THE NCEP NONHYDROSTATIC MESOSCALE FORECASTING MODEL

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Considerable experience with nonhydrostatic models has been accumulated at the scales of convective clouds and storms. However, numerical weather prediction (NWP) deals with motions over a much wider range of temporal and spatial scales. Difficulties that may not be significant or may go unnoticed at the smaller scales, may become important in NWP applications. For example, an erratic gain or loss of mass would be hard to tolerate in operational NWP applications. Another problem may arise regarding the control of spurious motions generated at upper levels by nonhydrostatic dynamics and numerics. Forcing the variables in the top layers toward a constant in time basic state in response to this problem appears to be inadequate for NWP. On the other hand, specifying time dependent computational top boundary conditions further limits the ability of the regional nonhydrostatic model to produce more accurate forecasts than the parent hydrostatic model.

Based on these considerations, a new approach has been applied in developing the NCEP Nonhydrostatic Meso Model (NMM) within the WRF effort (Janjic et al., 2001, Janjic, 2002). Namely, instead of extending the cloud models to synoptic scales, the hydrostatic approximation is relaxed in a hydrostatic model formulation. In this way the validity of the model dynamics is extended to nonhydrostatic motions, the number of prognostic equations remains the same as in the hydrostatic model, and at the same time the favorable features of the hydrostatic formulation are preserved. This approach does not involve any additional approximation.

“Isotropic” horizontal finite differencing employed in the model conserves a variety of basic and derived dynamical and quadratic quantities. Among these, the conservation of energy and enstrophy improves the accuracy of the nonlinear dynamics of the model. In the vertical, the hybrid pressure-sigma coordinate has been chosen as the primary option. The forward-backward scheme is used for horizontally propagating fast waves, and an implicit scheme is used for vertically propagating sound waves. The inexpensive Adams-Bashforth scheme is applied for non-split horizontal advection of the basic dynamical variables and for the Coriolis force. In real data runs the nonhydrostatic dynamics does not require extra computational boundary conditions at the top.

The computational cost of the nonhydrostatic extension is about 20% of the cost of the hydrostatic dynamics, both in terms of computer time and memory. The relatively low cost of the nonhydrostatic dynamics justifies its application even at medium resolutions.

In high resolution NWP applications, the efficiency of the described computational algorithm significantly exceeds those of several established state-of-the-art nonhydrostatic models. It is argued that the high computational efficiency has been achieved primarily due to the design of the time-stepping procedure. The high computational efficiency of the model demonstrates that meaningful nonhydrostatic forecasting/simulations are rapidly becoming feasible at smaller centers also, using workstations and PC’s.

The dynamical core of the NMM has been adopted as one of the three major alternative dynamical cores within the WRF model. The conversion of the NMM code to the WRF standards and its incorporation into the WRF modeling infrastructure are nearing completion.

The NMM has been run operationally at NCEP (Black et al., 2002). In high resolution NWP applications, the model has been highly competitive with mature hydrostatic NWP models and with other nonhydrostatic models. The 42 hour forecasts of 10 m wind in Southern California, valid February 6, 2003, 00 UTC, obtained using the operational hydrostatic 12 km Eta model (left panel) and the 8 km NMM (right panel) are shown in Fig. 1. The heavy arrows represent the observed winds. As can be seen from the plots, the NMM forecast agrees much better with the observations than does the Eta forecast. Further examples of the NMM forecasts can be found in Black et al. (2002).

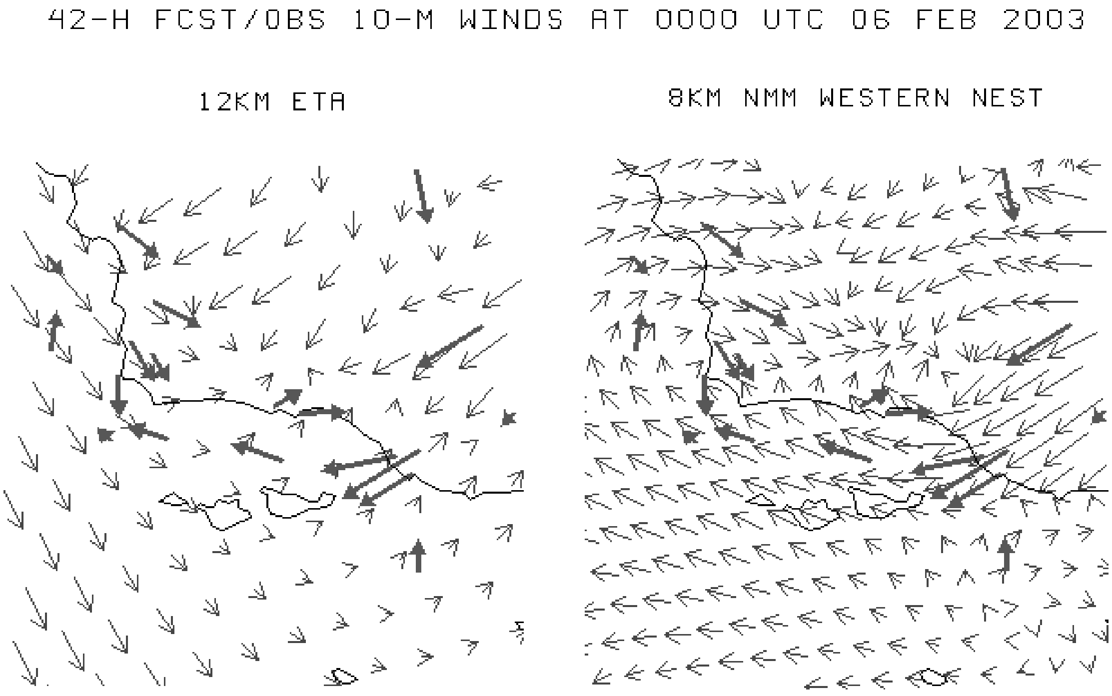

Fig. 1. The 42 hour forecasts of 10 m wind in Southern California valid February 6, 2003, 00 UTC obtained using the operational hydrostatic 12 km Eta model (left panel) and the 8 km NMM (right panel). The heavy arrows represent the observed winds.

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