

High-Resolution Mesoscale Atmospheric Model Prediction and Validation

Sue Chen

Naval Research Laboratory

Monterey, CA 93943-5502

phone: (831) 656-4737 fax: (831) 656-4769 e-mail: chen@nrlmry.navy.mil

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LONG-TERM GOAL

The long-term goal of this work is to explore and test new techniques that can improve the predictive skill of COAMPS, particularly when applied at high horizontal resolution (grid increments less than 10 km). New validation techniques will be developed and used as guidance to improve COAMPS high-resolution forecasts.

OBJECTIVES

One objective of this work is to evaluate the skill of COAMPS coarse and fine-resolution nested grids. New methods of validation for high-resolution mesoscale model forecasts will be explored using conventional and non-conventional observations. The flexibility of COAMPS nested grid applications will be improved including nest initialization, nest relocation, and flexible nest start up time.

APPROACH

For the validation work, our approach is to use COAMPS reanalysis forecast fields created by the Air/Ocean Model and Prediction Systems Development (6.2-CplMeso) project (ONR Award # N0001400WX20704). Several other COAMPS forecasts experiments over the same Mediterranean region are performed for an extended period of time to investigate predictive skill as a function of various characteristics of the prediction system architecture such as the data assimilation update cycle and horizontal resolution. Statistical measures of forecast skill such as bias, mean errors, root mean square errors, standard deviations, and quantitative precipitation are computed using conventional observations (rawinsonde and surface stations). These skill metrics are averaged over a statistically significant period of time to examine the impact of decreasing the horizontal grid increment and the benefit of the mesoscale data assimilation cycle. Non-conventional observations such as satellite, aircraft, and pibal data will be used compute the metrics of predictive skill for high-resolution model validation. To further investigate how accurate the COAMPS high-resolution forecasts are, we will perform and examine detailed COAMPS high-resolution case studies on specific meteorological events that are of interest to the Navy's operations.

The flexibility of COAMPS high-resolution nested grid applications will be improved. Our approach is to implement modifications to COAMPS that will allow the nested grids to: (1) start and terminate at any given time during the forecast, (2) be continually relocated to follow a battleground or a meteorological phenomenon of interest, and (3) to be initialized from another COAMPS forecast

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(rather than from the global model, NOGAPS). Case studies will be performed and the COAMPS reanalysis fields will be used to evaluate the impact of using digital filter initialization methods and silhouette terrain.

WORK COMPLETED

1. We performed two six month (30 Sep 1998 to 1 Jan 1999) COAMPS reanalysis experiments for validation work. These forecasts cover the same geographical area over the Mediterranean area as the COAMPS reanalysis performed by the 6.2-CplMeso project. All of these COAMPS forecasts contain two grid nests with 30 vertical levels.
2. The COAMPS verification software was improved by adding: (i) a user-friendly graphical display, (ii) additional statistical measures such as mean and variance, (iii) the ability to compute statistics on user-specified domains and, (iv) removal of observations below the model terrain field.
3. We computed statistical skill scores for the sets of COAMPS forecast experiments described below using quality controlled rawinsonde data. For the experiments (a)-(c), 70-90 rawinsonde stations were available for computing the statistics on the inner grid mesh while for experiment (d) there were approximately 20 stations available to compute the model statistics.
 - (a) *The control experiment:* A nested (81, 27 km horizontal grid spacing, respectively) 24-hour forecast with a continuous 12 hour data assimilation cycle using COAMPS derived forecasts as the first guess field, i.e., the 6.2-CplMeso reanalysis.
 - (b) *The cold start experiment:* Same as (a) but without the data assimilation cycle (NOGAPS is used as the first guess field).
 - (c) *The high-resolution experiment:* Same as (a) except the horizontal grid increment was reduced to 36 and 12 km on the coarse and fine meshes.
 - (d) *The reduced area experiment:* Same as (a) except the areal coverage of the inner mesh was reduced by 80% to explore the impact of grid domain size on the forecast skill.
4. Algorithms were developed to use other COAMPS forecasts as the first guess and lateral boundary conditions for higher-resolution COAMPS forecasts.
5. Techniques were developed to enable the nested grid domains to initiate at any given time during forecast.

RESULTS

COAMPS Validation:

Root-mean square (RMS) error and bias statistics (Fig.1) for the control experiment from October 1998 through February 1999 showed errors increasing between the 12- to 24-hour forecast times. The bias scores, which are a measure of the systematic model performance, indicate a wind bias of near zero and

a cold temperature bias of 0-1°C, while the relative humidity bias indicated too much moisture was predicted. The RMS temperature errors were generally larger near the surface, while the wind RMS error was largest at level of the jet stream. These statistics are similar to those computed for the eastern Pacific area as well, and the magnitudes were similar to those reported by White et al. (1999) for other mesoscale models (ETA and MM5) over the western US.

Comparison between the control and cold start experiments indicate similar statistics for all fields except for relative humidity (RH), which was significantly improved by the data assimilation cycle. Further examination of the precipitation forecast fields (Fig.2) reveal that without data assimilation there is considerably less resolved precipitation, especially during the early portion of the forecasts. Convective precipitation is similar in both studies. This result suggests that without data assimilation, the model moisture cycle for resolved or grid-scale processes is limited due to “spin up” issues (spin up is generally considered to be a common problem in the numerical models related to the time scale of the development of precipitating clouds at the start of a forecast).

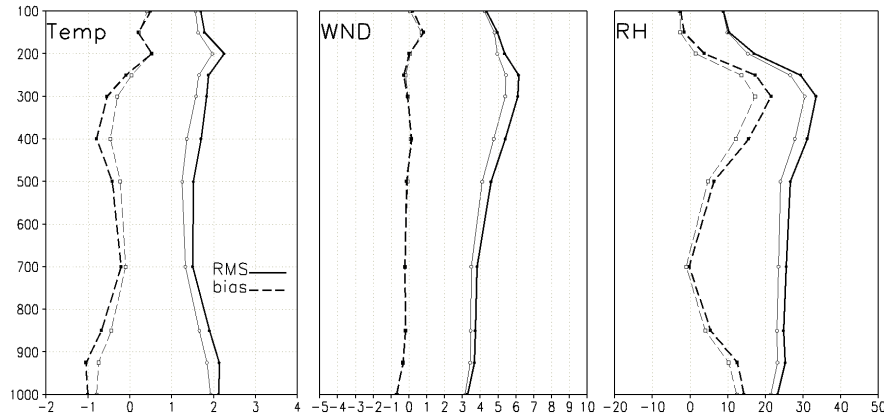
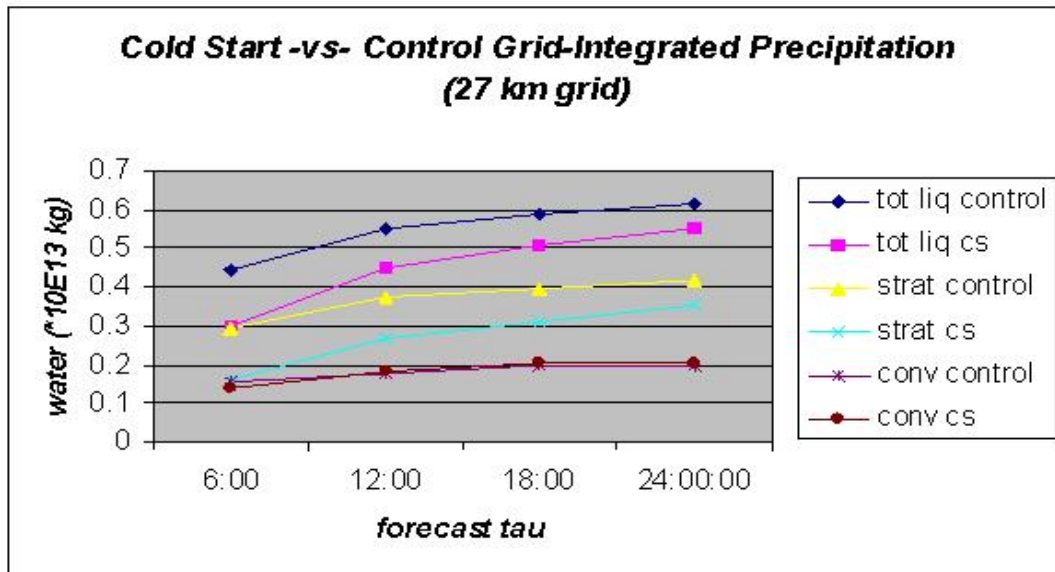


Fig. 1. RMS (solid) and bias (dashed) errors for the period from 30 September 1998 to 1 March 1999 for the control simulation. Temperature, wind speed and RH are plotted in (a), (b), and (c), respectively. Thick and thin lines represent verifications from the 24- and 12-hour forecasts, respectively.



- **Total liquid dominated by stratiform (stable) precipitation**
- **Cold start runs have about 50% less stratiform precipitation from tau 6 –12**
- **Convective precipitation is similar in both cases**
- **Precipitation “spin-up” curve is similar for both runs, though slightly steeper for the cold starts.**

The lack of improvement in the RMS errors with increasing grid resolution (comparison between the control and high-resolution experiments) is consistent with the findings of White et al. (1999), however it does not necessarily indicate that forecast skill does not improve. The high-resolution skill scores are penalized by small phase and spatial errors due to fine-scale atmospheric phenomena. Since the sounding network is too coarse to resolve many of the features predicted by the model, RMS statistics based on rawinsondes alone are thus limited as an observation data source for high-resolution model verification. The use of non-conventional observation data types for high-resolution model verification, such as satellite data, are currently being examined. The improvements in the bias scores are encouraging in that they indicate increased grid resolution reduces the systematic error. Most of the improvements were in the lower troposphere, perhaps due to resolving phenomena that are inherently smaller-scale and forced by the lower boundary such as topographically-forced flows.

When the aerial coverage of the nested grid was decreased by 80% (comparison between the control and reduced area experiments), the temperature and RH bias scores were only slightly degraded compared to the control experiment. The other skill scores were nearly identical for both experiments. These results show that for this particular grid architecture, the synoptic forecast skill is surprisingly insensitive to the size of the inner grid mesh.

More sophisticated verification techniques are under development to characterize the error from the high-resolution model forecasts. These schemes will make use of remotely sensed data, which would augment the current sounding network, and evaluate the predictive skill of particular mesoscale events such as Mistral winds over the Mediterranean.

Fine Grid Applications:

An intense typhoon case was used to examine the delayed COAMPS nesting feature. The results indicate that there were some differences in the simulated typhoon structure and position resulting from delaying the nest startup time. The typhoon from the delayed nest experiment was somewhat weaker. The total precipitation is less than the control.

Comparison of a control run (standard nested configuration) with a sensitivity experiment (using a single grid mesh forced by COAMPS boundary conditions) showed slight differences in the grid-averaged wind speed bias. These differences likely resulted from the degradation in the boundary conditions arising from errors in interpolation, a reduction in boundary update frequency, and the lack of update in the cloud species along the nest boundary.

IMPACT/APPLICATIONS

The results from the COAMPS validation work indicate that running COAMPS without a data assimilation cycle decreases the forecasted precipitation. The validation results also showed a regional size nest covering an area 2000x2000 km² may have similar predictive skill as a nested grid covering an area 80% larger.

The delayed nest feature can improve computational efficiency. The option to use other COAMPS forecasts as initial and boundary conditions requires less computer memory and may be an attractive option for on-scene modeling efforts. Although both features add some flexibility in the nested grid applications, our tests showed there were larger forecast errors introduced with these methods. The user needs to be aware of the limitations of using these nested grid initialization options.

TRANSITIONS

Improved algorithms for the fine grid initialization and displacement will transition to 6.4 programs (PE 0602435N and PE 0603207N) for applications within COAMPS and for subsequent transition to Fleet Numerical Meteorology and Oceanography Center (FNMOC) and regional Naval Meteorology and Oceanography Centers for operational use.

RELATED PROJECTS

Related 6.2 projects within PE 0602435N are BE-35-2-18, for the *Mesoscale Modeling of the Atmosphere and Aerosols*, and BE-35-2-19, for the *Exploratory Data Assimilation Methods*.

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PUBLICATIONS

Nachamkin, J.E. and R. Hodur, 2000, Verification of short-term forecasts from the NAVY COAMPS over the Mediterranean. 15 Conference on Probability and Statistics in the Atmospheric Sciences, Amer. Metero. Soc., 8-11 May 2000, Asheville, NC.