Moist and Boundary Layer Physics

Jerome M. Schmidt and Stephen D. Burk
Naval Research Laboratory
Monterey, CA 93943-5502
Ph (831) 656-4702/Fax (831) 656-4769
Schmidt@nrlmry.navy.mil
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LONG-TERM GOALS

Improve the understanding of cloud and boundary layer processes within the littoral through the use of the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) and relevant observations. Improve the moist and boundary layer physics schemes used in COAMPS based on knowledge gained through extensive testing and verification of high-resolution (1-20 km horizontal grid spacing) numerical simulations in the littoral.

OBJECTIVES

Develop scientific knowledge on the dynamics of boundary layer processes and stratiform, coastal orographic, and meso-convective cloud systems. Evaluate the impact of these processes on regional-scale forecasts and weapon and sensor systems used by the Fleet. Evaluate model biases in moisture, precipitation, and cloud coverage forecasts in regions of complex coastal orography using case study analyses and real-time forecasts of observed events. Use explicit cloud simulations to test and make improvements in the computationally efficient bulk microphysical and cumulus parameterization schemes currently used in high-resolution (1-20 km horizontal grid spacing) COAMPS forecasts. Complete term-by-term analyses of the boundary layer forcing terms in COAMPS and assess model biases in boundary layer structure such as predicted boundary layer depth, vertical stability and moisture profiles, and EM/EO characteristics. Improve boundary layer physics schemes used in COAMPS based on testing and model verification with relevant observational and numerical data bases.

APPROACH

Tests of the cumulus parameterization and bulk microphysical schemes will be made for a variety of geographical and meteorological conditions to gauge the model's performance against verifying data for a broad spectrum of observed and modeled stratiform and meso-convective cloud systems. It is the intent to examine the model-derived cloud structure, evolution, and cloud/environmental feedback processes using high-resolution, nested simulations initialized with either real data or idealized thermodynamic and vertical windshear profiles derived from case studies or previously published cases. Results from explicit cloud simulations will be used to gauge the quality of and make improvements in the computationally efficient bulk microphysical and cumulus parameterization schemes currently used in high-resolution (1-20 km horizontal grid spacing) COAMPS forecasts. For the boundary layer processes, we will utilize special data sets which permit validation of individual terms that are parameterized within COAMPS. All terms contributing to the surface energy budgets of momentum, heat, and moisture will be examined and test of new approaches will be conducted where warranted.

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The COAMPS parameterizations above the surface layer will also be assessed using field experimental data sets; improvements will be sought as necessary.

WORK COMPLETED

We identified two factors contributing to the over-prediction of low-level clouds in the littoral and open ocean areas in the COAMPS model. We successfully replicated known meso-convective cloud dynamical behavior using high-resolution explicit cloud simulations in COAMPS. We also improved the ice nucleation processes, the convective trigger function, and participated in the well-observed California Landfalling Jets Experiment (CALJET). COAMPS has been extensively validated using data sets from the ONR-sponsored COAST and Coastal Waves 1996 field experiments.

RESULTS

Numerous COAMPS simulations with real data have shown that the model tends to over-predict the low-level cloud cover over the open water. The problem was traced to the choice of thermodynamic variables used to formulate the vertical mixing coefficients and to the vertical grid stagger. Initial tests using the equivalent potential temperature in the mixing calculation showed a significant reduction in the overall model predicted cloud cover over the open water when compared to the original virtual potential temperature formulization used in COAMPS. These tests remain somewhat preliminary and further tests are being conducted to determine if the use of the equivalent potential temperature is best under all circumstances. It was also discovered that the averaging used to calculate the vertical temperature lapse rate at the mass points in the vertical grid stagger could mask shallow unstable layers. This was a problem near the top of well-mixed layers capped by shallow, one-level cloud layers. A recommended solution for this problem is to calculate the mixing at the model momentum points directly. Tests have also indicated that the implicit vertical diffusion has a strong tendency to vertically mix vapor and cloud mass well beyond the regions in which they were initially diagnosed. This tendency may have an undesired impact on the overall moisture budget between the various microphysical species. Further testing is being conducted to determine what possible solutions may be derived to correct the excessive vertical mixing of the modeled moisture parameters.

Tests were also performed on the COAMPS explicit cloud prediction using horizontal grid spacings on the order of 2km. The tests successfully replicated known cloud dynamical behavior in the weak and strong vertical wind shear regimes. This step will help pave the way for further work incorporating dynamic initialization and test results to be obtained between the implicit and explicit cloud prediction schemes. Software was developed and/or enhanced to perform moisture verification with real data and to conduct term-by-term analyses of the moisture budget within the model. The model was also run for the CALJET experiment during a six-week period between January and March of 1998. Initial case studies have been selected for further analyses. Modifications were also made to the ice nucleation processes used in the explicit microphysics package. Finally, the Kain/Fritsch convective scheme has been tested in a tropical environment. Initial simulations have shown that this scheme strong over-predicts convection over the open water. This problem has been traced to the convective trigger function. A modified trigger function was developed for use over the open water that significantly reduced the areal coverage of implicitly resolved convection over water. The modified scheme is currently undergoing testing and evaluation.

In terms of the boundary layer (BL) component of the work unit, COAMPS forecasts were produced for the full two-week period of the Variability of Coastal Atmospheric Refractivity (VOCAR) experiment. The extensive set of special VOCAR raobs was used to validate COAMPS BL forecasts and test methods to improve the forecasts. Model biases in BL depth and BL humidity were found to be sensitive to vertical resolution. Substantial improvement could be attained by a modest redistribution of the grid levels that results in better BL resolution. Also, The so-called "COARE algorithm" for computing over-water surface fluxes, developed over many years as part of an international effort, is being tested within COAMPS as a potential upgrade to the current Louis (1979) surface parameterization scheme. A program of testing a column model version of COAMPS against numerous published test cases of other boundary layer and LES codes has been initiated. Also, the impact of coastal orography on EM propagation conditions is under investigation.

IMPACT/APPLICATIONS

The littoral is considered the most important and challenging region for conducting military operations. Part of the challenge stems from the need for accurate prediction of the weather parameters (such as cloud ceiling, visibility, EM/ and E/O conditions, etc.) that impact naval forces in the littoral.
The desire from the fleet for detailed forecasts of clouds and boundary layer parameters in the littoral is leading to mesoscale model simulations run at increasingly fine horizontal resolution (model grid spacing on the order of 1-20 km). It is at such scales where the proper treatment of boundary layer processes and stratiform and meso-convective cloud systems play an increasing role in the overall accuracy of the short-term (0-36 hour) mesoscale forecasts used in the Strike Warfare and general Naval operation decision making process. Currently there is no deterministic method for providing or quantifying the overall accuracy of the cloud and boundary layer parameter forecasts to the tactical decision makers. This project addresses these needs through a greater understanding of the relevant cloud and boundary layer dynamics and through evaluation of the Coupled Oceanic and Atmospheric Mesoscale Prediction System (COAMPS) moisture and boundary layer schemes that will be used to derive the required atmospheric tactical parameters.

TRANSITIONS

Improvements to COAMPS that result from this research will transition to 6.4 (PE 0603207N, task X-0513, SPAWAR PMW-185) for incorporation into the operational COAMPS forecast model.

RELATED PROJECTS

Related 6.2 projects within PE 0602435N are award numbers, N0001498WX30165 (COAMPS improvements for on-scene modeling), N0001498WX30166 (development of radar data assimilation techniques), and N0001498WX400008 encompassing the following NRL base projects: BE-35-2-18 (mesoscale model development) and BE-35-2-19 (data assimilation technique development). The related 6.4 projects under PE 0603207N, X0513 are STAFC and Mesoscale Atmospheric Models.

PUBLICATIONS

Rogers, D.P., C.E. Dorman, K.A. Edwards, I.M. Brooks, W.K. Melville, S.D. Burk, W.T. Thompson, T. Holt, L.M. Strom, M. Tjernstrom, B. Grisogono, J.M. Bane, W.A. Nuss, B.M. Morley, and A.J. Schanot, 1998: Highlights of Coastal Waves 1996. *Bull. Amer. Meteor. Soc.*, **79**, 1307-1326.

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