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A GLOBAL VERSION OF MM5: METHOD AND VERIFICATION

Jimy Dudhia[1] and Jim Bresch
National Center for Atmospheric Research
Boulder, Colorado

1. INTRODUCTION

In 1999 we developed a global version of MM5 (Dudhia[1] and Bresch 2000). This model was created by joining together two hemispheric domains at the equator. See Dudhia and Bresch (2002) for more details on the method. Since 1999 this model has been run regularly for five-day forecasts, and its output has been archived since January 2001. In this paper we will present some initial verification of the performance of this model that will show its level of skill particularly with regard to predicting the 500 hPa height field. This is the first field we chose to verify, and is traditionally one used to evaluate the tropospheric dynamics in numerical weather prediction models. The 200 hPa wind has also been evaluated, but the results will not be presented in this abstract. Here we will focus on the period from January 1 - April 30 2003, which represents about 200 twice-daily forecasts. The grid size is 120 km, which varies from 128 km at the pole to 64 km at the equator in physical space.

2. VERIFICATION METHOD

The forecasts of 500 hPa height will be verified against the analyses that are used to initialize the forecasts. These are based on the GFS (NCEP) analyses available in real time, and are enhanced by an objective analysis including all available observations at the data cut-off time. Therefore the zero-hour fields, archived with the forecasts, are used as the "truth" in the verification of forecasts verifying at the same time. Given an analysis and forecast, several skill measures may be used to evaluate the forecasts statistically over long periods. Here we will focus on three; correlation, root mean square error, and bias.

[1] *Corresponding author address:* Jimy Dudhia, MMM Division, NCAR, P.O. Box 3000, Boulder, CO 80307-3000. *E-mail:* dudhia@ucar.edu

2.1 Correlation

The correlation score is a value with a magnitude between zero and unity indicating the similarity between the two height patterns. Here the *full* correlation is chosen to evaluate the forecasts. Often an *anomaly* correlation is used, but that requires a "climatology" height to be subtracted from the fields before correlating them. We had no climatology information, and so proceeded with the simpler full correlation. However, it should be noted that the full correlation even gives high scores for unskillful forecasts owing to the mean decrease of height towards the poles, and so we need to evaluate these correlations against "no-skill" values. Two such no-skill values are easily determined. The persistence correlation is that between an analysis at time zero and at the forecast time, which rapidly drops from unity in the first few days. A second measure is a "background" correlation found by correlating analyses that are widely separated in time (two weeks or more). This yields a mean background value of about 0.84 for the Northern Hemisphere, so a forecast is no better than a randomly chosen analysis if its full correlation is near this background value.

2.2 Root Mean Square Error

The RMS error is another traditional measure used. It also simply depends on the analysis and forecast, and a persistence forecast can again be used as a comparison to measure skill. A "background" value can be obtained by determining the average RMS score for a time-mean height field versus the analyses.

2.3 Bias

Part of the RMS error is due to any bias that may be present, so it is of value to determine the bias, which is the mean error of the height field.

All the above measures were evaluated both for a North American region and a Northern Hemispheric region (between 20 N and 80 N). In the latter case the values were area-weighted because each model grid box has a different physical area due to the map-scale factor. This removes the projection bias from the skill scores, otherwise a polar projection would be biased by the tropical region because of the closer spacing of grid-points there.

3. RESULTS

3.1 North America

In evaluating forecasts it is useful to separately evaluate the forecasts regionally in an area of interest because ultimately it is the regional pattern that matters for a forecast, rather than a hemispheric pattern. For example, a misplaced low center or trough is brought out more in a verification domain covering a smaller region. The North American window chosen is only approximately 5 % of the global area.

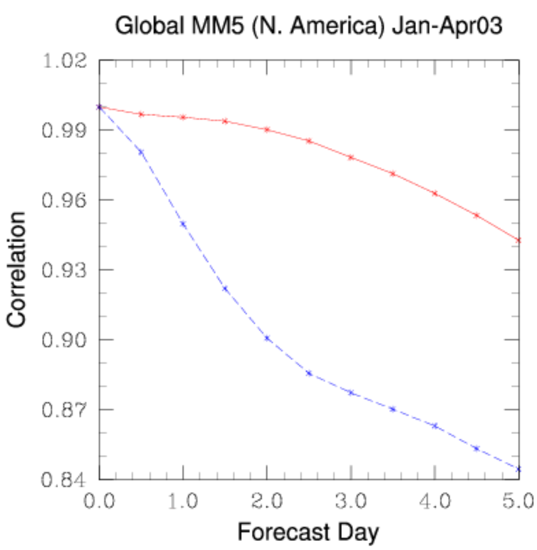

Figure 1. Correlation of 500 hPa height versus forecast length (solid) and for persistence analysis (dashed).

Figure 1 shows the decay curve for the mean correlation of about 200 forecasts for the 500 hPa height over North America. It can be seen that the skill of the forecast persists through 5 days. For this region the background correlation is about 0.8, so a correlation in excess of 0.94 shows that, on average, 5-day forecasts are useful. For comparison, persistence is shown and indicates the decay in correlation of analyses with increasing time between them. This gives a measure of the rate of change of the analysis in this verification window. A 5-day forecast has a similar correlation score to a 24-hr persistence forecast, indicating that errors are comparable with that due to the motion of features in one day. There is a considerable scatter in the skill of the 5-day forecast from day to day, and in this period it ranges from 0.84 to 0.98 (not shown).

Figure 2 shows the bias and RMS for North America for January to April 2003.

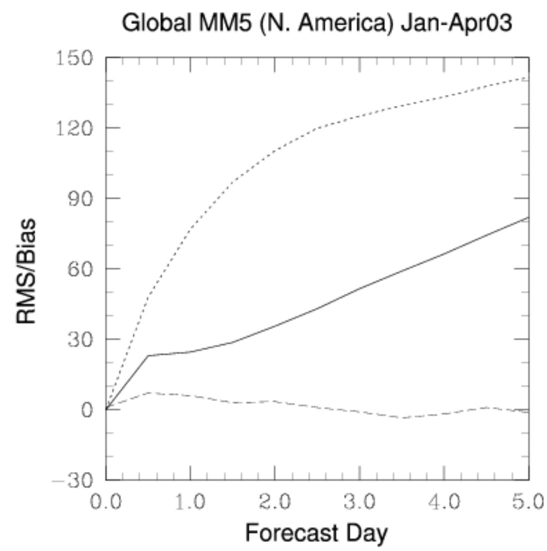

Figure 2. RMS error (meters) in 500 hPa height field (solid), compared to persistence (dotted), and bias (dashed)

The RMS difference between the analyses and the time-mean field is about 124 meters, so it can be seen that the 5-day errors are still better than that of the mean field, indicating skill. Operational models have RMS errors closer to 60 meters for a similar region, but MM5's bias error, which is close to zero is better than that for many current operational models that have biases nearer 10 meters.

The RMS and bias errors show a slightly anomalous increase at 12 hours that disappears thereafter. This is an effect of a propagation of a sound wave from the Antarctic where the surface pressure estimate is poor. Since the global version of MM5 is 3.3 (for the parallel version), a method of improving the Antarctic surface pressure has not been implemented in the *INTERPF* pre-processor yet. The anomalous pressure wave amounts to about 1 hPa at these latitudes at 12 hrs, but this disperses thereafter.

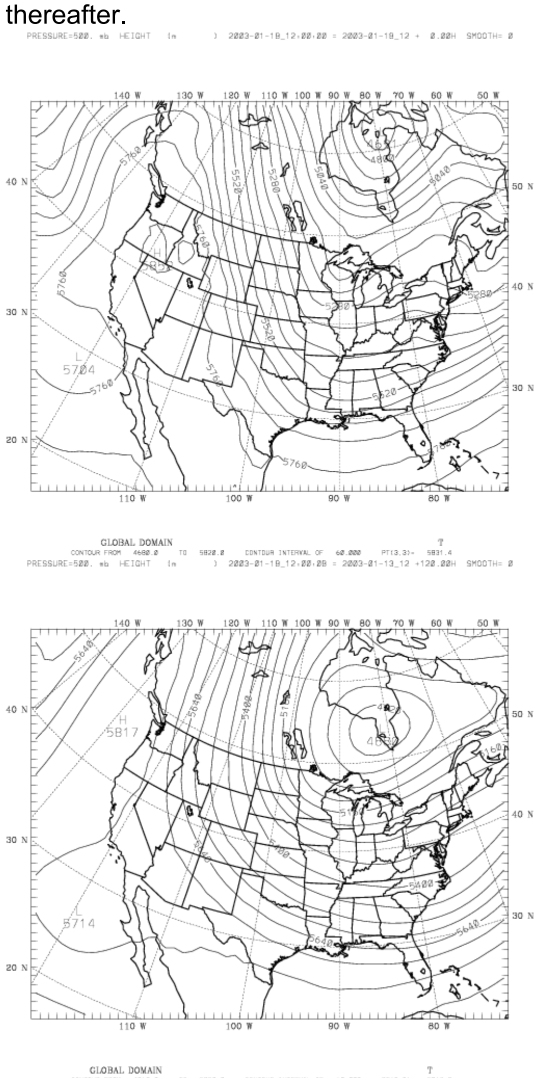

Figure 3. (upper) Analysis of 500 hPa height at 12Z 18 Jan 2003, and (lower) 120-hr forecast verifying at the same time.

An example of a typical 5-day forecast is given in Figure 3, which shows the 12Z 18th January 2003 forecast, and also shows the domain used for the North America verification statistics.

The correlation, 0.951, is close to the median value, and this example demonstrates a fairly successful forecast of an eastern trough.

3.2 Northern Hemisphere

Similar scores have been calculated for the Northern Hemisphere between 20 and 80 degrees latitude, for the same period. Figure 4 shows the correlation score for the Northern Hemisphere.

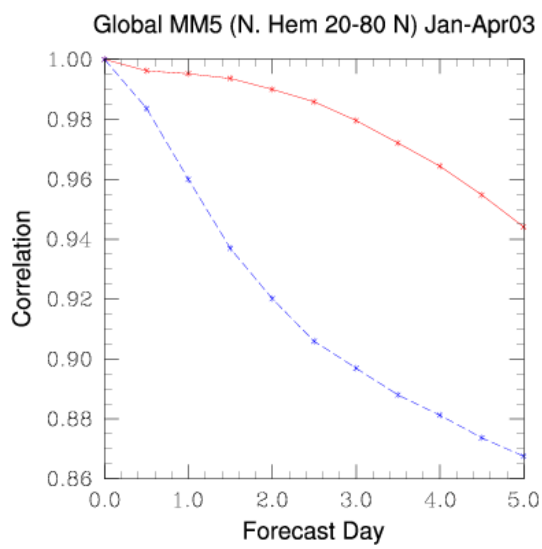

Figure 4. Correlation of 500 hPa height versus forecast length (solid), and for persistence analysis (dashed).

The variation of the 5-day correlation is still high for individual cases (0.87-0.97), and the basic skill is still similar to that for North America.

Figure 5 shows the RMS and bias for the same area. Here note that the bias is still small over this larger area, and also that the 12-hr maximum seen in Figure 2 is not there because the anomalous sound wave is averaged out in this larger region, but the RMS still shows its effect. The RMS of the mean field compared to analyses is 118 meters for this area.

Closer examination of regional biases indicates that the global model tends to have its highest bias in the region north of 80 degrees, with a slight negative bias at low latitudes and a positive bias at high latitudes. It is possible that the model top at 50 hPa influences the polar stratospheric dynamics, and that may lead to this bias.

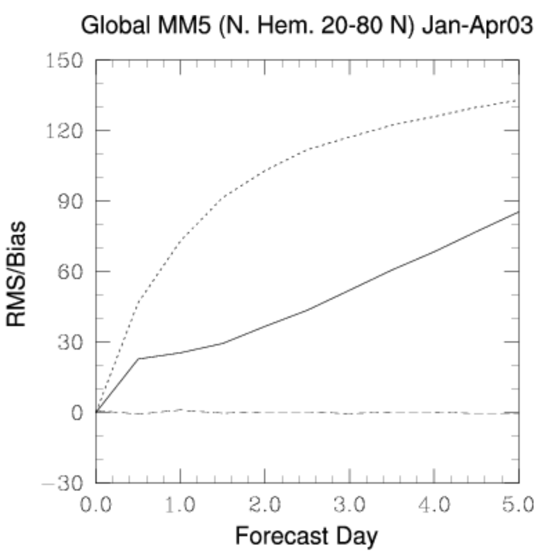

Figure 5. RMS error (meters) in 500 hPa height field (solid), compared to persistence (dotted), and bias (dashed)

Figure 6 shows an example of a Northern Hemisphere 5-day forecast that is again near the median in its correlation skill (0.946). The wave patterns are basically well forecast.

4. CONCLUSION

The performance statistics give us confidence in the model's ability to produce skill at five days with little significant drift.

Further studies are needed to evaluate surface fields, upper winds, and kinetic energy, and to see how forecast skill varies in individual cases between MM5 and GFS.

Our global outputs have been archived since January 2001, and we have a wealth of data for statistical or case studies.

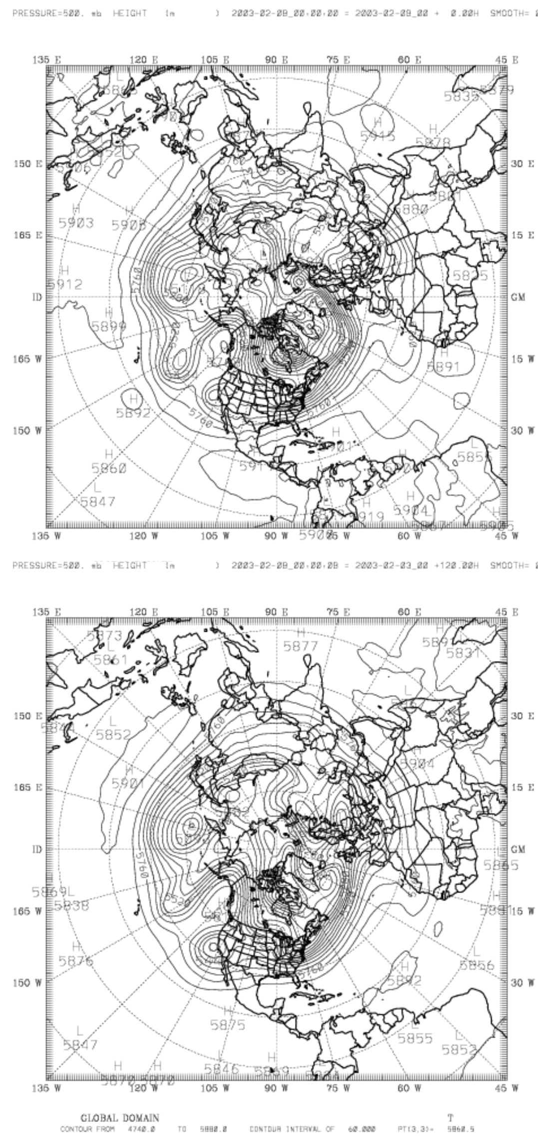

Figure 6. (upper) Analysis of 500 hPa height at 00Z 8 Feb 2003, and (lower) 120-hr forecast verifying at the same time.

5. REFERENCES

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Dudhia, J. and J. F. Bresch, 2002: A global version of the PSU-NCAR mesoscale model. *Mon. Wea. Rev.,* **130,** 2989-3007.