AFWA MM5 PERFORMANCE DURING THE "MILLENNIUM STORM" AND THE WINTER 2000-2001 SEASON

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1. INTRODUCTION

The Air Force Weather Agency (AFWA) has used the Penn State/NCAR Mesoscale Model 5 (MM5) as its operational model since September 1998. Model output is available for 19 theaters that collectively cover most of the Earth's surface (Figures 1 and 2). Horizontal resolution ranges from 45 to 5 kilometers, and the vertical resolution consists of 41 sigma levels. Forecasts are generated 2 to 4 times daily with forecast lengths as long as 72 hours. The model output is post-processed to generate a complete suite of standard and derived meteorological parameters.

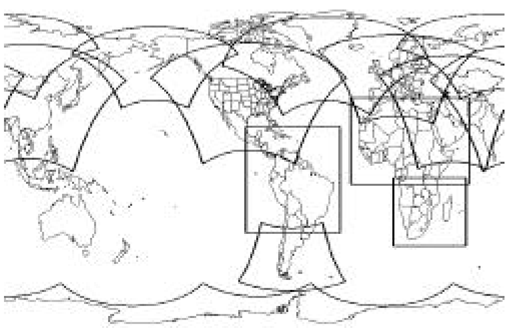

Figure 1. MM5 Extra Tropical Window Configurations (only the 45km windows are shown).

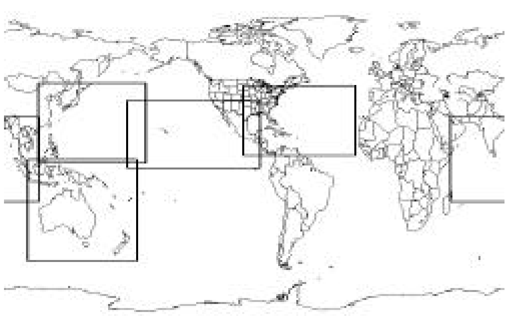

Figure 2. MM5 Tropical Window Configurations.

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2. MM5 AT AFWA

The AFWA MM5 (hereafter MM5) runs on IBM SP2 supercomputers with a horizontal resolution of 45km. Higher resolution inner nests of 15km and 5km are run over specific regions of interest. The current configuration is characterized by the following:

- Grell Cumulus Parameterization
- MRF Planetary Boundary Layer scheme
- Reisner I (mixed phase) microphysics
- Cloud-Radiation scheme
- 5-Layer Soil Model

Global fields from the Aviation run of the MRF (AVN) or Navy Operational Global Atmospheric Prediction System (NOGAPS) are used as background fields for model boundary conditions. A newly developed Mesoscale Data Assimilation System (MDAS) currently provides initial conditions. A parallel test of two separate data assimilation schemes took place during 2000 through early 2001.

From December 1998 - January 2001, data assimilation was accomplished using a modified version of the FSL's Local Analysis and Prediction System (LAPS). This method uses most surface and upper air observations. The second method is the aforementioned MDAS, which uses a more complex Multi-Variate Optimal Interpolation (MVOI) scheme developed at AFWA. This data assimilation scheme incorporates many additional data sources including surface, upper air, aircraft, and several different types of satellite observations. Our analysis has shown substantial improvement in the MM5 forecasts initialized by MDAS/MVOI, and this initialization scheme was implemented in January 2001. Complete details on MDAS/MVOI are found in a paper by Ritz et al. in this preprint volume.

3. FORECASTING WINTER WEATHER

AFWA produces roughly 250,000 products per day for the theaters covered by the AFWA MM5 (hereafter MM5), for shipment to the Joint Air Force and Army Weather Information Network (JAAWIN), AFWA's main information dissemination point. Two products in particular have been specifically developed to aid precipitation type forecasting during winter storms, the surface precipitation type and composite low-level thickness products.

AFWA's precipitation type product is based on an algorithm which uses surface temperature, temperature profile, two thickness parameters (1000-850mb and 850-700mb), and elevation (via surface pressure) to separate model forecast precipitation into four types: Snow, Sleet/Mix, Freezing Rain, and Rain (AFWA, 1998). Additionally, the algorithm uses convective precipitation and the Thunderstorm Potential Index (TPI) to provide thunderstorm and severe thunderstorm information, respectively. (Knapp and Brooks, 2000).

This product is an excellent first guess tool for users who need to forecast worldwide. However, since slightly different thresholds are often used in certain regions of the world, we also produce a low-level thickness composite chart that colors the 1000-850mb and contours the 850-700mb thickness, at 20-meter intervals. These products, along with the Interactive Meteogram and Skew T's (IMaST) tool available on JAAWIN, allow forecasters to get a complete picture of the MM5 solution at various resolutions at user selected gridpoints.

4. "END OF THE MILLENNIUM" STORM

Large model differences were the norm as ground zero approached for this major East Coast/New England storm at the end of December 2000. The MM5 forecast differed significantly from the ETA forecast especially south of a PIT - PHL - S NJ line (roughly 40N). In the highly forecast-sensitive Washington D.C. area, the models presented extremely varied solutions. There were many discussions on the 28th and 29th of December 2000 about the "potential for a foot of snow in the Washington Metro area." The MM5 was the only "dry model" during the two days prior to the storm with runs on the 28th and 29th consistently forecast no precipitation for this area cycle after cycle. By the 29 Dec 12Z run, the ETA model still forecast a storm total precipitation of nearly an inch (liquid water equivalent) at Ronald Reagan Washington National Airport (KDCA). The NGM had two-tenths of an inch, and the MM5 once again had no precipitation at KDCA (nor for nearby Andrews AFB). MM5-based meteograms (projection time-height cross-sections) showed clouds for Andrews AFB, Washington Dulles International Airport, and KDCA, but no precipitation.

Analyzing the precipitation type forecasts, the 45km and 15km MM5 forecasts from the 29 Dec 06Z and 18Z runs correctly forecast the changeover to rain over portions of central and eastern Long Island, NY around 30 Dec 18Z. It also correctly kept the precipitation type as snow for places like LaGuardia Airport in western Long Island and New York City throughout the entire storm. However, the 29 Dec 18Z 15km run brought the warm air and rain changeover too far west, into New York City. The 30 Dec 06Z 45km run also suggested this, serving to keep snow amounts down in this area. For Boston, MA, the MM5 correctly forecast a nearly all-rain event.

The MM5 forecasts were superior to the ETA with respect to the position of the surface low's initial development and its deepening off the DelMarVa coast. The MM5's storm track forecasts were much better than the ETA's on the runs from 28 and 29 Dec; and slightly better or nearly the same for runs from the 30th (with the event already started).

Verification showed the MM5 forecasts were correct--Andrews AFB, the DC area, and even Baltimore, MD received no precipitation at all--rain or snow. This surprised nearly all forecasters who, up to the night of the 29th, were still forecasting 4+ inches of snow. As the secondary low formed the night of the 29th, and it became clear that moisture was very limited for the DC area, most official forecasts were cut back to 1 to 3 inches.

Though the MM5 forecast did an excellent job delineating the corridor of the heaviest snowfall, the forecast amounts were roughly about 2/3 of what actually was reported (about 1/2 to 2/3 in the areas that experienced 2 feet or more of snow). Further analysis showed that the snow-to-liquid water equivalent ratios experienced were generally greater than the ratios used by the MM5 snowfall accumulation algorithm for the temperature range observed.

Following this event, there were a number of discussions regarding the ETA SST analysis. It should be noted that AFWA uses the Navy's high resolution (1/4)x(1/4) degree SST data, updated daily.

5. SEASONAL PERFORMANCE

No model should be judged solely on its performance during a single event. At AFWA, extensive objective and subjective verifications of model performance are performed. The MM5 is verified against observations over most of the theaters. Model data are interpolated to observation sites using a bi-quadric scheme before the differences are generated. Standard statistics generated are Root Mean Square Error (RMSE), bias, Anomaly Correlation, and S1 skill score. For precipitation data we also produce Equitable Threat Score (ETS), Heidke Skill Score (HSS), Probability of Detection (POD), False Alarm Rate (FAR), and Critical Success Index (CSI). Anomaly correlations are calculated using climatology for each observation site. NCEP's AVN and ETA models and the Navy's NOGAPS model (denoted FNC in Figures 3 and 4) are also verified and compared with MM5. The coarser resolution AVN and NOGAPS model outputs are first remapped to each MM5 45km theater grids using a bi-quadric interpolation, and then verified against observations.

For the winter season, MM5 temperature, wind, and moisture forecast performance has been at least equal to that of the ETA model. For example, the HSS for precipitation occurrence shows that the MM5 was better than the ETA, AVN, and NOGAPS through the first 24-36 hours, equal to the ETA from 36 to 48 hours, and slightly less skill than AVN and NOGAPS from 48 to 72 hours (Fig. 3). These results are not unexpected, since the forecasts beyond 48 hours are close to the limit of skill for a high-resolution NWP model. In terms of CSI values for precipitation occurrence, MM5 performed best during the past winter (Fig. 4).

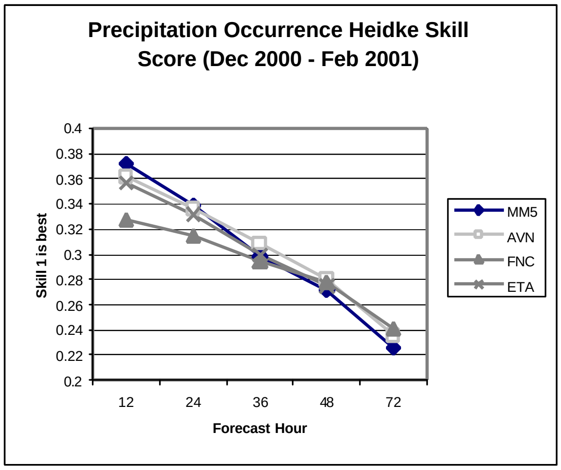

Figure 3. Heidke Skill Score, Winter 2000-01.

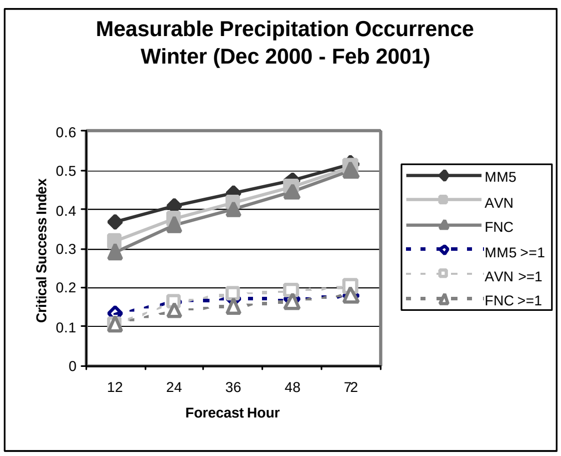

Figure 4. Critical Success Index Winter 2000-01.

6. CURRENT MDAS/MVOI STATUS

MDAS/MVOI initialization scheme precipitation forecasts during the tests of the throughout the 2000-2001 winter showed 45km resolution run POD improved by nearly 15% for 12 and 24 hour forecasts and by 8% for 36 hour forecasts. For 15km resolution runs, the POD improved 10% for 12 and 24 hour forecasts and by 8% for 36 hour forecasts. PODs of up to 86% were experienced and CSIs reached 76%. The rate of CSI improvement by MDAS/MVOI over LAPS decreased with forecast projection time, a direct result of the FAR increasing above the LAPS runs at T+36 hours.

Earlier parallel tests of MDAS/MVOI during the summer of 2000 focused on initialization and resolution effects on convective precipitation forecasts. The 45km resolution MDAS/MVOI POD displayed an improvement of 11% over the 45km LAPS. This was anticipated as the MDAS scheme greatly reduced model moisture spin-up times, producing precipitation much sooner in the run. In fact, the 45km MDAS MM5 was found to have 2% greater POD and a 7% lower FAR than the 15km LAPS run.

7. FUTURE INITIATIVES

Incorporation of the NCAR Land Surface Model, in test at this time, is expected to improve surface temperature and boundary layer moisture forecasts.

It is anticipated that the MDAS/MVOI system will be replaced by the 3-Dimensional Variational Analysis (3DVAR) system currently under development at NCAR. This is slated to occur during the summer of 2002.

In the area of model data visualization, AFWA has developed a web-based interactive weather chart generator. The Interactive Gridded Analysis Display System (IGrADS) is a prototype software package that is accessible through the JAAWIN Beta Page. It enables the forecaster to create products directly from GRIB model output for all the MM5 theaters, as well as from ETA, AVN, MRF, and NOGAPS. The products available with this cutting-edge tool include:

- standard and specialized meteograms
- user defined meteograms
- forecast Skew-T charts
- user-defined weather forecast maps
- vertical cross sections
- forecast RAOB alpha-numeric output, and
- FOUS-like A/N model output.

8. REFERENCES

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