P1.28

SIMULATION OF THE ATMOSPHERIC STATE OVER THE ARCTIC RIVER BASINS WITH THE POLAR MM5 AND THE NCAR LAND SURFACE MODEL

Yan Ma [1*], David Bromwich[1] and Helin Wei[2]
[1]Polar Meteorology Group, Byrd Polar Research Center, The Ohio State University, U.S.A.
[2] National Centers for Environmental Prediction/NOAA, U.S.A.

1. INTRODUCTION

There are many northward flowing rivers that discharge into the Arctic Ocean. This freshwater input helps to sustain the low salinity surface layer and thus maintain the perennial sea ice cover. The changes of temperature and precipitation in the Arctic region can affect global climate through alterations in sea ice distribution and Arctic Ocean circulation. For these reasons, the atmospheric state over the Arctic river basins is important to study.

In this paper, we examine the success of a modified version of the Pennsylvania State University-National Center for Atmospheric Research (PSU-NCAR) fifth-generation mesoscale model (MM5, version 3.4) and the NCAR Land Surface Model (LSM version 1.0) in simulating meteorological features across the Arctic river basins. MM5 was adapted by the Polar Meteorology Group at the Byrd Polar Research Center for use in the polar regions, and is termed Polar MM5 (http://www-bprc.mps.ohio-state.edu/PolarMet/pmm5.html).
Successful numerical simulations of the atmospheric circulation over the Antarctic and Greenland ice sheets with Polar MM5, which is based on version 2 of the PSU-NCAR MM5, have been conducted (Cassano et al. 2001; Bromwich et al. 2001; Guo et al. 2003). The purpose of the study is to illustrate the skill of the coupled model (Polar MM5+LSM) in simulating the atmospheric state over the Arctic river basins.

2. DATA AND METHOD

The Polar MM5 used in the study is based on version 3.4 of the PSU-NCAR mesoscale model (MM5). Physical options used in the paper include the Reisner explicit microphysics parameterization for the large-scale cloud and precipitation processes (Reisner et al. 1998) and Grell cumulus parameterization for the subgrid-scale cloud processes (Grell et al. 1994). Overestimated cloud cover using MM4 (same physics as MM5) was found over the Antarctic by Hines et al.(1997) and over the continental United States by Manning and Davis (1997). So in the Reisner scheme, replacement of the Fletcher (1962) equation for ice nuclei concentration with that of Meyers et al. (1992) eliminates the cloudy bias in polar regions found with standard MM5. The National Center for Atmospheric Research (NCAR) community climate model version 2 (CCM2) radiation scheme is also modified and used in Polar MM5. Cloud cover is predicted by cloud water and ice mixing ratios instead of being a simple function of the grid-box relative humidity that is used in the standard MM5; this approach eliminates excessive cloud liquid water path (Hines et al. 1997). The planetary boundary layer (PBL) is parameterized using the 1.5-order turbulence closure scheme of Janjic (1994). The NCAR Land Surface Model (LSM, Bonan 1996) is implemented into the Polar MM5 to describe the land surface characteristics in detail. The LSM provides to the Polar MM5 surface albedos, upward longwave radiation and surface heat fluxes at every time step. Detailed soil and vegetation modules contained in LSM are helpful for studying the near-surface meteorological variables over the Arctic river basins.

Near real-time predictions of atmospheric behavior over the Arctic river basins are performed once a day using the coupled model (Polar MM5+LSM). Two model domains are used, one centered at (65 ^{o}N, 95 ^{o}W) with 150 by 150 grids (termed North America), and the other at (65 ^{o}N, 75 ^{o}E) with 180 by 180 grid points (referred to as Eurasia), both with a horizontal resolution of 60 km. First, parallel simulations of the Polar MM5 and the original MM5 for 19-29 April 1997(10-day simulation) over North America are carried out. Then extended evaluation of real-time Polar MM5+LSM simulations (15 November 2002 to 15 January 2003) are presented to indicate the forecast skill of coupled model over the Arctic river basins. The initial and boundary conditions for the simulations were obtained from daily 00 UTC run of the Aviation Model (AVN) issued by National Centers for Environmental Prediction (NCEP). The MM5 runs are initialized at 00 UTC for a 48-h short duration simulation with the first 24-h simulation discarded for spin-up purposes. The observations used for validation of the MM5 simulations are obtained from global surface observations from NCEP, the University of Wyoming and automatic weather station (AWS) observations from the Greenland Climate Network (GC-NET) (Steffen and Box 2001).

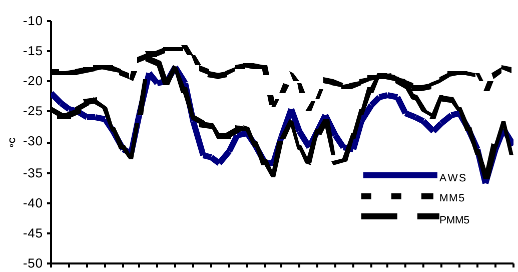


Fig.1 Time series of the original MM5 and the Polar MM5 forecasts and the Tunu_N observations from 00 UTC 20 April to 00 UTC 29 April 1997 for temperature (00/20= 00 UTC 20 April 1997)

* *Corresponding author address*: Yan Ma, Byrd Polar Research Center, The Ohio State University, Columbus, OH 43210-1002; e-mail: yma@polarmet1.mps.ohio-state.edu

3. RESULTS

3.1. Comparisons of the forecasts between the Polar MM5 and the original MM5, both with specified land surface characteristics

It is clear from above the description that there are big differences in physical parameterization schemes between standard and the Polar MM5. First, the comparisons of 10-day simulation of the near-surface variables from the original MM5 and the Polar MM5 with AWS observations are presented here. The prediction for Greenland station Tunu_N is selected to display the improvement of the Polar MM5 over the North American Arctic region. Time series plots of the Polar MM5, standard MM5 predictions and AWS observation at Tunu_N for surface pressure, temperature, mixing ratio, wind speed and wind direction are analyzed. In general, the Polar MM5 performs better than the standard MM5 over the North American Arctic, especially for simulations of near-surface temperature and mixing ratio. The Polar MM5 time series of the near-surface meteorological variables are in good agreement with the observations, apart from a slight cold bias. The time series of near-surface temperature, Fig. 1, show that the Polar MM5 reproduces the observed temperature with a high degree of accuracy. On the other hand, standard MM5 does not have good forecasts for the near-surface temperature at Tunu_N. The mean biases in temperature are -0.4 °C in the Polar MM5 and 8.3 °C in the original MM5. The original MM5 predicted much too warm near-surface temperatures . Compared with the prediction of the original MM5, the Polar MM5 simulated the clear diurnal temperature cycle. The Polar MM5 modeled mixing ratio displays a slight moist bias of 0.1 g/kg; the time series circle shows a very good agreement with the observed (not shown). Similarly, the time series of near-surface mixing ratio from the original MM5 shows a large moist bias.

From above analyses and comparisons, the Polar MM5 produces better near-surface variable forecasts than the original MM5 for both magnitude and trend. The high degree of forecast skill at Tunu_N, which represents the Arctic region, verifies the ability of the Polar MM5 over the Arctic. The well predicted near-surface temperature and mixing ratio with the Polar MM5 further confirm that the modified physical parameterization schemes are appropriate for the North American Arctic.

Table 1. Statistics of the Polar MM5 predictions and the surface observations for four areas during19-29 April 1997.

Area	Sea-level Pressure (hPa)				Temperature (°C)			
	number	bias	rmse	corr	number	bias	rmse	corr
130W-70W 30N-50N	292	0.1	1.2	0.98	311	-1.8	1.9	0.98
140W-70W 50N-60N	122	-0.5	2.1	0.96	133	-1.1	2.0	0.94
140W-70W 60N-70N	39	0.6	1.9	0.93	41	2.0	2.6	0.96
20W-60W 60N-80N	23	1.7	3.1	0.97	28	-0.7	1.1	0.87

3.2. Verification of the Polar MM5 forecasts with NCEP global surface observations.

The observations of four stations near the Arctic river basins were used to verify the Polar MM5 forecasts with specified land surface characteristics during April 1997. Stations Highvale and Rosetown are near the Mackenzie River basin; Schefferville lies in the La Grande River basin; and the Pass is located in the Nelson River basin .The four stations are selected to best represent the Arctic river basins. For example, Fig. 2 shows the time series of near-surface temperature for the Schefferville (54.8 °N,66.8 °W) from 00 UTC April 19 to 00 UTC April 29 1997 at 12 h intervals. Polar MM5 captures the temperature variations very well.

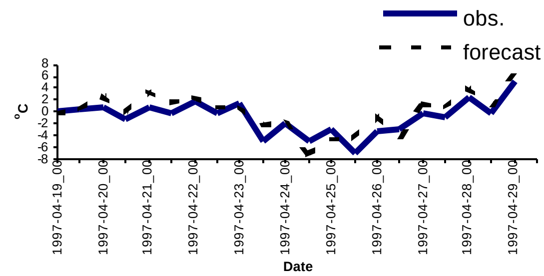


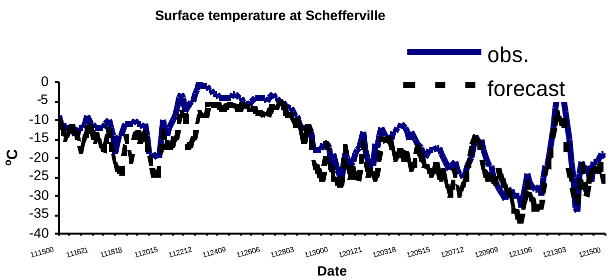
Fig.2 Time series of the Polar MM5 forecasts (dashed line) and observations (solid line) at Schefferville, 19-29 April 1997.

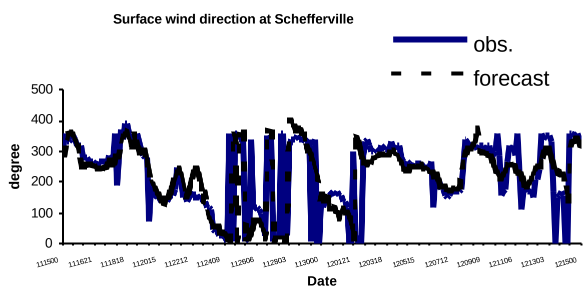
To further understand the forecast accuracy of Polar MM5 over large areas, the characteristics of the near-surface meteorological variables for four areas are considered as well. They are area#1 (130 °W-70 °W, 30 °N-50 °N) representing United States, area#2 (140 °W-70 ° W, 50 °N-60 °N) and area#3 (140 °W-70 °W, 60 °N- 70 °N) representing Canada and the fourth area (20 ° W- 60 °W, 60 °N-80 ° N) representing Greenland. Based on comparisons every 12 h, the number of observations, bias (mean modeled-mean observed), root mean square error (rmse) and the correlation coefficient between the observed and the modeled time series for the four areas are listed in Table 1.

A review of Table 1 and Fig.2 indicates the high level of skill displayed by the Polar MM5 forecasts over the North American domain. The 10-day time series of the modeled near-surface temperature are in close agreement with the observed time series. The modeled near-surface temperature reproduces the observed diurnal temperature range with high degree of accuracy at the stations considered, which represent the land surface features over North American Arctic river basins. The maximum bias in the sea-level pressure over the four areas is 1.7 hPa, and the maximum bias of the near-surface temperature is 2.0 °C. The diurnal circle of the near-surface temperature is forecasted clearly and successfully over the four areas; the time series of modeled sea-level pressure matches the observed time series very well (not shown).

3.3. Verification of the real-time coupled model with surface observations

Comparisons between the Polar MM5 and the coupled model (Polar MM5+LSM) reveal that the coupled model can improve the forecast skill for surface variables at some sites (not shown). The real-time forecasts using the Polar MM5+LSM are run every day for a 48-h prediction to describe the atmospheric state over North America and Eurasia (http//:www-bprc.mps.ohio-state.edu/PolarMet/arcticnwp.html). The comparisons use 25 sites from North America and 27 sites from Eurasia. For North America, the average bias, root mean square error and the correlation coefficient from 15 November to 15 December 2002 for sea-level pressure are 1.9 hPa, 4.1 hPa and 0.91; for the near-surface temperature, they are –2.5 °C, 4.6 °C and 0.80. For the Eurasia domain, they are 1.5 hPa, 3.6 hPa and 0.93 for sea-level pressure; and they are –2.9 °C, 4.6 °C and 0.82 for the near-surface temperature. Considering sites poleward of 50 °N, the statistics are better than for the entire North American and Eurasian domains. The model simulation performs better over mid-high latitude areas.





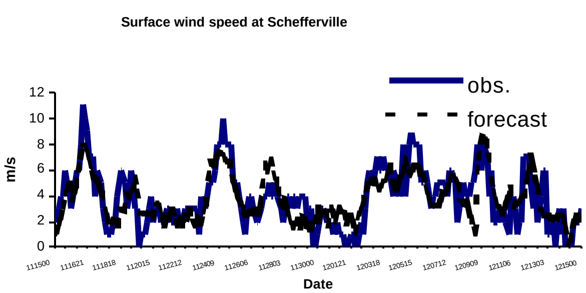
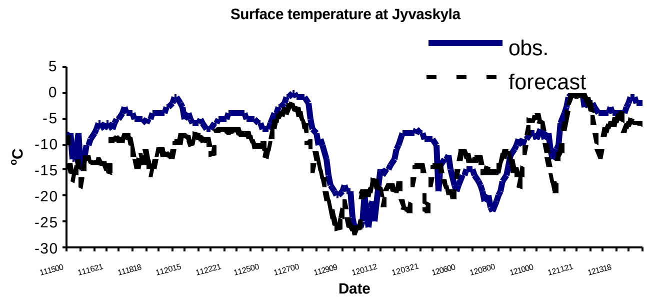
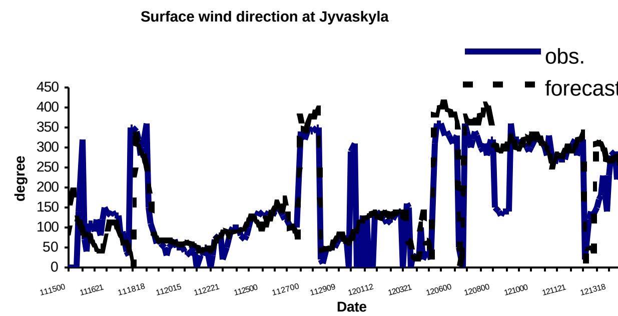


Fig.3 Time series of the coupled model forecasts and Schefferville observations. 111500 means November 15 at 00 UTC.

The time series for the real-time forecasts of the near-surface temperature and winds at Schefferville selected to represent North America and Jyvaskyla (62.4 °N, 25.7 °E) selected to represent Eurasia from 15 November to 15 December 2002 are presented in Figs.3-4. The two sites represent the Arctic river basins as well. The time series of the modeled near-surface variables match the observed trends very well. The correlation coefficients for temperature and wind speed are 0.93 and 0.72 at Schefferville; they are 0.76 and 0.74 at site Jyvaskyla.





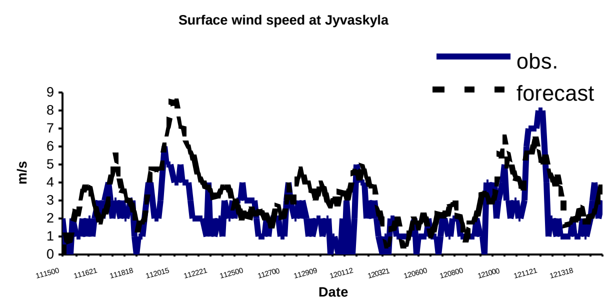


Fig.4 Time series of the coupled model forecasts and Jyvaskyla observations.

Because of limited observations, the simulations from 1 January to 31 January 2003 compared against the surface observations at Barrow (71.3 °N, 156.8 °W) which represents Kuparuk River basin in Alaska are displayed in Fig.5. The modeled time series of the variables are in close agreement with the observed, especially for the winds that are usually hard to predict over complex land surfaces. The correlation coefficients for sea-level pressure, temperature, dew-point temperature, wind speed and wind direction are 0.97, 0.83, 0.75, 0.70 and

0.91, respectively. It is obvious that the comparisons between the real-time forecasts and the observations show that the coupled model has good forecast skill over the Arctic river basins.

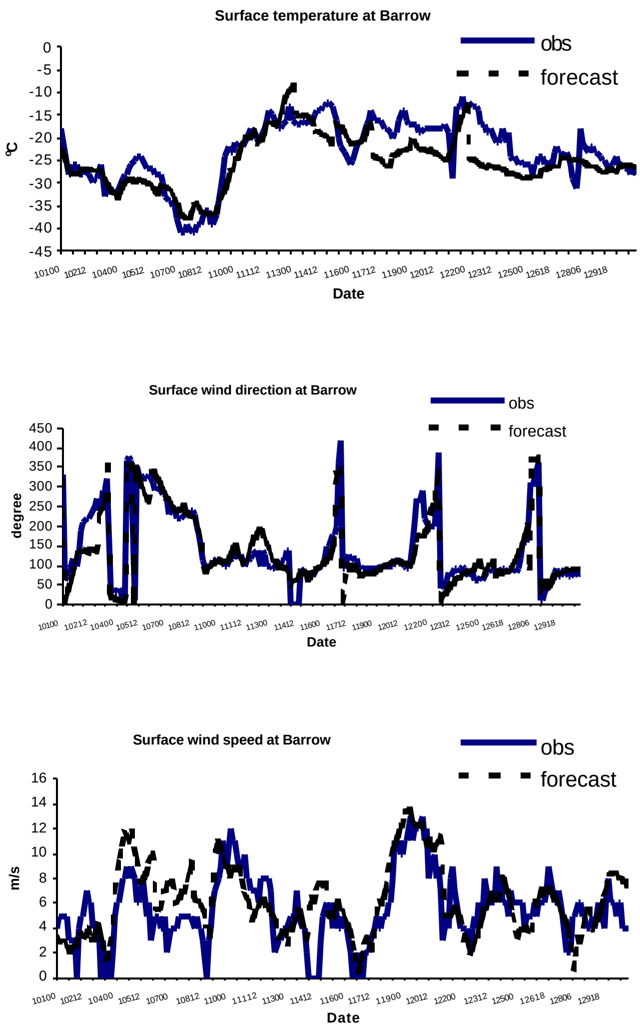


Fig.5 Time series of the coupled model forecasts and Barrow observations.

4. CONCLUSIONS

The real-time coupled model captures much of the variation of surface variables at sites considered although there is a slight cold bias near the surface. The coupled model particularly improves the forecast skill of near-surface temperature and dew-point temperature in relation to Polar MM5 with specified land surface characteristics. However, the resolution of 60 km is too coarse to study the land surface characteristics over the Arctic river basins in detail. Therefore enhanced horizontal resolution and some physical parameterization improvements are desirable.

ACKNOWLEDGEMENT

This study is funded by NASA grant NAG5-9596 and NSF grant OPP-9910334.

REFERENCES

Bonan, G. B., 1996: A land surface model (LSM) for ecological hydrological and atmospheric studies: Technical description and user guide. NCAR Tech. Note, NCAR/TN-417+STR, 150 pp.

Bromwich, D.H, J.J. Cassano, T. Klein, G. Heinemann, K.M. Hines, K. Steffen, and J.E. Box, 2001: Mesoscale modeling of katabatic winds over Greenland with the Polar MM5. *Mon. Wea. Rev.,***129**, 2290-2309.

Cassano, J.J., J.E. Box, D.H. Bromwich, L. Li, and K. Steffen, 2001: Evaluation of Polar MM5 simulations of Greenland's atmospheric circulation. *J. Geophys. Res*., **106**, 33,867-33,890.

Fletcher, N.H., 1962: Physics of rain clouds. Cambridge University Press, 386pp.

Grell,G.A., J.Dudhia, and D.R. Stauffer,1994: A description of the fifth-generation Penn State/NCAR mesoscale model (MM5). NCAR Tech.Note NCAR/TN-398+STR,122pp.

Guo, Z., D.H. Bromwich and J.J. Cassano, 2003: Evaluation of Polar MM5 simulations of Antarctic atmospheric circulation. *Mon. Wea. Rev.***,131**, 384-411.

Hines, K. M., D. H. Bromwich and Z. Liu, 1997: Combined global climate model and mesoscale model simulations of Antarctic climate. *J. Geophys. Res*., **102**, 13,747-13,760.

Janjic, Z.I.,1994: The step-mountain eta coordinate model: Further development of the convection, viscous sublayer ,and turbulence closure schemes. *Mon. Wea. Rev*.,**122**,927-945.

Manning, K.W., and C.A.Davis, 1997: Verification and sensitivity experiments for the WISP94 MM5 forecasts. *Wea. Forecasting*, **12**, 719-735.

Meyers, M.P., P.J. DeMott, and W.R.Cotton,1992: New primary ice-nucleation parameterizations in an explicit cloud model*. J. Appl. Meteor*., **31**, 708-721.

Reisner, J., R.M. Rasmussen, and R.T. Bruintjes, 1998: Explicit forecasting of supercooled liquid water in winter storms using the MM5 mesoscale model. *Quart. J. Roy. Meteor.Soc*., **124**,1071-1107.

Steffen, K., and J.E. Box, 2001: Surface climatology of the Greenland ice sheet: Greenland climate network 1995-1999. *J. Geophys. Res*.,**106**, D24, 33951-33964.