4.3 THE PERFORMANCE OF THE ANTARCTIC MESOSCALE PREDICTION SYSTEM (AMPS) FOR AN INTENSE SUMMER STORM IN THE ROSS SEA

Andrew J. Monaghan and David H. Bromwich
Byrd Polar Research Center, Columbus, OH

Ying-Hwa Kuo, Tae-Kwon Wee, and Jordan G. Powers
National Center for Atmospheric Research, Boulder, CO

Arthur M. Cayette
SPAWAR Systems Center, Charleston, SC

1. INTRODUCTION

The Antarctic Mesoscale Prediction System (AMPS) is an experimental system run at the Mesoscale and Microscale Meteorology Division of the National Center for Atmospheric Research (NCAR) and dedicated to real-time numerical weather prediction in Antarctica (Powers et al. 2003a; http://www.mmm.ucar.edu/rt/mm5/AMPS/). AMPS employs the Polar MM5 (PMM5), a version of the Pennsylvania State University/NCAR fifth generation mesoscale model (MM5; Grell et al. 1994) optimized for the environment of polar ice sheets by the Polar Meterology Group (PMG) of the Byrd Polar Research Center at Ohio State University (Bromwich et al. 2001, Cassano et al. 2001; www-bprc.mps.ohio-state.edu/PolarMet/pmm5.html). The role of PMG in AMPS is to provide validation and continual model development. AMPS consists of five domains: 1) a 90-km domain covering most of the Southern Hemisphere; 2) a 30-km domain covering the Antarctic continent; 3) a 10-km domain covering the western Ross Sea; 4) a 3.3-km domain covering the immediate Ross Island region (the hub of the U.S. Antarctic Program); and 5) an additional 10-km domain encompassing Amundsen-Scott South Pole station. A more detailed description of AMPS and a diagram of the domains can be found in Powers et al. (2003b; this issue).

PMM5 has shown promising skill over Antarctica (Guo et al. 2003). The authors' evaluation of a complete annual cycle of 72-h nonhydrostatic simulations indicates that the Polar MM5 accurately captures both the large and regional scale circulation features with minimal bias in the modeled variables. The observed synoptic variability of the pressure, temperature, wind speed, wind direction, and mixing vapor ratio, as well as the diurnal cycle of temperature, wind speed, and mixing ratio are reproduced by the Polar MM5 with reasonable accuracy.

Described here is the first phase of this study, in which the performance of the AMPS PMM5 is assessed for a severe weather event occurring in the Ross Sea in December 2001 (Fig. 1). The minimum pressure in the Ross Sea was 936 hPa according to the European Centre for Medium-Range Weather Forecasts (ECMWF) operational analyses. Winds often exceeding 50 m s^{-1}, precipitation, and blowing/drifting snow caused aircraft operations at McMurdo Station to cease for about a week at the height of the operational season. Thus, it is important to assess model strengths and weaknesses for such an event. Output from the AMPS 30-km domain is evaluated versus observations from manned

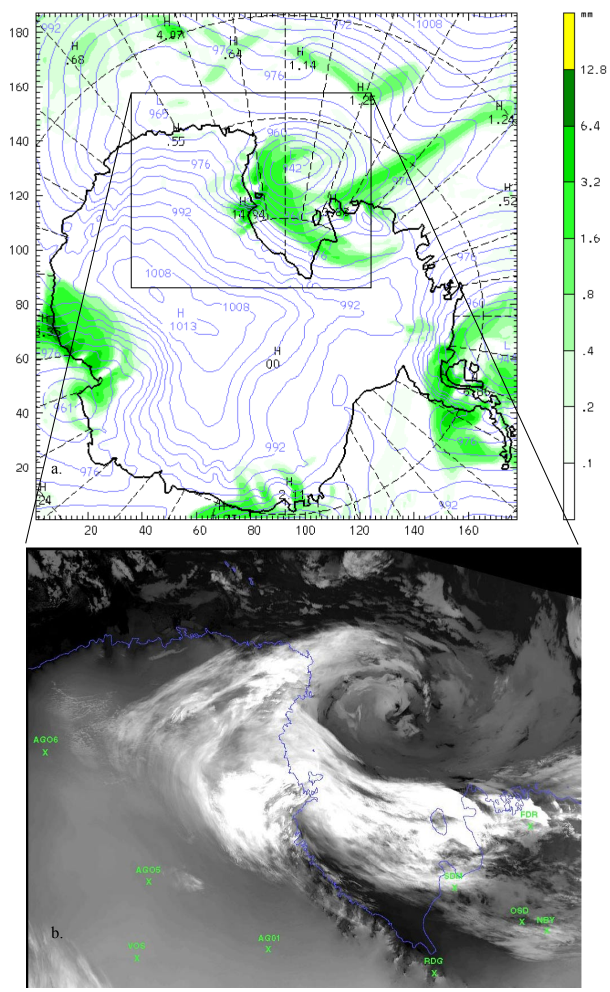

Fig. 1. Mean sea level pressure and precipitation from the AMPS PMM5 30-km domain and the satellite-observed cloud band on Dec 14, 2002.

Corresponding author address: Andrew J. Monaghan, Polar Meteorology Group, Byrd Polar Research Center, The Ohio State University, 108 Scott Hall, 1090 Carmack Rd, Columbus, OH 43210; email: monaghan@polarmet1.mps.ohio-state.edu

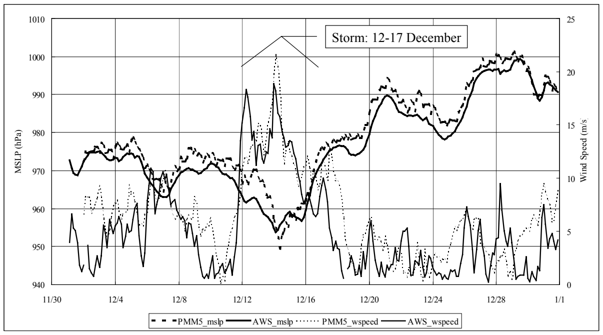

Fig. 2. AMPS 3-hourly PMM5 versus observed mean sea level pressure (hPa) and wind speed ($m\ s^{-1}$) at Ferrell AWS (77.9S, 170.8E), near McMurdo.

and automatic stations, radiosondes, satellite data, and analyses from ECMWF. The second phase of this study will include performing additional AMPS simulations using 3 and 4-dimensional variational data assimilation schemes and incorporating novel data sources such as GPS radio occultations. These will be compared to simulations using the current AMPS configuration, and are expected to bring considerable improvement in model forecast skill and forecast lead-time.

2. DESCRIPTION OF THE STORM

Figure 2 shows the AMPS PMM5 versus observed mean sea level pressure and wind speed at Ferrell AWS, near McMurdo. Winds were considerably higher than normal, sustained at nearly 20 m s-1 at Ferrell, and higher in areas closer to McMurdo (not shown). The maximum intensity (minimum sea level pressure) was less than 960 hPa. Table 1 shows the number of storms in the past 22 years that have had a minimum sea level pressure lower than 960 hPa in the vicinity of McMurdo. Storms this strong are not an uncommon occurrence in the winter and early spring months, when large equatorward mass transport can cause significant pressure falls across the continent (Parish and Bromwich 1998). However, this particular storm is the only event in the McMurdo area in at least the past 22 years that has exceeded a minimum sea level pressure of 960 hPa during December.

Table 1. Total number of storms with minimum sea level pressure < 960 hPa in McMurdo region for Jan-1981-Nov 2002. Calculations are based on sea level pressure at Ferrell AWS. Data from Laurie AWS and Williams Field AWS were used when Ferrell data was missing. (n=number of instances; %-obs=percentage of data available for each month).

Month	Jan	Feb	Mar	Apr	May	Jun
n	0	2	1	4	7	5
%-obs	88	100	99	99	98	97
Month	Jul	Aug	Sep	Oct	Nov	Dec
n	7	8	7	14	2	1
%-obs	94	90	84	91	95	86

3. RESULTS

Figure 3 compares the satellite-observed storm track to the tracks from the AMPS PMM5 forecasts initialized at 1200 UTC 12 December (12/12) and 0000 UTC 14 December (14/00). Intensities at selected times are also plotted, with the observed intensities represented by the ECMWF analyses (the ECMWF tracks and intensities were checked against observations and found to be in good agreement). Inspection reveals that the 12/12 run is generally in good agreement with the observations, while the 14/00 run is too far to the west, and the intensities are too weak. If the initial placement of the forecast lows are compared to the observed placement, it is found that the 12/12 initial fields are much more accurate than the 14/00 fields. The track error of the low in the initial field of the 12/12 forecast (12/18 is used here because the low is not discernable at 12/12 in the satellite imagery) is about 70 km, while the track error of the low in the initial field of the 14/00 forecast is about 250 km. The initial intensity of the 12/12 forecast is too weak by about 6 hPa, but the maximum intensity (939 hPa compares well to the observed maximum intensity (936 hPa). The initial intensity of the 14/00 forecast is too weak by about 7 hPa; the maximum intensity is also too weak by about 7 hPa. These results indicate that for this case, the forecast accuracy and lead-time are very sensitive to the initial fields, which are derived by an objective analysis scheme from the National Centers for Environmental Prediction (NCEP) aviation (AVN) model.

Figure 4a compares the AMPS PMM5 track error for the initial conditions to the mean track error over each 72-h forecast initialized between 10-18 December. A strong relationship (r=0.71) is noted between the initial track error and the subsequent forecast track error. Figure 4b shows the progression of track and intensity error versus forecast hour for the mean of the forecasts between 10-18 December. Improvements over the initial conditions in forecast track and intensity are noted by hour 12. This suggests that the model is compensating for dynamic inconsistencies in the initial fields.

Figure 5 shows the correlation coefficients for the AMPS PMM5 versus McMurdo radiosonde observations throughout the troposphere for geopotential height, temperature, zonal, and meridional wind for the mean of all forecasts between 10-18 December. Inspection indicates that the model depicts geopotential height throughout the troposphere with reasonable skill (r>0.90), although when compared to the correlations for the geopotential height for the 30 days centered on 15 December (not shown; r>0.95), the model performs with less skill. Temperature is simulated with good skill in the mid troposphere (r>0.80), but lacks skill in the boundary layer and at the tropopause (~250 hPa). Zonal winds are captured well above the boundary layer, but are of poor skill near the surface, having a negative correlation with the observations below 900 hPa. This is most likely due to the AMPS PMM5 topographic representation of the Transantarctic Mountains

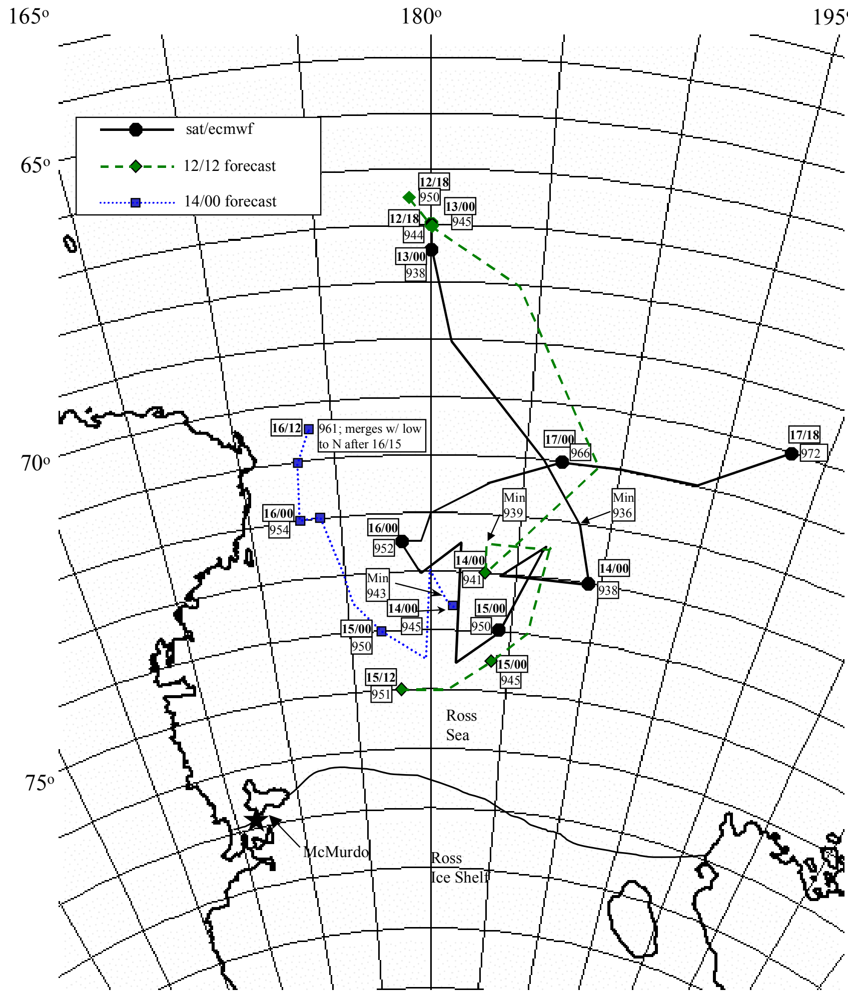

Fig. 3. Storm tracks for the Dec 12-17 low in the Ross Sea for observed (from satellite imagery) and the AMPS PMM5 12/12 UTC and 14/00 UTC model runs. Intensities (hPa) are also plotted for selected times; observed intensity is from ECMWF analyses

immediately to the west, as well as to the high variability and relative weakness of the zonal wind component (the predominant wind direction near McMurdo is southerly). On the other hand, the strong, relatively persistent meridional component is well represented throughout the troposphere (r>0.80 except at 150 hPa).

4. CONCLUSIONS

The performance of the AMPS PMM5 is evaluated for an intense synoptic scale storm in the Ross Sea in December 2001. A December storm of this intensity has not occurred near McMurdo for at least 22 y. Analysis of forecast tracks and intensities indicates that the model is very sensitive to the initial fields for this case. The forecast track error is strongly correlated to the initial track error (r=0.71). Inspection of track and intensity errors versus forecast hour indicates that the forecast improves over the initial conditions by hour 12. This suggests that the model is compensating for dynamic inconsistencies in the initial fields. Correlation coefficients for the AMPS PMM5 versus McMurdo radiosonde observations indicate that the AMPS PMM5 predicts geopotential height with reasonable skill (r>0.90), although this is less than the model skill for the 30-d period centered about this event. The forecast temperature is weakest at the tropopause and in the near-surface boundary layer. The zonal winds are not well depicted in the boundary layer due to high topography to the west, and because of the relatively weak contribution and high variability of the zonal winds compared to the meridional winds. The meridional winds are depicted with good skill throughout the troposphere.

The results of this study provide strong evidence of the AMPS PMM5 sensitivity to the initial conditions, especially in the near-surface layer. Important enhancements in forecast skill might be achieved by improvements to the initial fields. The second phase of this study will include performing additional AMPS

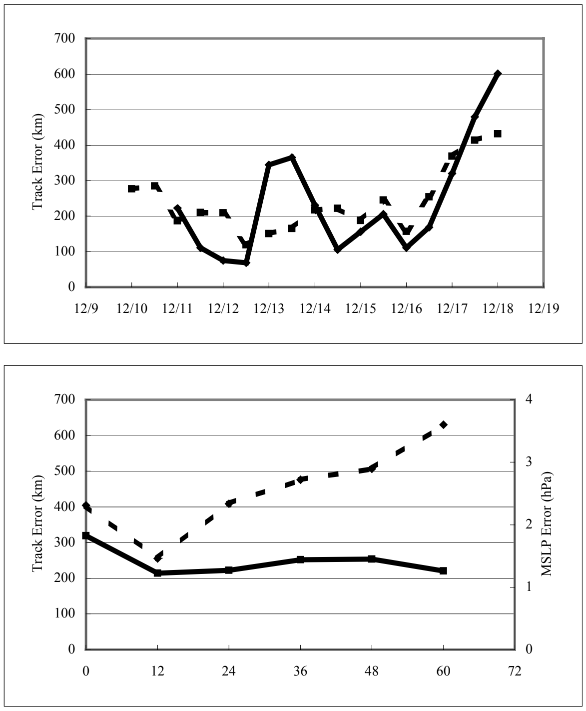

Fig. 4. a) Track error (km) for the AMPS PMM5 initial conditions (solid) and the mean for each 72-h forecast (dashed). b) Track error (solid; km) and intensity error (dahed; hPa) versus hour-of-forecast for all model runs from Dec 10-18. Track error is calculated with respect to satellite imagery. Intensity error is calculated with respect to the ECMWF analyses.

simulations using 3 and 4-dimensional variational data assimilation schemes and incorporating novel data sources such as GPS radio occultations. These will be compared to simulations using the current AMPS configuration, and are expected to bring considerable improvement in model forecast skill and forecast lead-time

Acknowledgments

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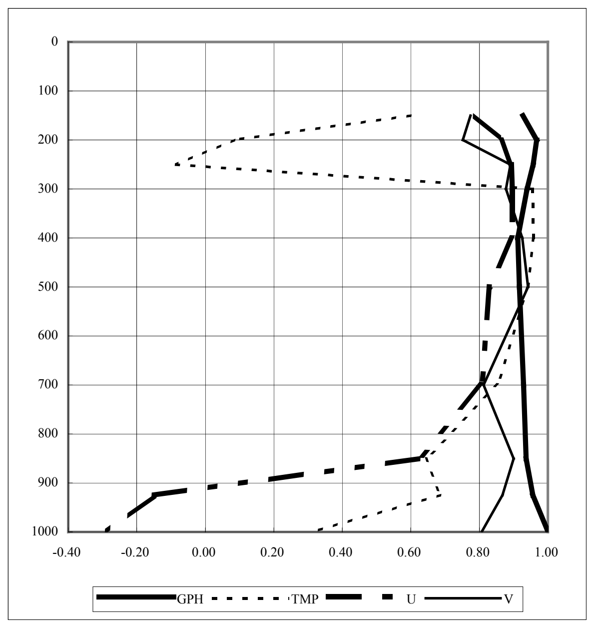

Fig. 5. Correlation coefficients for the AMPS PMM5 versus McMurdo radiosonde observations for the mean of the forecasts from 10-18 December.