POLAR OPTIMIZED WRF FOR ARCTIC SYSTEM REANALYSIS

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1. INTRODUCTION

The need for a broad, interdisciplinary, multi-scale study of the Arctic inspired the Study of Environmental Arctic Change (SEARCH) project (Overland et al. 2003). A prime component of SEARCH will be a comprehensive reanalysis of the atmosphere, ice, ocean and land from all available data. The Arctic System Reanalysis (ASR) will be conducted with a polar-optimized version of the next generation Weather Research and Forecasting (WRF, http://wrf-model.org/). The ASR will take advantage of the extensive knowledge gained during previous mesoscale modeling work for the polar regions. Since 1995, the polar version (PMM5) of the Penn State/National Center for Atmospheric Research (NCAR) Mesoscale Model version 5 (MM5) has been developed at The Ohio State University. The PMM5 has enhanced physics specifically adapted to the polar regions, and has achieved a much better performance than previous versions of the MM5 (Bromwich et al. 2001; Cassano et al 2001). In addition to modern Arctic and paleoclimate applications of the polar-optimized model, operational numerical weather prediction for NSF-supported Antarctic field operations is performed daily at NCAR (Bromwich et al. 2003; Powers et al. 2003).

2. POLAR WRF

The WRF is currently being developed by a broad cross-section of the U.S. atmospheric science community including the National Centers for Environmental Prediction and NCAR. For polar applications, high-latitude physics in Polar MM5 needs to be ported over to WRF and further enhanced. Improvements are needed in the boundary layer, cloud physics, snow surface physics, and the sea ice treatment. Recent field projects such as the Surface Heat Budget of the Arctic and the Atmospheric Radiation Measurement, combined with various in-situ and remote-sensing observations need to be tapped into to best facilitate the polar-optimized WRF.

Currently, version 1.3 of WRF is being tested over Arctic ocean, land and ice sheet surfaces. This version runs on a local Linux cluster, and the Aviation (AVN) model is used to provide initial and boundary conditions. The model was first tested for July and December, 2002 on an Arctic grid similar to that used for current mesoscale Arctic studies with PMM5 (Fig. 1). Grid size is 150×150 points on a polar stereographic grid, with a horizontal resolution of 60 km, and 29 levels in the vertical. The stability of the simulations shows some sensitivity to the selection of turbulence and boundary layer parameterization and the specification of the upper boundary treatment. The most stable simulations are obtained with the use of the 2nd order horizontal diffusion, the Monin-Obukhov similarity surface layer physics similar that of the Eta model, the OSU/MM5 Land Surface Model, and the 1.5-order turbulent kinetic energy Mellor-Yamada-Janjic planetary boundary layer. Better results are achieved when the depth of the upper damping layer is set at 2000 m, and the damping coefficient is set at 0.2.

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3. RESULTS

Early results with the Arctic grid for July and December indicates that the unmodified version of WRF simulates the synoptic meteorology with similar skill to the polar-optimized version of MM5. This can be seen in the output of a 48-hour simulation initialized at 0000 UTC 1 July 2002. The upper panel in Fig. 1 shows a sea level pressure analysis (the 0-hour forecast of PMM5) for 0000 UTC 3 July. The middle panel shows a 48-hour forecast by PMM5, while the lower panel shows the 48-hour WRF simulation also for 0000 UTC 3 July. Both forecasts are quite reasonable for two-day simulations.

A separate grid was centered over Greenland to test the model's ability to simulate the katabatic layer. Results for the Greenland grid, however, indicate that improvements are needed in the boundary layer representation for the katabatic environment with a very shallow, very stable boundary layer. Figure 2 shows the results of 13 48-hour simulations, each initialized at 0000 UTC for December 2002. A forecast is initialized for each day from 1 December to 13 December. The Lambert grid consists of 110 points in the east-west direction and 100 points in the north-south direction. Grid spacing is 40 km. Fortunately, automatic weather station (AWS) data are readily available for comparison against the observations (Steffen and Box 2001; Box et al. 2004). Four sites are selected for the comparison: Swiss Camp (69.57°N, 49.32°W, 1149 m), Crawford Point (66.48°N, 46.28°W, 2165 m), Summit (72.58°N, 38.50°W, 3208 m), and

DYE-2 (66.48°N, 46.28°W, 2165 m). The surface pressure trend in Fig. 2a interpolated to DYE-2 shows that WRF is well capturing the synoptic pressure change. Due to some uncertainty in the AWS station heights, it is not clear what the surface pressure bias is over Greenland. It is encouraging that the 48-hour pressure simulations, initialized on different days, tend to run together and do not separate over time. Notice especially, how WRF captured the large pressure increase on 6-8 December.

The 2-m temperature at Crawford Point, however, indicates a warm bias for the WRF winter boundary layer over the ice sheet (Fig. 2b). The synoptic-scale changes in temperature appear to be well captured, although higher frequency temperature change may not be captured as well. A strong, shallow inversion over an ice sheet is frequently not well represented in model initializations. The model physics, however, should correct the error over time. It is not obvious from Fig. 2b that the error is decreasing over the course of the forecasts. Therefore, the WRF boundary layer physics need to be modified for high static stability. Furthermore, there appears to be a negative bias in the 10-m wind speed for the AWS sites (not shown). Version 1.3 of WRF appears to be underrepresenting the katabatic boundary layer over Greenland.

4. SUMMARY

The development of Polar WRF will provide a model applicable for the upcoming Arctic System Reanalysis. The early returns show that version 1.3 of WRF well captures the synoptic variability of the Arctic. Adjustments are needed, however, for the very stable winter boundary layer, analogous to the polar changes that were implemented into MM5. Both Polar WRF and the ASR will represent an important contribution from the mesoscale modeling community to the goals of the upcoming International Polar Year (2007/2009).

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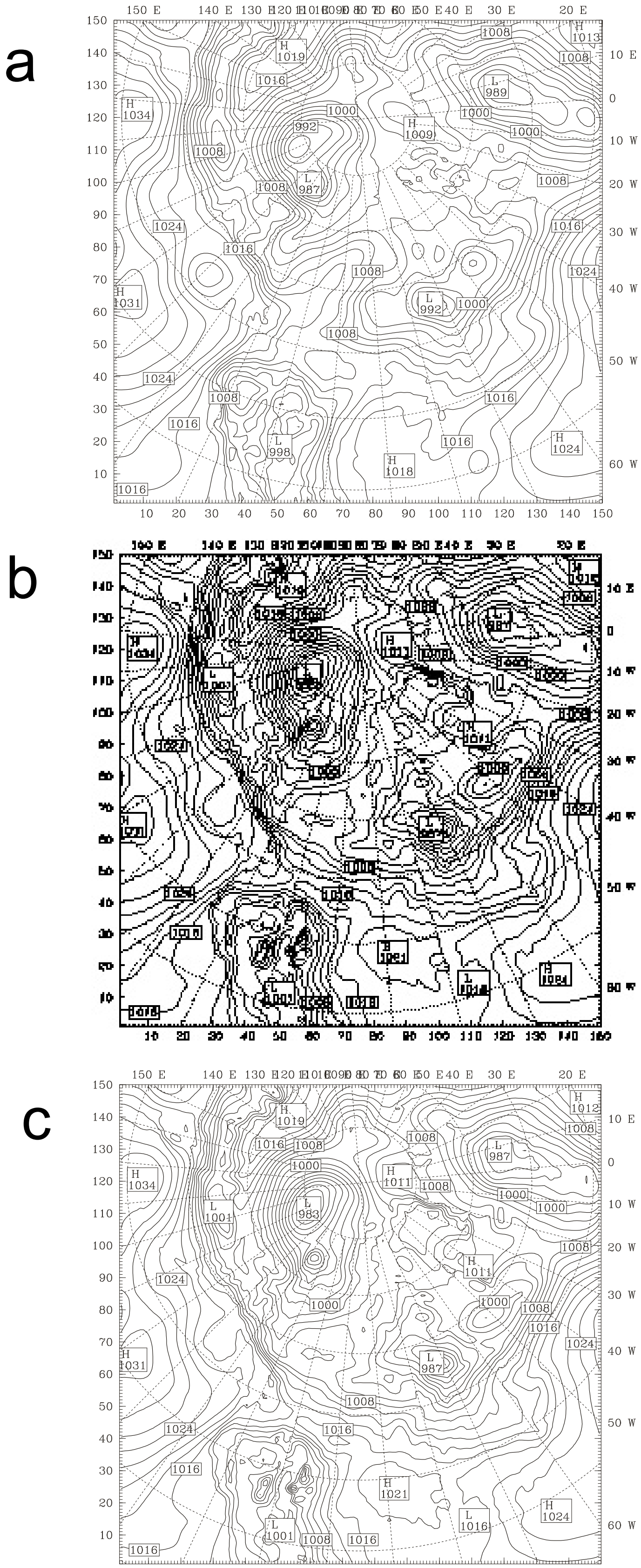

Figure 1. Sea level pressure (hPa) over the 150×150 Arctic grid for 0000 UTC 03 July 2002 for (a) the analyses (0-hour MM5 forecast), (b) the 48-hour MM5 forecast, and (c) the 48-hour WRF forecast. Contour interval is 2 hPa.

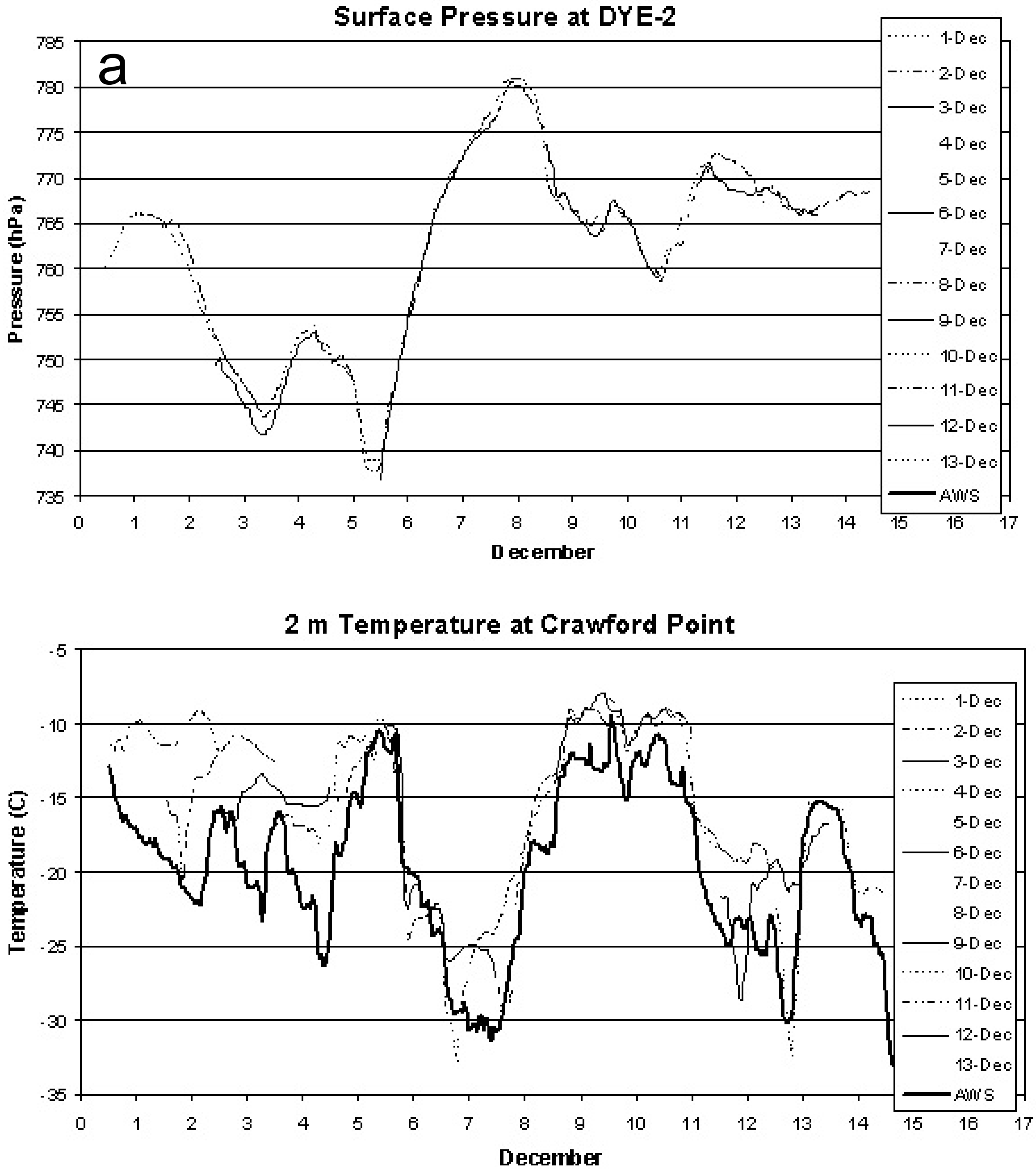

Figure 2. Surface pressure (hPa) from observations (thick solid line) and 13 48-hour forecasts initialized at 0000 UTC at (a) DYE-2 automatic weather station (66.48°N, 46.28°W, 2165 m) inside the 110×100 Greenland grid between 01 December and 15 December 2002, (b) Temperature at 2 m for Crawford Point (69.88°N, 46.99°W, 2022 m).