VERIFICATION OF MM5 PRECIPITATION FORECASTS NEAR THE CREST OF THE WASHINGTON CASCADES DURING THE 1997-98 WINTER SEASON

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ABSTRACT: Twice daily forecasts from the Penn State/National Center for Atmospheric Research mesoscale model (MM5) are currently available for the Pacific Northwest from the University of Washington on the World Wide Web. The accuracy of the precipitation forecasts has been statistically verified at lower elevation sites, but how well does the MM5 forecast precipitation near the Cascade crest? In order to verify the model, observed precipitation data for the 1997-98 winter season was gathered for 9 Northwest Weather and Avalanche Center sites in the Cascades. Bias, mean error, and root mean square error statistics were calculated for the three MM5 resolutions (36, 12, 4 km). Results indicate that for the lighter precipitation events the 36 km resolution has slightly better accuracy than the 12 and 4 km resolutions, although all 3 resolutions generally tend to over predict the lightest events. But the 36 km resolution also misses many of the heavier events. Conversely, the 12 km resolution and especially the 4 km resolution, have high false alarm rates for the heavier events, but many observed heavy precipitation amounts were also predicted with some accuracy.

KEYWORDS: weather forecasting

1. INTRODUCTION

The Penn State/National Center for Atmospheric Research numerical mesoscale model (MM5) is run at the University of Washington with resolutions as fine as 4 km covering western Washington. Real-time results are available on the World Wide Web (www.atmos.washington.edu/data/mm5.cgi). Some of the questions that this paper attempts to answer are as follows. Is the model useful for quantitative precipitation forecasting for the Cascade Mountains? Does the increasing resolution result in more accurate forecasts?

2. DATA

Hourly precipitation data was first gathered from several Northwest Weather and Avalanche Center (NWAC) sites in the Cascades (Figure 1) for the 1997-98 winter season. All of these measuring sites are at the bases of ski areas. Precipitation gages used by the NWAC are electrically heated tipping bucket gages with an 8 inch collection diameter, which are monitored by Campbell CR-10 data-loggers accessed via phone lines. While the gages are generally located in sheltered locations, under catchment of 20-60% may occur during snowy and windy conditions (Dingman 1994). Quality control efforts with this data included the removal of single hour amounts greater than .50 and the interpolation of single missing hours. The hourly data was then summed into 24 hour amounts ending at 00 UTC and 12 UTC. The 24 hour data was compared to handwritten records of precipitation for each site to insure accuracy.

The MM5 is run twice a day at the University of Washington with initialization at 00 UTC and 12 UTC, and 3 resolutions (36, 12 and 4 km). The 36 km domain covers much of the northeast Pacific Ocean, western Canada and the western U. S., while the 12 km domain covers Washington and Oregon, along with Vancouver Island and southern British Columbia. See Colle et al. (1998) for a diagram of the exact locations of the 36 and 12 km domains. The 4 km domain covers western Washington and is also shown in Figure 1, along with the model topography used in the 4 km domain. The model topography is much less detailed within the 36 and 12 km domains. For example, the Olympic Mountains and Oregon

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coastal range are not represented in the 36 km domain.

Initial and boundary conditions for the MM5 are obtained by interpolating the National Center for Environmental Prediction (NCEP) ETA 48 km forecasts (see Colle et al. 1998). The 12 to 36 and 24 to 48 hour periods of the MM5 model runs were used in this study and the gridded precipitation forecasts were interpolated to the observations sites using an inverse distance Cressman method as in Colle et al. (1998). The statistical parameters described in the following sections were calculated for the period of 15 November 1997 to 15 March 1998.

3. STATISTICAL PARAMETERS

The primary verification scores used in this study are the bias score, the mean error and the root mean square error. These scores were compared for the various model resolutions using the same forecast periods and observations. The bias score (B) is defined as

$$B = F / O \quad (1)$$

where F is the number of forecasts for each site that predict precipitation equal to or greater than a threshold amount, and O is the actual number of observations that meet or exceed the threshold. Thresholds used in this study where .1, .3, .5, .7, .9 and 1.1 inches for the 24 hour periods. The bias score reveals systematic over prediction (B>1) and under prediction (B<1) when averaged over many cases. Because the bias score simply compares the frequency of these occurrences it provides no measure of the accuracy of the forecasts.

The mean error (ME) is simply a sum of all the predicted minus observed (P-X) precipitation (inches) for the 24 hour period, divided by the number of observations (#).

$$ME = \text{sum} (P - X) / \# \quad (2)$$

One must remember that an average of positive and negative values given by the difference P-X may have a canceling effect, giving the appearance of low mean error. However, a significant positive or negative value of the mean error can give an indication of persistent over or under forecasting, respectively.

The root mean square error (RMSE) sums the square of the differences P-X, divides by the number of observations (#), and takes the square root of that amount.

$$RMSE = (\text{sum} (P - X)^2 / \#)^{1/2} \quad (3)$$

The RMSE does not have the ME cancellation problem. However, since the error is a squared difference, small timing and spatial errors of weather features can result in large RMS errors.

In order to create the figures described in the following section, values of both the ME and RMSE were averaged within certain ranges of observed 24 hour precipitation. The ranges used were 0-.1, .1-.3, .3-.5, .5-.8, .8-1.2, and greater than 1.2 inches of precipitation in 24 hours.

4. RESULTS

Bias scores averaged using all the NWAC stations are presented in Figure 2. The low scores (B<.5) for the 36 km resolution at the higher thresholds (O>~.8 inches/24 hours) indicate that many more heavy events occurred than were forecast for this resolution. The higher scores for the 12 km and especially for the 4 km (B>2) resolutions at similar higher thresholds indicate that many more forecasts were made for heavy events than actually occurred (a high false alarm rate).

Mean errors for the 9 stations are presented in Figure 3. All three MM5 resolutions generally predict too much precipitation for light events (X<~.2 inch/24 hours). Strongly negative results with increasing precipitation is evident for the 36 km domain. For example, for events of about 1 inch/24 hours, the 36 km resolution captures about .5 inches on average. When combined with the trend seen in the bias scores for the 36 km domain (cf. Fig. 2), one can conclude that the 36 resolution misses the heavier events. Somewhat conversely, the 4 km mean errors are closer to 0 for the heavier events. This indicates that although Fig. 2 suggests a high false alarm rate for the 4 km resolution, the 4 km resolution offers more potential to accurately predict the heavy precipitation events.

RMSE scores are presented in Figure 4. Generally, the 36 km resolution seems confirmed as more accurate for the lighter precipitation events (O< ~.5 inches/24 hours). Although the 36 km RMSE values are generally lower for larger amounts of observed precipitation, one should not conclude that the 36 km resolution is more accurate for heavy events. As mentioned above, small spatial and timing errors will punish the 4 km more than the 36 and 12 km resolutions.

It should be mentioned there is some interesting spatial variability in the statistics between the individual sites (not shown). Most

notably, for heavy precipitation events, the 4 km resolution tends to over predict precipitation near the volcanic peaks (MBK, PRD). Although it is beyond the scope of this paper to present figures of the above statistical parameters for each site, diagrams of this data will be on hand at the conference.

5. CONCLUSIONS

The MM5 generally over predicts precipitation for light events (less than ~.2 inch/24 hours) near the Cascade crest. The 36 km resolution is usually more accurate for amounts less than ~.5 inch/24 hours. But the 36 km resolution also tends to miss or overlook heavier events (more than ~1 inch/24 hours), likely due to a lack of sufficient terrain resolution. The finer resolutions, especially the 4 km resolution, tend to over forecast heavier events but also have some skill in forecasting these events when they actually occur. This is not surprising when considering the more accurately represented topography in the 4 km domain.

6. REFERENCES

Colle, B. A., K. J. Westrick, C. F. Mass, 1998: Evaluation of MM5 and Eta-10 Precipitation Forecasts Over the Pacific Northwest During the Cool Season. *Wea. Forecasting*, in press.

Dingman, S. L., 1994: *Physical Hydrology*. Prentice Hall, 575 pp.

Figure 1. NWAC precipitation sites used in this study, along with the MM5 4 km domain topography. Stations are as follows: Mt Baker (MBK), Stevens Pass (ST9), Tumwater (TUM), Alpental (SNO), Snoqualmie Pass (SSM), Mission Ridge (MSR), Crystal Mtn (CMT), Paradise (PRD), White Pass (WP9).

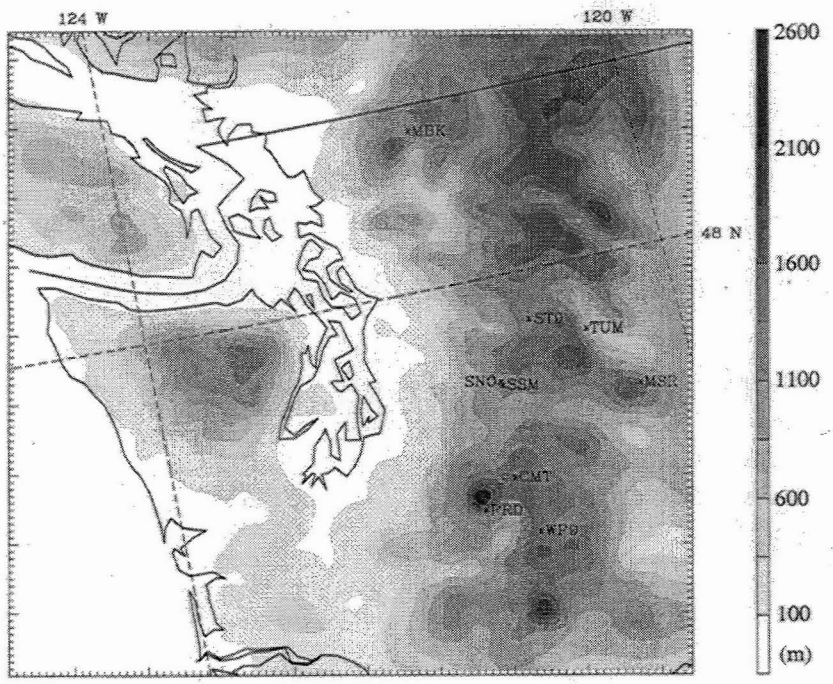
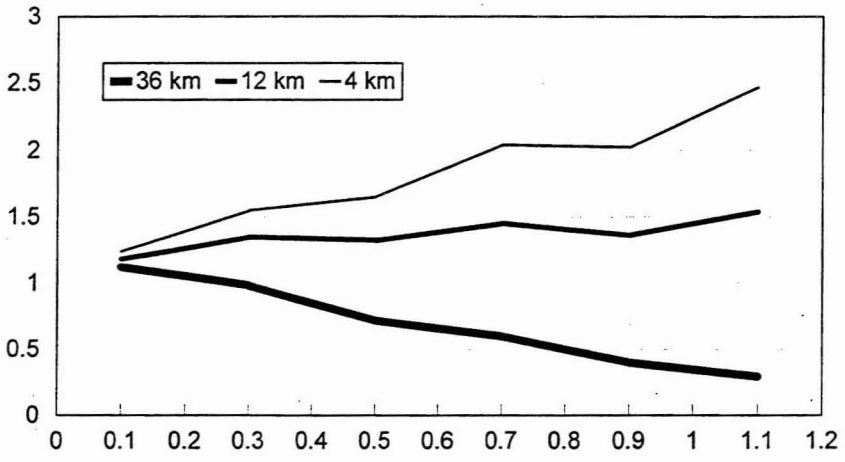
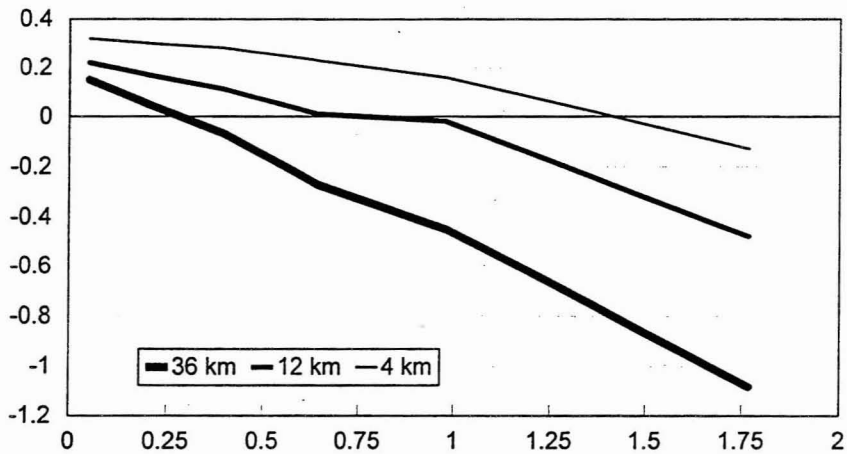


Figure 2. Average Bias Score (all stations)



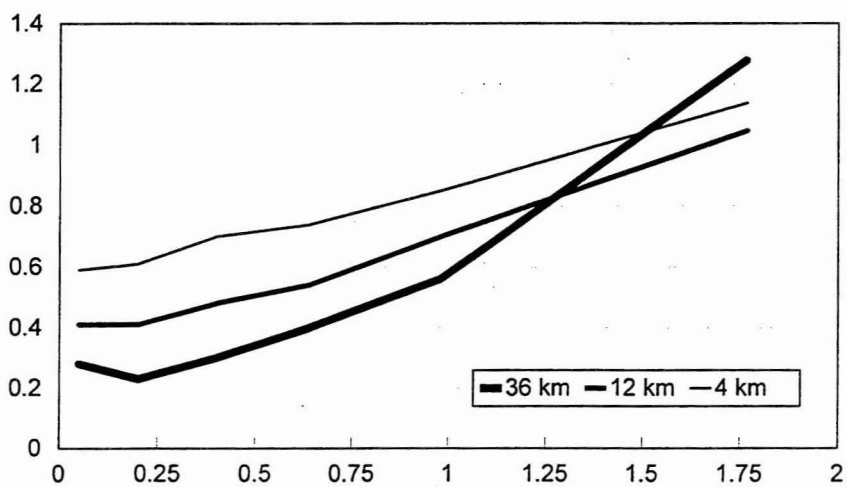
Vertical axis: bias score. Horizontal axis: 24 hour observed precipitation threshold (inches).

Figure 3. Mean Error (all stations)



Vertical axis: mean error (inches). Horizontal axis: 24 hour observed precipitation (inches).

Figure 4. Average Root Mean Square Error (all stations)



Vertical axis: average rms error (inches). Horizontal axis: 24 hour observed precipitation (inches).