (SST) field for the initial time of the Opal forecast was adjusted so that the mean over the grid matched the observed SST used as the initial conditions in the uncoupled run. The structure of the spin-up fields represented the observed warm-core eddy (WCE) in the Gulf of Mexico in both its position and its intensity.

Both the coupled and uncoupled runs captured the rapid intensification of Opal as it crossed the WCE. However, the uncoupled simulation better represented the actual minimum pressure attained by the cyclone. The central pressure in the coupled run was about 5-8 mb higher than in the uncoupled simulation at the time of the lowest observed pressure. This difference is attributed to the colder SST in the vicinity of the tropical cyclone due to both the mixing and the upwelling of colder subsurface water. Significantly larger differences were found using the unadjusted SST field from the global spin-up as initial conditions for the Opal simulations. The adjustments were on the order of 2C, indicating that the specification of an accurate initial SST was more important for this simulation than the time evolution of the SST over the 48 h forecast period.

Several changes were made to POM. These include the introduction of improved numerical algorithms and an improved method for the computation of the pressure gradient force and density. Dynamic arrays and a nested grid option were built into the system for added capabilities and for consistency with the COAMPS atmospheric model. The revised model was benchmarked on several computers, including Cray, Sun, SGI, and Windows NT systems. Work has been started to test POM and NCOM over the Mediterranean Sea using atmospheric forcing from the COAMPS 27 km Mediterranean area that is operational at FNMOC.

IMPACT

The development of a fully-coupled atmosphere-ocean prediction system is considered to be the cornerstone for studies of air-ocean research. An analogy can be drawn to the development of the atmospheric component of COAMPS. This system is now used for a variety of basic research topics, such as topographic flows, fetch-limited flows, littoral phenomena, and convection. COAMPS is also used for applied research, including real-time forecasts for field experiments such as COAST, CALJET, and LABSEA. In addition, COAMPS has been transitioned to the Fleet Numerical Meteorology and Oceanography Center (FNMOC) for operational mesoscale forecasts for four areas over the globe. It is expected that the development of a fully-coupled atmosphere/ocean COAMPS in this program would enable an expansion of the types of mesoscale studies that can be done in 6.1, an expansion of the 6.2 applications of the system, and improved operational mesoscale forecasts. The use of fully-coupled atmosphere-ocean prediction systems will not come without a price. The addition of a full-physics ocean model to the existing COAMPS atmospheric model approximately doubles the required memory and increases the total time to complete a given forecast by approximately 15%.

TRANSITIONS

The addition of an ocean component of COAMPS could be included in our cooperative research with universities (e.g., University of Oklahoma, North Carolina State University) and other agencies (e.g., Lawrence Livermore National Laboratory, Central Intelligence Agency, Defense Special Weapons Agency) that we currently support with the atmospheric component of COAMPS.

RELATED PROJECTS

The fully-coupled COAMPS is expected to be used in related 6.1 projects within PE 0601153N, which include studies of fetch-limited flows, in related 6.2 projects within PE 0602435N, including BE-35-2-18 which focuses on the development of the atmospheric component of COAMPS, BE-35-2-19 which focuses on the importance of satellite data on the prediction of tropical cyclones, and 035-23 which focuses on the study of the effects and feedbacks that occur between the atmosphere and the ocean. A related 6.4 project within PE 0603207N is X0513-02 which focuses on the transition of COAMPS to FNMOC. Another 6.4 project, within PE 0603785N is 0120-ADV which focuses on the development of an ocean data assimilation system for COAMPS.

PUBLICATIONS

Hong, X., S.W. Chang, S. Raman, L. K. Shay, and R. M. Hodur, 1998: The interaction between hurricane Opal (1995) and a warm core eddy in the Gulf of Mexico. Submitted to *Monthly Weather Review.*

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