# High-Resolution Mesoscale Atmospheric Model Prediction and Validation

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## LONG-TERM GOAL

The long-term goal is to explore and test new techniques that can validate and improve the applications of the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) high-resolution nested grids.

## OBJECTIVES

The objectives are: compare validation results on COAMPS coarse and find grids; investigate methods and types of observations that can be used for validation for high-resolution mesoscale model forecasts; and improve the flexibility of COAMPS fine grid initialization and displacements.

## APPROACH

The traditional statistical metrics, such as the bias and root mean square (RMS) error, provide limited information when applied to high-resolution model validation. High-resolution model forecasts contain high degree of variability in time and space in association with a particular type of weather event. Averaging statistics over a long period of time from a variety of conditions is not sufficient to describe the spatial and temporal variations of meteorological events derived from higher resolution model forecasts. The statistics computed from a composite of “look alike” events may provide more useful information such as observed and model simulated climatology for that event. Specific events can then be precisely defined to further categorize the model forecast. Our initial approach is to examine a composite of wind-based events over the Mediterranean Sea using the Special Sensor Microwave/Imager (SSM/I) satellite observations to explore the type of validation information that can be extracted in an effort to better quantify the high-resolution model forecast skill. Other COAMPS forecasted weather events of interest to the US Navy can then be validated using a similar compositing technique.

The COAMPS validation effort also needs to be expanded to include the quantitative precipitation forecast (QPF). The standard precipitation validation technique requires comparison with the observed rain analysis usually obtained by analyzing high-density rain gauge data. However, such high-resolution rain data is difficult to obtain globally. With advanced satellite technology, an experimental SSMI+ Tropical Rainfall Measurement Mission (TRMM) satellite retried rain rate developed by NRL is useful for COAMPS QPF validation, especially for the rain data void ocean area. The approach is to develop rain analysis software to validate the satellite retrieved rain rate over the continental US (CONUS) region against the high-density rain gauge data from National Center for Environmental Prediction (NCEP) on a common grid. Before we are fully confident about the quality of the satellite

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14. ABSTRACT
**The long-term goal is to explore and test new techniques that can validate and improve the applications of the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) high-resolution nested grids.**

15. SUBJECT TERMS

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retrieved rain analysis, the effort will be concentrated on validating COAMPS QPF over the continental US where NCEP's rain gauge data is easily available.

To improve flexibility and utility of the high-resolution forecasts, the approach is to (a) develop a moving nest algorithm to follow the battleships or meteorological phenomenon, reducing the overall time needed to generate the forecast and allowing even finer grids to track features of interest; and (b) perform case studies and sensitivity tests to fine-tune the silhouette terrain parameters.

## WORK COMPLETED

1. Developed software to use the NCEP River and Forecast Center (RFC) rain gauge data for COAMPS QPF validation over CONUS. Developed COAMPS rain analysis software to analyze the rain estimates from the SSMI+TRMM satellite retried rain rate and surface METOC rain report to the COAMPS validation grid. Validated the SSMI+TRMM rain rate over CONUS.

2. Computed COAMPS QPF scores over the CONUS area for selected periods.

3. Conducted and evaluated the event-based verification technique using the SSM/I wind observations over the Europe and Eastern Pacific regions.

4. Implemented and tested the moving grid algorithm.

5. Improved the silhouette terrain algorithm run time efficiency. Conducted case studies on the effect of the envelope and silhouette terrain analysis. Performed sensitivity tests on the silhouette parameters.

## RESULTS

*COAMPS QPF Validation:* A summer and winter month rain analysis comparison was conducted over the CONUS region. The NCEP RFC rain gauge analysis was used to validate the rain analysis with surface METOC station data and the satellite retrieved rain rate. The results showed: (a) the analysis using the METOC data lacked the necessary resolution especially in the mountainous regions; (b) the areal coverage of the satellite rain analysis was comparable to the NCEP RFC rain analysis; (c) the satellite rain analysis overestimated the rain rate over the mountain and coastal areas while underestimated rain rate in light rain areas. In general, the satellite rain analysis has problems estimating the precipitation amount accurately. Although the retrieved satellite rain rate can't be used to validate the COAMPS QPF, it can be used as an indication of the rain area.

The COAMPS QPF scores for the summer month of July 1999 were computed using eight different thresholds of rain rate. The QPF scores include the equitable threat score (ETS) and the bias score. The ETS score is between 0.0 and 1.0 with 0.0 and 1.0 representing no skill and perfect forecasts, respectively. The QPF validations were performed on a 80 km horizontal grid resolution.

The COAMPS 27 km rain forecasts were produced with two different versions of the Kain-Fritch cumulus scheme. The results show COAMPS over-predicted the amount of light precipitation (< 10 mm/day) while it under-predicted the heavy precipitation (> 10 mm/day). The ETS score show that

COAMPS always under-predicts the correct precipitation areas in all rain threshold categories with the heavy precipitation threshold (> 50 mm/day) being the worst.  Comparison of COAMPS QPF vs. the NCEP ETA and Navy NOGAPS QPF is shown in Fig 1. COAMPS has slightly better QPF scores than NOGAPS but worse than the ETA scores (ETA is known to be highly tuned for QPF). The validation results indicate that future improvement of the COAMPS moist physics, including convective and explicit schemes for the forecast of heavy summer-time convective precipitation, is needed.

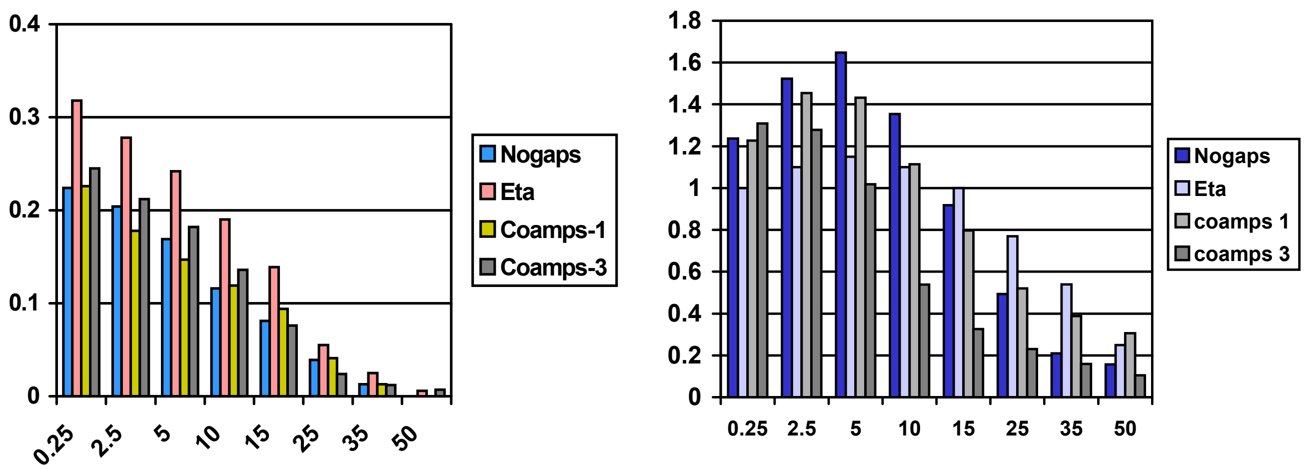


***Figure 1. COAMPS equitable thread score and bias score for July 1999.***
***[Also shown are the ETA and NOGAPS forecast results. The validation was performed on a common 80 km horizontal grid resolution. Left: equitable thread score; Right: bias score]***

*Event-Based Verification:*Wind events with wind speed greater than 10 m $s^{-1}$ were examined over two regions: (a) the Mistral over the Mediterranean, and (b)the  wind surge off the US west coast.  The 27 km grid COAMPS 10 meter wind forecasts were validated against the SSM/I winds retrieved using the Goodberlet et al. (1990) regression. Contingency statistics (correct hit, missed forecast, false alarm, and correct no) were calculated based on the overlap between the wind > 10 m $s^{-1}$ areas predicted by the model versus those in the observations.

Results for the 21-hour COAMPS Mediterranean forecasts between 15 and 28 November, 2000 showed the probability of a correct forecast of wind greater than 10 m $s^{-1}$ is 76%. Most of the forecasts initialized at 0000 UTC contained over 1000 SSM/I observations; between 200 and 400 observations met or exceeded then 10 m $s^{-1}$ criteria. The majority of the forecast errors were due to an underestimation in the aerial coverage. The model wind speed bias with respect to the SSM/I was –0.9 m $s^{-1}$, reflecting a tendency for the model to underestimate wind speeds. The average daily equitable threat score (ETS) was about 0.3. When ETS was recalculated over a portion of the Mediterranean where most of the ocean grid points had 50-60 observations over the two-month period, much higher ETS scores were obtained (Fig 2).  Values as high as 0.8 existed south of the French coast in and near the oval circle shown in Figure 2.  This region is well known for frequent strong northerlies (Mistral) that result from the channeling between the Pyrenees and the Alps mountains.  Also of note is the region of low scores paralleling the coast, which result from coastal contamination of the SSM/I.

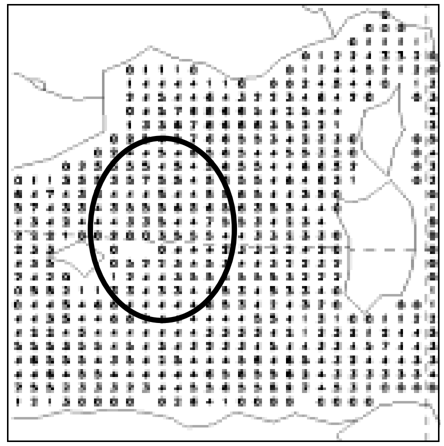

***Figure 2 Equitable threat scores calculated at individual grid points.***
***[All ETS values have been multiplied by ten. An area of elevated scores likely associated with the Mistral is indicated by the oval.]***

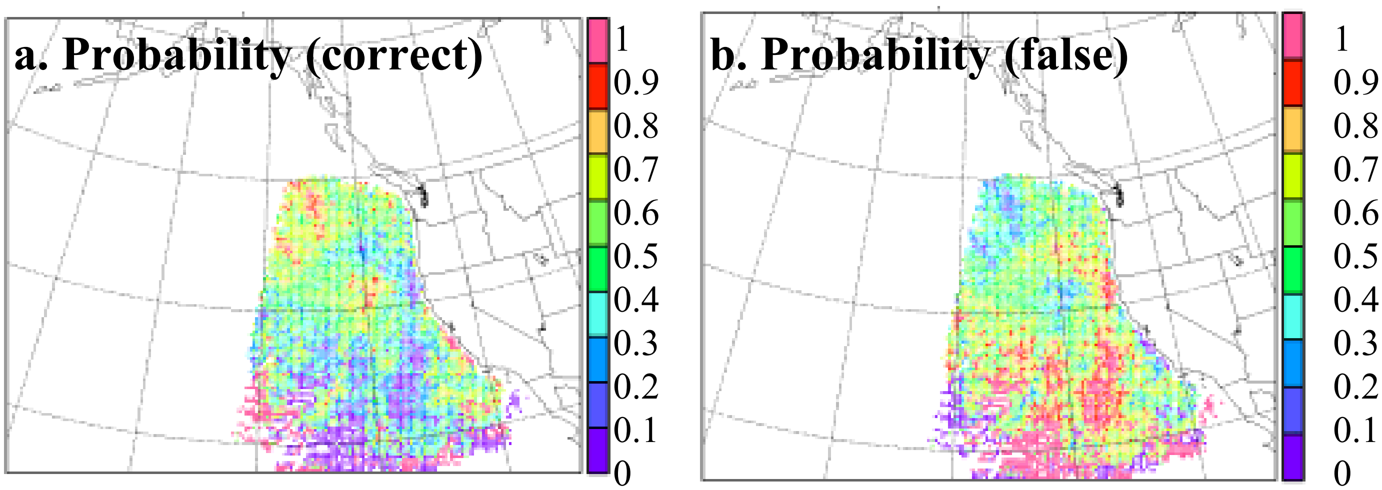


***Figure 3 Contingency statistics for the 42 hour forecast. COAMPS 10 meter wind occurrences greater than 10 m/s (Nov-Dec, 2000) compared with the SSM/I observations. The colored plots represent (a) probability of correct forecast and (b) probability of the false alarm respectively.***

The contingency statistic in the region off the US west coast from November to December, 1999 showed an opposite result. In this region COAMPS produced a greater number of strong wind events than observed. A high probability appeared in the northern portion of the validation region (Fig. 3a) where a higher occurrence of observed strong wind events existed. Examination of the false alarm probability (Fig. 3b) shown over the southern region indicates that COAMPS had a higher probability to forecast strong wind events not observed by the SSM/I. This result may indicate a possible phase error in the southern portion. Further examination is required to determine the nature and the magnitude of this phase error if it indeed exists in the COAMPS forecasts.

*Moving Grid:* Several 48 hour COAMPS simulations for hurricane Gordon (00Z 17-19 September, 2000) were performed to examine the COAMPS moving nest algorithm. The moving nest domain size was about five times smaller than the fixed nest, and was moved every 6 hours to a prescribed location based on the position of hurricane Gordon obtained from the control simulation (fixed nest). The results showed the moving nest simulation was able to reproduce nearly identical hurricane features compared to the fixed nest case. A threefold cpu time speed up was obtained using the moving nest option.

*Improved Silhouette Terrain:* The two weeks averaged COAMPS 27 km statistics (30 September to 14 October, 1998) over the Alps showed a slightly improvement in the bias and RMS scores at levels below 750 mb. The original terrain created more precipitation on the mountain peaks than the silhouette terrain due to a higher topography value at the peak. Several 27 km model simulations (5 – 7 April, 2001) were performed over the CONUS region where the observed NCEP RFC rain analysis is available to examine this precipitation difference. When compared to the observed precipitation, the silhouette runs were closer to the observed precipitation amount and pattern even at areas downstream from the mountain. The tests on the several silhouette parameters showed small sensitivity to the averaged bias and RMS scores. The total averaged precipitation also showed negligible small differences.

## IMPACT/APPLICATIONS

The COAMPS QPF validation over the CONUS area showed the COAMPS moist processes (explicit and convective) were not able to produce enough precipitation, especially in the heavy precipitation category. These results provide a benchmark for future improvement of COAMPS QPF. The software that was developed to perform rain analysis and QPF validation will help to continually validate the improvement of COAMPS moist processes.

The initial implementation of the moving nest algorithm demonstrated the option to follow a battle group (moved by locations). An automatic moving nest following a hurricane is under development in collaboration with 6.2 ONR program for the Improvements to Tropical Cyclone Model Forecasts. The automatic moving algorithm will allow a higher model grid resolution forecast to better track the hurricane movement and intensity.

## TRANSITIONS

Improved algorithms for the silhouette terrain and moving nests 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, BE-35-2-44*, for the Advanced Moist Physics Modeling, and BE-35-2-19, for the *Exploratory Data Assimilation Methods*.

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