5D.4 Hurricane Forecasting using Adaptive Unstructured Grids

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1. INTRODUCTION

The Operational Multiscale Environment model with Grid Adaptivity (OMEGA) is an atmospheric simulation system that links the latest methods in computational fluid dynamics and high resolution gridding technologies with numerical weather prediction. In the fall of 1999, OMEGA was used for the first time to examine the structure and evolution of a hurricane (Floyd, 1999). The first simulation of Floyd was conducted in an operational forecast mode; additional simulations exploiting both the static as well as the dynamic grid adaptation options in OMEGA were performed later as part of a sensitivity / capability study. While a horizontal grid resolution ranging from about 120 km down to about 40 km was employed in the operational run, resolutions down to about 15 km were used in the sensitivity study to explicitly model the structure of the inner core. All the simulations produced very similar storm tracks and reproduced the salient features of the observed storm such as the re-curvature off the Florida coast with an average 48 hour position error of 65 km. In addition, OMEGA predicted the land-fall near Cape Fear, NC with an accuracy of less than 100 km up to 96 hours in advance.

2. OMEGA MODELING SYSTEM

OMEGA is a complete, operational, atmospheric simulation system (Bacon, 2000) built upon an unstructured triangular grid, which can adapt to a variety of static user-defined fields as well as dynamically during the simulation (Figure 1).

While the goal of OMEGA is to try to explicitly resolve large areas of convection, there will always be regions that are not sufficiently resolved. To circumvent this problem a version of cumulus parameterization that was originally proposed by Kuo (1965, 1974) and later modified by Anthes (1977) is incorporated to account for the effect of sub-grid scale deep cumulus convection on the local environment. The coupling between the sub-grid scale cumulus parameterization scheme and the explicit cloud microphysics is still a great research area for numerical modelers. The most troublesome scales for parameterizing convective processes are those between 3 and 50 km. Because of the continuous range of scales, OMEGA treats the cross over between cumulus parameterization and explicit microphysics by keeping both processes active and weighting the cumulus parameterization terms by a factor of the form:

$$f = \min(1, A_i/A_c)$$

in which A_i is the area of the i^{th} OMEGA cell and A_c is the cut-off value (100 km^2). For large cells, this factor is unity and cumulus parameterization is fully weighted. In this situation, it is assumed that explicit microphysics will contribute little unless there is a stratiform situation in which case the cumulus scheme is inactive. For small cells, the factor is near zero and cumulus parameterization is not a significant contributor to the system.

Another important component of the OMEGA system for hurricane forecasting is the *tracker* routine which post-processes OMEGA output to determine the location of a tropical storm. *Tracker* has proven to be robust enough for automated processing, even in cases with strong shear.

3. HURRICANE SIMULATIONS

As mentioned above, the first storm studied was hurricane Floyd (1999). In performing a baseline and six (6) sensitivity simulations, it was found that a higher resolution in the eye-wall region of hurricane, provided by dynamic adaptation, was capable of generating better organized cloud and flow fields and a well defined eye**.** Higher resolution also resulted in precipitation forecasts in agreement with the observations (Figure 2).

Forecasts have since been performed for a number

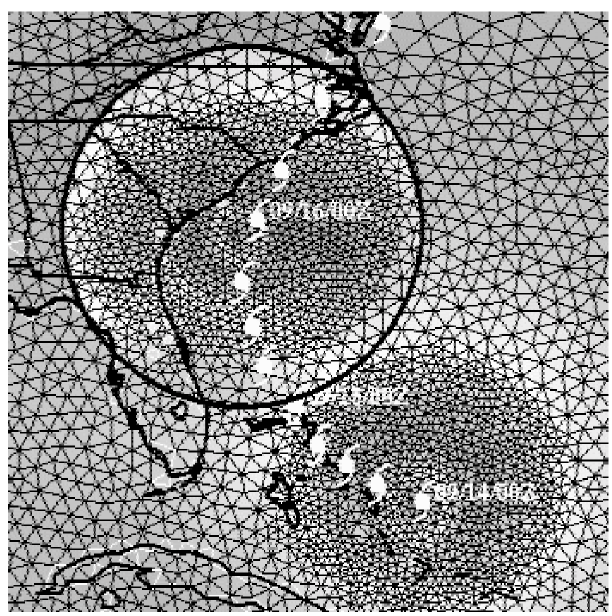

Figure 1. Dynamic grid adaptation puts high resolution only where needed, leading to the accurate and computationally efficient prediction of high wind speed (color) and track of hurricane Floyd. The initial conditions are shown with an inset showing the high-resolution area at 48 hours into the forecast. The yellow dots show the observed storm track.

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of other storms including Georges (1998) and six 2000 storms (Tropical Storms Beryl and Chris, Hurricanes Debby and Florence, Tropical Storm Helene, and Typhoon Xangsane). Figure 3 compares the 96-hour track forecasts for hurricane Georges (1998) with the observations; Figure 4 compares the forecasted central pressure, maximum, and surface winds with the data.

The OMEGA mean track error for all 20 forecasts spanning 8 storms was 101, 140, and 298 km at 24, 48, and 72 hours, respectively. This represents a significant improvement over the National Hurricane Center 1998 average of 156, 268, and 374 km, respectively (McAdie and Lawrence, 2000). In a direct comparison with the GFDL model performed independently by Mr. Miles Lawrence of the NHC, OMEGA started with a considerably larger position error yet came within 5% of the GFDL 72 hour track error.

4. REFERENCES

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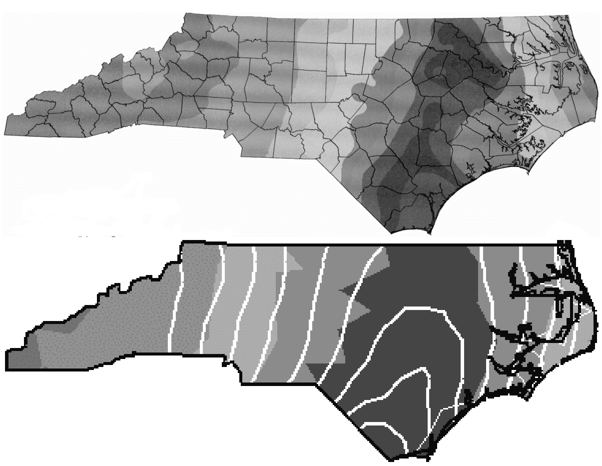

Figure 2. Comparison of observed and simulated rainfall distribution valid September 14-16, 1999. The observed precipitation (top) is compared with an OMEGA simulated precipitation using the same gray scale. (Observations courtesy of Dr. Sethu Raman.)

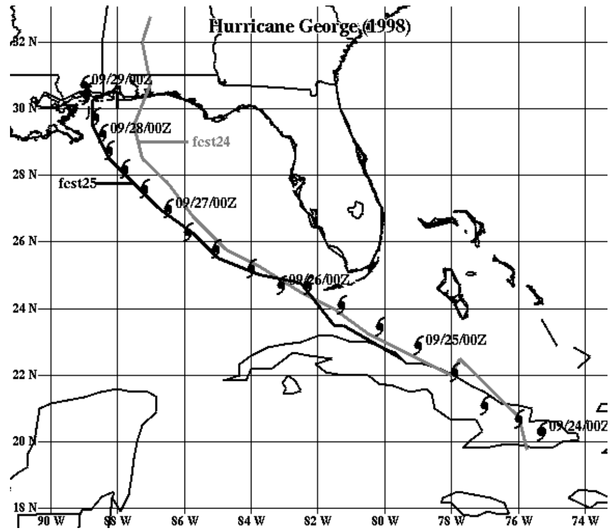

Figure 3. OMEGA 4-day forecasted storm tracks for Hurricane Georges. The gray and black forecasts were initialized on September 24 and 25, respectively.

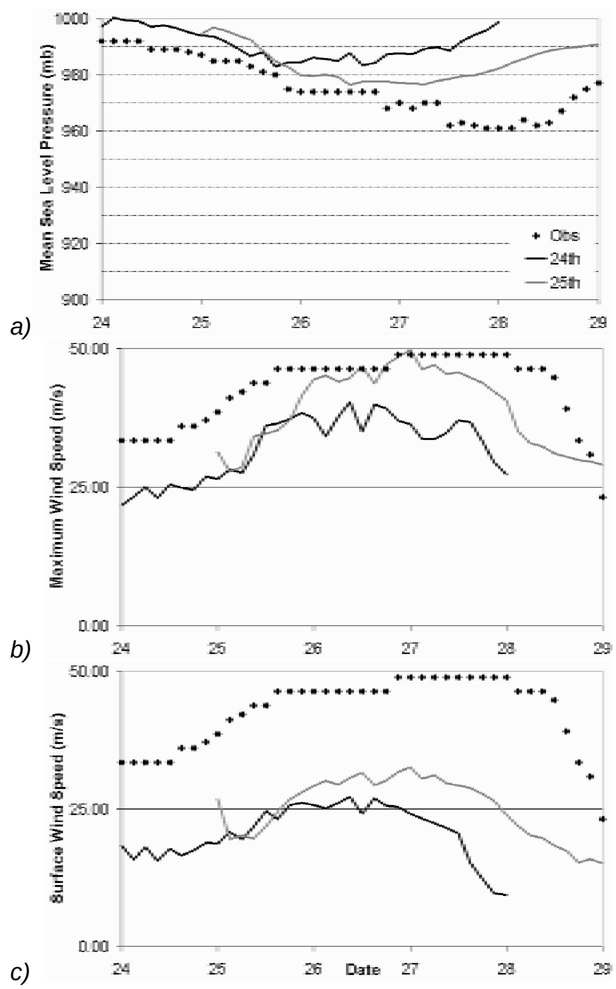

Figure 4. Comparison of the OMEGA forecasted (a) Central Pressure; (b) Maximum Wind; and (c) Surface Wind with observations.