Remote Sensing And Prediction
Of The Coastal Marine Boundary Layer

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LONG TERM GOALS

The long-term goal is to improve numerical (computer-aided) weather prediction in coastal regions, especially of weather events that impact naval operations.

OBJECTIVES

We seek to forecast weather events in the right place at the right time. The weather events of primary concern are convective storms, boundary layer clouds and drizzle. A measurement of our success could be improved forecasts by the USN's mesoscale model COAMPS.

APPROACH

Approaches using the USN's mesoscale weather forecast model COAMPS are:

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1. COAMPS forecasts, with alternative land surface schemes, are to be compared with data from the new Oklahoma Atmospheric Surface-Layer Instrumentation System (OASIS), with the aim of improving the COAMPS scheme.

2. A prototype Visually-Aided Data Assimilation (VASA) system is being built to perform critical, but essentially simple, data assimilation tasks. Examples are background (first-guess, forecasted) fields with: (1) a front out of place (a “phase-error”) (2) storms with a phase-error, (3) spurious storms or (4) missing storms. Our strategy will emphasize data-assimilation “First Aid” in a which a human being can rapidly intervene in the forecast-analysis cycle.

3. The cloud analysis system, that has been developed by the Center for Analysis and Prediction of Storms, is investigated for its benefits in COAMPS. The goal of the cloud analysis scheme is to improve cloud moisture fields by using surface, satellite, radar and lightning observations.

4. The positive-definite and conservative Flux-Corrected Transport Scheme is investigated for its benefits in COAMPS.

5. Requirements for forecasting fog and low cloud at the San Francisco Airport are investigated.

6. Data from LES case studies and observations from field programs are used to develop cloud microphysics and radiation parameterizations which will result in more accurate marine stratocumulus cloud and drizzle forecasts.

7. The requirements for an NWP model to simulate mesoscale cellular convection are investigated.

Approaches not using COAMPS are:

8. Further development and testing of single Doppler and dual-Doppler radar data retrieval/analysis and assimilation algorithms.

9. Precipitation and SST from TRMM investigated for possible use in COAMPS.

10. Quasi-inverse method developed for data assimilation of storms.
11.

WORK COMPLETED

1. In a comparison of a two-day COAMPS forecast with OASIS data in June 1999, we again find the simple non-vegetated scheme in COAMPS and the lack of sufficient soil moisture lead to expected errors. Two alternative schemes in COAMPS are investigated, one from the ARPS and one simple adjustment of the COAMPS scheme.

2. The Visually-Aided Data Assimilation System (VADA) is applied to three case studies of severe convective weather in Florida: the events of 23 April 1997, 2 February 1998 and 23 February 1998. A GUI for fixing a phase error in a background field, by manually “morphing” it, has been developed. A key feature of the phase correction and storm surgery is that it operates on the divergence and vorticity fields. Thus spurious horizontal convergence, and spurious vertical

velocity, are not introduced by the morphing. Solenoidal velocity fields of storms can be effectively removed and inserted, but not yet by the GUI.

3. We have added the use of lightning data to the cloud initialization scheme and used cloud initialization in the events of 23 April 1997, 2 February 1998 and 23 February 1998.

4. The Flux-Corrected Transport Scheme is implemented into COAMPS and tested in four “events”.

5. Two low-cloud events on the California coast, and in the San Francisco Bay Area in particular, are forecasted with COAMPS.

6. The CIMMS drizzle parameterization has been implemented into COAMPS. The development of a conceptually new drizzle parameterization based on the full moments of the drop size distribution (DSD) function has been started and coagulation rates for new parameterization have been determined based on the regression analysis of data from LES case studies. The parameterization of the cloud drop effective radius has been developed for drizzling marine stratocumulus.

7. COAMPS is used to make two-day forecasts of an idealized strato-cumulus cloud deck in a periodic domain. Experiments are conducted that isolate factors which lead to the development of mesoscale cellular convection.

8. Upgraded DOWs were deployed in dual-doppler measurements over the Lamont vertical wind profiler. Single and dual Doppler retrievals using earlier data collected by the DOWs were performed.

9. The quasi-inverse method is tested in the ARPS model.

10. Familiarization with TRMM products occurred.

RESULTS

1. The operational COAMPS soil model can be improved, at least over Oklahoma, by either doubling the depth of soil moisture resevoir in COAMPS, or by using the ARPS soil model.

2. VADA, with its current phase correction capabilities, and the storm surgery produced obvious benefits in the initialization and subsequent forecasts of three convective weather events in the vicinity of Florida.

3. The cloud analysis system also produced obvious benefits in the initialization and subsequent forecasts of three convective weather events in the vicinity of Florida.

4. The benefits of the FCT scheme would be significant in COAMPS if boundary layer convection were being resolved, say with a grid on the order of 1 km, or if long-lived boundary layer waves were being modeled. The operational scheme apparently is satisfactory for grid resolutions greater than 8 km. In fact, the operational scheme produces a respectable supercell thunderstorm at 1km resolution.

5. COAMPS can make an accurate 18 hour forecast for the temporal and spatial details of the burn-off of low-cloud in the San Francisco Bay, at least in the two cases that were investigated. What is not known is whether COAMPS would predict fog in cases where it did not occur, or whether it adds skill to other means of predicting the time of burn off.

6. Idealized simulations with the newly implemented drizzle parameterization produce results which agree reasonably well with an LES benchmark thoroughly verified against integrated observations. The important feature of the new drizzle parameterization is its realistic response to variation in the ambient CCN concentration. Boundary layer stability, in-cloud liquid water, and drizzle water content all evolve in a physically consistent manner.The coagulation rates for the new cloud microphysics scheme based on the full moments of DSDs have been determined with an accuracy that is 5-10 times higher than the commonly used autoconversion and accretion rates. The empirical parameterization of the drop effective radius for non-precipitating clouds has been generalized for the case of drizzling marine stratocumulus. It was shown that in the latter case the effective radius may be determined quite accurately if the dependence on higher moments of the DSD is taken into account.

7. The operational COAMPS model does an admirable job at simulating MCC. The time for cell broadening, the dominance of the water vapor fluctuations, and the ultimate generation of cool regions beneath clouds, are all reproduced by the simulations. Questions still remain about whether the agreement is fortuitous. Simulations of a passive scalar in dry convection show broadening beyond what occurs in a high-resolution, primitive-equation model.
8. Single-doppler velocity retrievals can sometimes show regions where surprisingly good results are obtained, but, in general, there exist regions of the flow domain that suffer from problems of solution non-uniqueness. Simulated data test results of a new dual-Doppler analysis procedure have yielded very encouraging results and suggest that use of the anelastic vertical vorticity equation together with the traditional mass conservation constraint can greatly improve estimates of the vertical velocity field.

9. Reversibility of the numerical model, especially with the microphysical processes, is a major problem of the quasi-inverse method.

10. There is a potential opportunity to use the rainfall estimates from TRMM in the cloud analysis scheme. TRMM's TMI & PR and the coincident lightning observations from the TRMM's Lightning Sensor (LIS) will play an important role in coupling the occurrence of lightning to precipitation. Apart from these data sets, TRMM VIRS sensor can provide cloud top temperature, albedo and cloud optical depth. Some of the case studies will be selected according to the availability of TRMM observations. Though the spatial and temporal coverages are infrequent, these data sets will be used with SSM/I and GOES data products.

IMPACT

We expect to be successful in offering to the meteorological community (and to the Navy in particular) improvements for numerical weather prediction of storms, boundary layer clouds and drizzle.

TRANSITIONS

Fortran code for storm surgery, phase correction, drizzle, and FCT advection are now available for use by all COAMPS users. The Fortan2html converter, which was completed last year, has found active use in the UK Met Office.

RELATED PROJECTS

We work closely with the personnel of OU's Center for Analysis and Prediction of Storms, the Oklahoma Climate Survey (Mesonet), and the Marine Meteorology Division of the Naval Research Laboratory.

PUBLICATIONS

CMRP support is acknowledged in 8 refereed publications that have been either accepted or conditionally accepted, and in 24 conference preprints. Three notable papers are:

Fiedler, B.H., 1999: Thermal convection in a layer bounded by uniform heat flux: application of a strongly nonlinear analytical solution. Geophysical and Astrophysical Fluid Dynamics (accepted)
Khairoutdinov, M. F. and Y. L. Kogan, 1999: A large eddy simulation model with explicit microphysics: validation against aircraft observations of a stratocumulus-topped boundary layer. J. Atmos. Sci., 56, 2115-2131.

Shapiro, A., and J. Mewes, 1999: New formulations of dual-Doppler wind analysis. J. Atmos. Oceanic Technol. 16, 782-792.