ATMOSPHERIC MODELS
PE 0602435N (NRL BE-035-02-18)

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LONG TERM GOALS:

To better understand atmospheric dynamics, physical processes and air/sea/land/aerosol interactions, and to use this knowledge to develop improved modeling systems for objectively analyzing and predicting atmospheric structures from the global to the local space and time scales. The ultimate goal is to increase the Navy's numerical prediction capability for global and mesoscale weather.

OBJECTIVES:

To advance global medium-to-extended range forecast skill, thereby supplying improved time-dependent boundary conditions and background analyses in support of ocean/ice/wave, mesoscale weather, and coupled air/ocean systems. To develop mesoscale numerical prediction systems for littoral areas that depict the atmosphere at horizontal resolutions of 10 km or less; that can run on central site mainframes, as well as on remote workstations in some reduced capacity; and that interface to environmental decision aids. The objectives for both the global and mesoscale predictive systems require the development of improved numerical techniques and better physical parameterizations of vertical mixing, radiation, clouds, and precipitation; inclusion of predictive capacity of aerosols; coupling to ocean, ice, and wave models; and improvement to the treatment of surface parameters. Below 10 km resolution, we must also develop and improve techniques for the explicit treatment of moist processes and provide a more sophisticated treatment of the ground hydrology.

APPROACH:

The research focuses on the development of a hierarchy of numerical models to address the global to mesoscale range of atmospheric processes. Considerable ongoing development at weather forecast centers worldwide is leveraged to allow the Navy to remain at the forefront of weather prediction skill, while focusing in-house development on regions and processes of special relevance to the Navy and other DOD users (e.g. air-sea interaction, EM/EO propagation conditions, cloud prediction, etc.). Model development is undertaken in close coordination with Fleet Numerical Meteorology and Oceanography Center (FNMOC) to provide the computational and data environments encountered by operational numerical weather prediction.

Model development is focused in several areas of research and development in numerical weather prediction. Improved numerical methods, such as semi-Lagrangian advection and improved vertical differencing, are under development. New horizontal differencing methods for spherical geometries are being investigated, which are more efficient for the massively parallel computers of the future. This

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project has been the vehicle for the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS), the Navy Operational Regional Atmospheric Prediction System (NORAPS), and the Navy Operational Global Atmospheric Prediction System (NOGAPS) parameterization research. An advanced land surface flux scheme, a relaxed Arakawa-Schubert cumulus parameterization with downdrafts, cloud prediction, advanced planetary boundary layer, and new radiation parameterizations have been developed. An additional major focus of the project is on the identification of deficiencies in the representation of specific atmospheric processes. The new and powerful adjoint technique provides information of the sensitivity of forecast errors to initial conditions and parameterization parameters. Under this project, adjoints have been developed for both the global (NOGAPS) and mesoscale (COAMPS) models.

WORK COMPLETED:

The global numerical prediction research has concentrated on identifying systematic errors, improving the existing parameterizations, and developing new numerical methods to replace the spectral dynamical formulation. A major effort is underway to identify deficiencies in the various components of the parameterizations. Work has begun on implementing a semi-Lagrangian advection scheme into NOGAPS. Major work is continuing in improving the surface flux, vertical mixing, cumulus convection and radiation schemes. Conference and journal articles have been written and submitted, which include the development of NOGAPS' adjoint, mechanisms for improved cumulus convection, tropical cyclone forecasting, and numerical methods on geodesic grids. The advanced surface flux parameterization, semi-Lagrangian moisture advection, new solar and longwave radiation parameterization have been transitioned to 6.4.

In mesoscale research, the following tasks were performed: testing of a biospheric model in COAMPS that includes a multi-layer soil model, evapotranspiration, and an improved specification of surface vegetation parameters; development of a local fast FFT radiative upper boundary condition for improved numerical simulations in complex topography; improved COAMPS vertical mixing to reduce surface temperature and moisture biases; and reduced memory requirements in COAMPS forecast model by 10%. Testing began on a variational adjustment initialization technique to minimize height biases in the mid- to upper-troposphere.

For the coastal marine planetary boundary layer research, an extensive study of a southerly surge event which occurred during COAST 94 was conducted. The southerly surge is a wind reversal along the west coast during which warm, off-shore winds are replaced by a cooler, moist southerly flow. The research on this event involved careful analysis and comparison of COAMPS forecasts with observed surge features. A journal article on this topic has been recently accepted for publication (Thompson et. al, 1997). This material was presented at several conferences and featured on the Mesoscale Conference cover. A journal article on mesoscale refractivity variability in the southern California bight has also been recently published based on research in this work unit. Extensive coordination and collaboration was established with participants in the ONR COAST 96 field experiment. Studies of flow features, particularly low-level jets, in the vicinity of points and capes are on-going.

RESULTS:

The use of a newly developed treatment of mixing lengths and computation of surface fluxes in the stable boundary layer has led to improved forecast skill in NOGAPS. The use of a Direchelt type boundary condition for the momentum at the top of the model was found to dramatically increase the stability of NOGAPS, when compared to a Neumann boundary condition, particularly in the region of the polar night jet.

Simulations with COAMPS indicated that surface winds could be numerically predicted on scales finer than the average data density, particularly in littoral regions and areas with significant topographic features. Mesoscale cloud patterns, forced by these surface wind features, were also predicted in a limited number of cases. Specific examples of COAMPS ability to accurately predict coastal phenomena were demonstrated by comparing data collected from COAST 96 aircraft flights near Cape Mendocino to COAMPS low-level jet simulations.

IMPACT:

The improvements to NOGAPS have resulted in improved forecast capabilities, particularly evident in the prediction of the tropical cyclone track. NOGAPS is now recognized internationally for its ability to predict tropical cyclone development and subsequent motion.

The capability of COAMPS to predict forced circulations over tactical-sized areas has made it a popular choice for many real-time and historical applications. The real-time applications include the COAST 96 program and the Labrador Sea experiment in 1997. COAMPS has also been used to construct reanalyses over the Persian Gulf area in support of the project to study Gulf War Illness.

TRANSITIONS:

Model developments from this project are transitioned to existing 6.4 programs within PE 0603207N. COAMPS has been transitioned to many other sites, including the Air Force Research Laboratory, The Army Research Laboratory, Goddard Space Flight Facility, Lawrence Livermore National Laboratory, the Naval Postgraduate School, North Carolina State University, and the University of Oklahoma.

RELATED PROJECTS:

This atmospheric model development effort is part of our vertically integrated program for basic (6.1) and advanced (6.2) research as well as transition to operations (6.4). Related 6.1 projects within PE 0601153N include aerosols, tropical cyclones, and predictability (BE-033-02-45); coastal mesoscale processes (BE-033-03-4K); and air-ocean coupling (031-03). Related 6.2 projects within PE 0602435N include data assimilation and tropical cyclone studies (BE-35-2-19); the use of radiances in data assimilation (BE-033-2-32); aerosol modeling (BE-35-2-20); use of radar data for data assimilation, programming for distributed memory computers, and on-scene modeling (035-71); and coupled modeling (035-23) . Related 6.4 projects under PE 0603207N includes NOGAPS (X0513-01) and COAMPS transitions (X0513-02).

The atmospheric model development effort of this project is coordinated with the Air Force Ressearch Laboratory and the Army Research Laboratory with NRL as the lead laboratory, as formally described in Project Reliance, NAVAF Agreements, and TAP. FNMOC is a close partner in model transition, data base, and configuration management. There are a number of NRL interdivisional collaborations in coupled model development, application of remote sensing data, and numerical methods and an MOA is in force between NRL and Lawrence Livermore National Laboratory in collaborative research and application of NORAPS and COAMPS. MOA's for collaborative research on COAMPS are in place with North Carolina State University and the University of Oklahoma. In demonstration efforts, we are in partnership with SPAWAR, NAVCENT, and FNMOC.

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Thompson, W.T.,T. Haack, J.D. Doyle, and S.D. Burk, 1997: A nonhydrostatic mesoscale simulation of the 10-11 June 1994 coastally-trapped wind reversal, Mon. Wea. Rev., 125, to appear Dec.