EVALUATION OF OPERATIONAL WEATHER FORECASTS FOR ANTARCTICA FROM POLAR MM5-AMPS

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1. Introduction

The Polar MM5 is a hybrid version of the Pennsylvania State / National Center for Atmospheric Research (NCAR) Fifth Generation Mesoscale Model (MM5), modified by the Polar Meterology Group of the Byrd Polar Research Center (BPRC) to represent parameterizations over extensive ice sheets (Bromwich et al. 2001, Cassano et al. 2001). The primary changes include

- modification of the cloud fraction prediction parameterization,
- improved cloud-radiation parameterization,
- improved calculation of heat transfer through snow and ice surfaces,
- an added fractional sea-ice surface type, and
- adopting the planetary boundary layer (PBL) scheme of the Eta model.

The Polar MM5 code is downloadable from the Polar MM5 page at http://www-bprc.mps.ohio-state.edu/PolarMet/pmm5.html. These polar modifications will also be available as a part of MM5 version 3.5 from NCAR. Recent validations of Polar MM5 performance over Greenland and Antarctica reveal that the model shows high skill in capturing key variables such as temperature, pressure, and winds (Cassano et al. 2001, Bromwich et al. 2001, Guo et al. 2002). In addition, the Polar MM5 is employed in the Antarctic Mesoscale Prediction System (AMPS), an experimental numerical weather prediction program focusing on Antarctica (Fig. 1). AMPS, which is cooperative project between Mesoscale and Microscale Meteorology Group at NCAR and the Polar Meteorology Group at BPRC, resulted from the need for more accurate, longer-range forecasts in Antarctica (Bromwich and Cassano 2001, Powers et al. 2001). The United States Antarctic Program (USAP) operating out of McMurdo Station, Antarctica, relies heavily on weather forecasts for the coordination of short-term local field logistics, as well as flight operations from Christchurch, New Zealand. Flights from New Zealand take up to 8 hours to reach McMurdo – enough time for the weather to change dramatically in this terrain-dominated area with coastal mountains in excess of 3,000m high. This has the potential to endanger passengers and cargo, and can be very expensive if the flights must return to Christchurch. One element of AMPS is to assess the performance and accuracy of the Polar MM5 (PMM5) by employing case studies of unique weather events and performing extensive validations.

Here, we present some of the key findings of recent studies of PMM5-AMPS. These include highlights from

- a one year evaluation of PMM5 simulations for 1993,
- a case study of AMPS performance during a mesoscale cyclogenesis event in the Western Ross Sea in Jan 2001,
- the performance of several models in the rescue of Dr. Ronald Shemenski from South Pole in April 2001, and
- some preliminary findings from a detailed validation of AMPS performance from December 2001 to March 2002.

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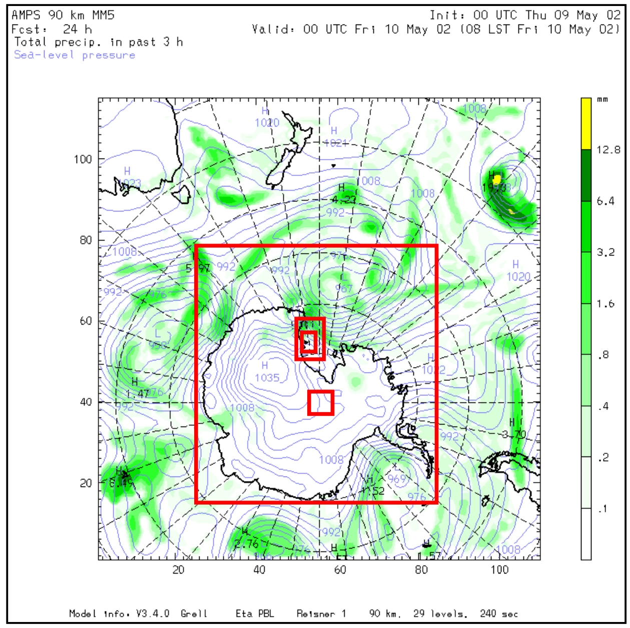

Fig. 1. AMPS 90-km , 30-km, 10-km, 3.3-km Ross Sea, and 10-km South Pole forecast domains.

2. Recent Studies of PMM5-AMPS

a. A one year evaluation of PMM5 simulations for 1993 (Guo et al. 2002)

For a one year (1993) evaluation of PMM5 over Antarctica, a series of 72-h simulations reinitialized every 48-h (the first 24-h were discarded for spin up) were performed. Figure 2 shows the observed versus modeled monthly means averaged over 28 sites in Antarctica. The plots indicate the model's good skill in capturing near surface pressure, temperature, wind speed, wind direction, and mixing ratio across the continent on monthly and annual timescales, indicating its usefulness for climate studies. The model does have a systematic cold bias that is most likely related to the interaction of clouds and radiation. This is a major focus of future model improvement efforts.

Figure 3 demonstrates PMM5's ability to capture the magnitude and variability of mid-tropospheric features in both summer (January) and winter (July) at synoptic time scales. Of particular interest is the ability to capture the moisture fields (Fig 3b, 3e), which is a common model deficiency in polar regions due to problems resolving clouds and a limited understanding of moisture conditions in extremely cold, dry conditions.

Figure 4 shows a monthly time series of 3-hourly observations versus PMM5 for Neumayer (70.7°S, 8.3°W) along the coast of East Antarctica during summer. The model shows high skill in resolving surface pressure and wind direction, and good skill in predicting surface temperature, wind speed and mixing ratio at synoptic time scales. The model tends to underpredict strong wind events, and shows a slightly dampened response to low-temperature and moisture events. Future improvements to the

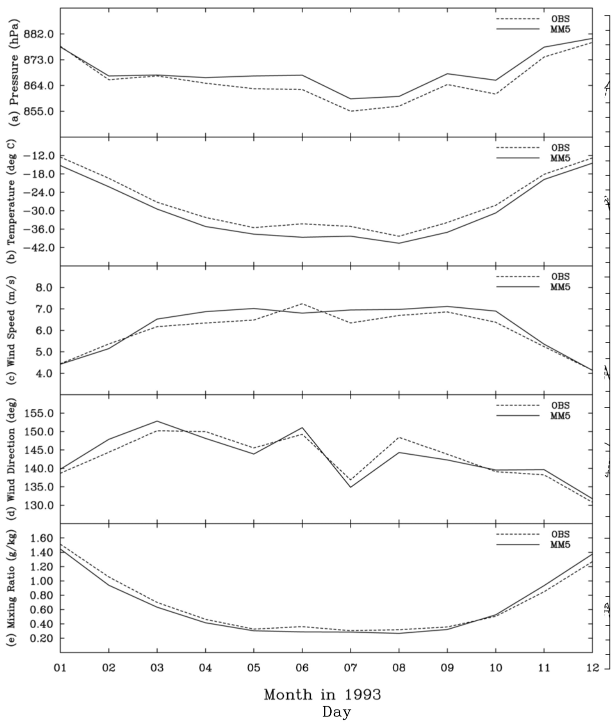

Fig. 2. Monthly mean values calculated from the Polar MM5 simulations (solid lines) and from the AWS and manned stations (dashed lines). The monthly mean values have been averaged over 28 sites.

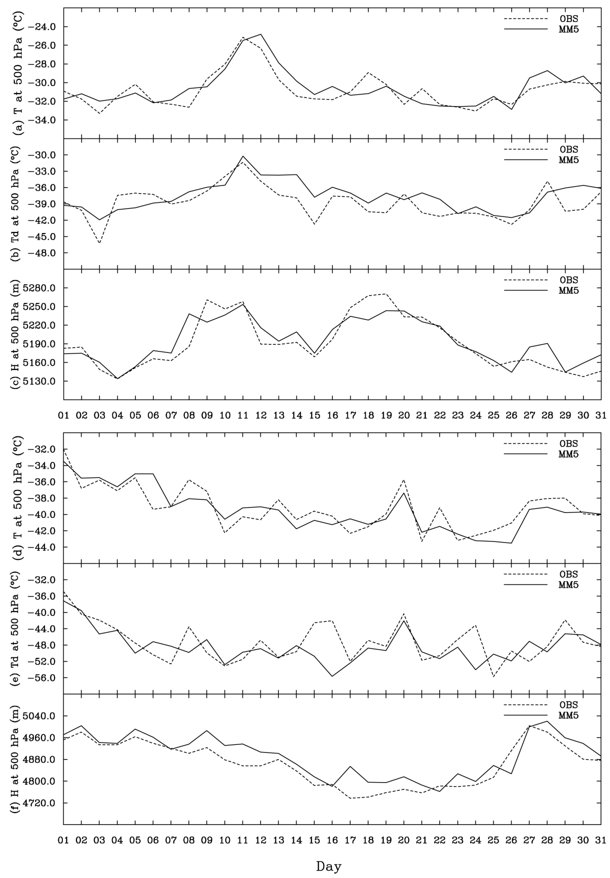

Fig 3. Time series of variables at 500 hPa calculated from the Polar MM5 simulations (solid lines) and station observations (dotted lines) for January ((a)-(c)) and July ((d)-(f)) 1993. The variables have been averaged over 5 radiosonde sites.

PBL scheme are aimed at improving the modeled surface response.

b. A case study of AMPS performance during a mesoscale cyclogenesis event in the Western Ross Sea in Jan 2001 (Bromwich et al. 2002)

A case study of the AMPS PMM5 performance during an event of mesoscale cyclogenesis in the Ross Sea during January 2001 was done to assess the weaknesses of the modeling system. Figure 5 demonstrates the dependence of the AMPS PMM5 on initial and boundary conditions (ICs/BCs), which are derived from the National Centers for Environmental Prediction's Aviation (AVN) model. In Fig. 5a, the ICs/BCs are derived from AVN, and in Fig. 5b, the ICs/BCs are derived from European Centre for Medium-Range Weather Forecasts (ECMWF) operational analysis data. It is seen that the evolution of the modeled pressure fields are quite different by hour 12 for the two cases, although all other factors remain identical. Though neither model captures the placement of the observed features ("L_N" and "L_S" in bold print), the run using ECWMF ICs/BCs resolve two lows, similar to observed, while the run using AVN ICs/BCs resolves one low.

c. The performance of several models in the rescue of Dr. Ronald Shemenski from South Pole in April 2001 (Monaghan et al. 2002)

The aircraft mission to South Pole in the rescue of Dr. Ronald Shemenski in April 2001 was an unprecedented operation, as it occurred in extremely cold (~-60^{o}C) temperatures and near 24-h darkness, about 2 months after the halt of aircraft operations for the season. The biggest challenge facing forecasters was accurately forecasting the decrease of the strong surface winds. Blowing snow resulted from the winds and delayed the flight from Rothera to Pole for several days. It is instructive, then, to evaluate the performance of several weather forecast models that provided important guidance to forecasters during this unique event. Figure 6 compares the performance of the 30-km domain of AMPS with the AVN model, the ECMWF forecast model, and the Global MM5 in forecasting the wind speed at Pole. The horizontal black bar at the top of the first plot indicates times when blowing snow was reported. The vertical gray bar in each plot indicates the time when the actual rescue flight to Pole was in the air, which corresponded to the surface winds at Pole subsiding (accurately predicted by the forecasters). In predicting the wind speed variability, particularly capturing the decline in wind speed on 24-25 April, AMPS displays the greatest drop (~4 m s^{-1}), while ECM and AVN predict a more moderate drop (~2 m s^{-1}). There is a small drop (~1-2 m s^{-1}) in the GLO wind speed during this period. The lack of the winds subsiding in GLO may be related to a discrepancy at Pole in the surface topographic dataset originally used. This has since been adjusted to reflect the accurate topography. Noting the observed wind speed during the blowing snow event, a blowing snow "wind speed threshold" can be approximated at about 6 m s^{-1}, which is confirmed by the forecasters at McMurdo. Using this general rule, AMPS and ECM would have accurately predicted the blowing snow event and its subsequent cessation on 24 April. The statistics (not shown) indicate that ECM has the lowest bias and RMSE and highest correlation with the observed values.

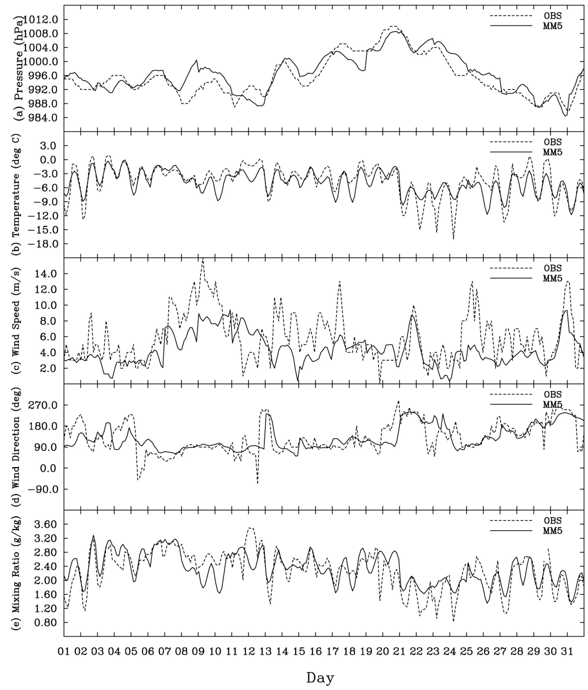

Fig 4. Monthly time series of 3-hourly station observations (dotted lines) and Polar MM5 simulations (solid lines) at Neumayer for January 1993.

d. Some preliminary findings from a detailed validation of AMPS performance from December 2001 to March 2002.

A one-year evaluation of the performance of AMPS is currently underway. Figure 7 shows the correlation statistics for observed versus AMPS PMM5 upper level temperature (Fig. 7a), geopotential height (Fig. 7b), wind speed (Fig. 7c), and relative humidity (Fig. 7d) at McMurdo Station for the 90-km, 30-km, 10-km, and 3.3-km resolution model domains. In general, all domains show high skill in capturing temperature, geopotential height and wind speed, and moderate skill in resolving the moisture field. There is an abrupt drop in skill in the temperature fields at the tropopause (~300 hPa). The correlations for geopotential height are 0.97 or above for all four domains, indicating an extremely good depiction of the large-scale forcing. Inspection indicates that model skill is generally poorest near the surface, indicating the need for future improvements in PBL parameterizations. Finally, it is rather surprising that the lower resolution domains demonstrate somewhat more skill than the finer resolution grids, which were expected to perform considerably better. This may reflect the limitations of the model initial conditions, or a feedback process due to the two-way nested that has not yet been examined.

3. Summary

The PMM5 is a promising model, both for climate simulations and for numerical weather prediction in the context of AMPS. The model shows high skill in capturing synoptic variability and in resolving wind and temperature fields as well. The best model performance is observed in the free atmosphere, where the direct influence of topography is reduced. This indicates the need for improvements to parameterizations in the PBL scheme to better reflect the unique subgrid-scale processes taking place over Antarctica. In addition, the models ability to capture the moisture fields with moderate skill is promising. Future work aimed at advancing the parameterizations of cloud fraction prediction and cloud-radiation interaction should serve to improve modeled precipitation estimates and reduce or eliminate the systematic cold bias. It is envisioned that these issues will be addressed in the context of the Ross Island Meteorology Experiment (RIME), a proposed field program with the goals of expanding our understanding of Antarctic meteorology and applying this toward the improvement of model physics. A detailed science plan for RIME is available at http://www-bprc.mps.ohio-state.edu/RIME-01/sciplan.html.

Acknowledgments

This work is supported by UCAR subcontract SO1-22961, NASA grant NAG5-9518, and NSF grants OPP-9725730 and OPP-9905381.

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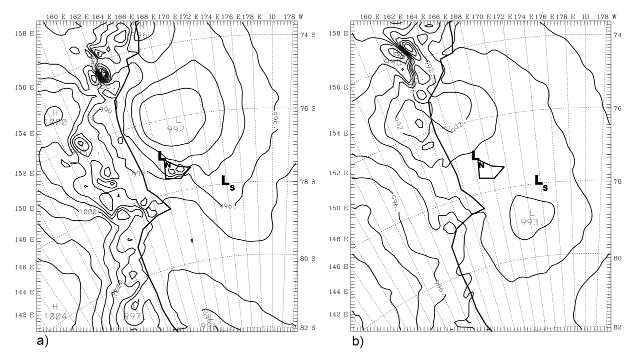

Fig 5. Hour 12 (0000 UTC 15 January 2001) of AMPS forecast initialized at 1200 UTC 14 January using a) AVN initial and boundary conditions and b) ECMWF/TOGA initial and boundary conditions. The positions of the observed surface lows are indicated by "L_N" and "L_S".

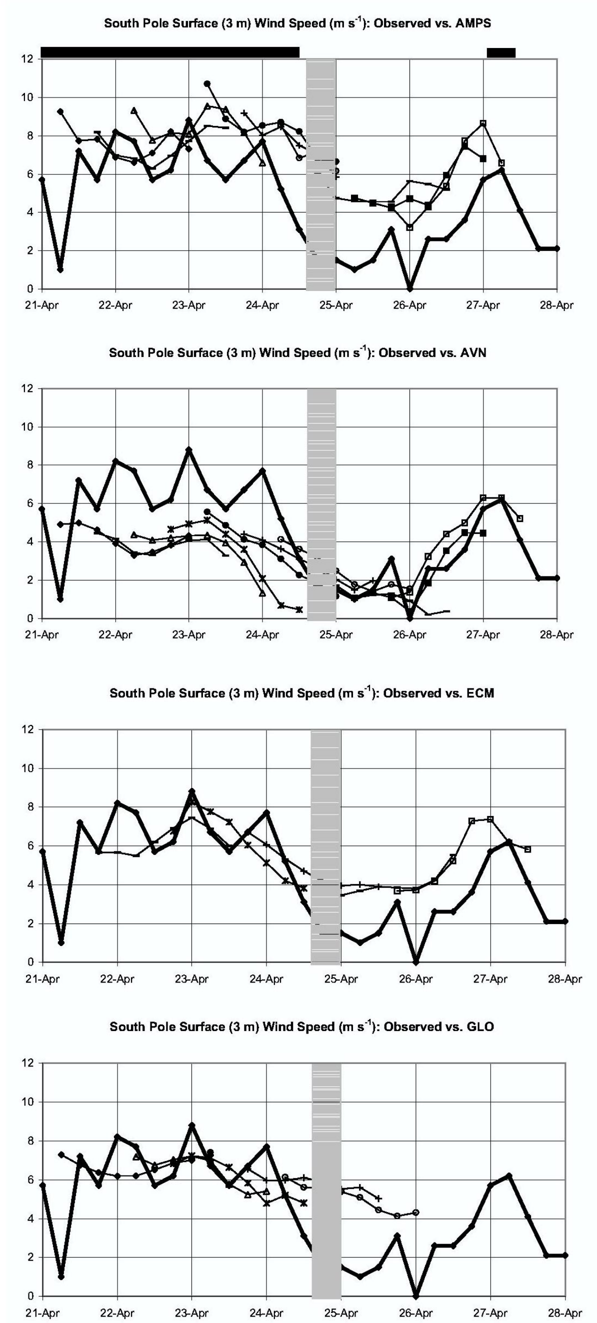

Fig 6. Observed vs. forecast surface (3 m) wind speed (m s^{-1}) at South Pole, 21-27 April 2001 for all forecasts out 06-48 h from the initial time. Observations (thick line) are from Clean Air AWS (90 S, 0 E). The grey vertical bar in each plot indicates the duration of the flight to Pole. The black horizontal bars at the top of the first plot represent times when blowing snow conditions was reported at Pole. Abbreviations: AMPS=AMPS 30-km MM5, AVN= NCEP's Aviation model, ECM=ECMWF Forecast model, and GLO=Global 120-km MM5.

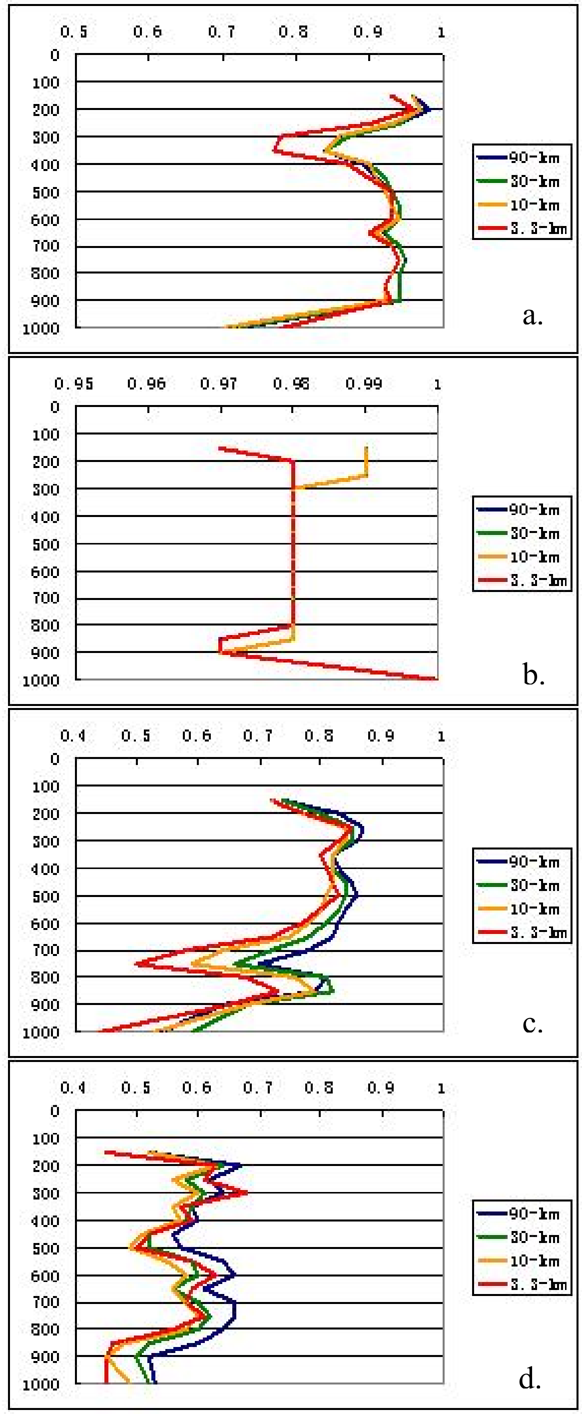

Fig. 7. Correlation statistics for observed versus the AMPS PMM5 for a) temperature, b) geopotential height, c) wind speed, and d) relative humidity for soundings at McMurdo Station, Antarctica, Dec 2001-March 2002. Approximately 200 radiosonde observations were used in the calculations.