7B.6 REGIONAL VERIFICATION OF POLAR MM5 OVER ALASKA

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1. INTRODUCTION

The Pennsylvania State University / National Center for Atmospheric Research Fifth Generation Mesoscale Model (MM5) is used by the Air Force Weather Agency (AFWA) to support Department of Defense (DoD) operations. Operational forecasters have identified prominent warm biases in MM5 surface temperatures in Alaska. The Polar Meteorology Group, Byrd Polar Research Center and NCAR have made high-latitude modifications to the MM5 for Antarctica and Greenland. This modified MM5, Polar MM5 (PMM5), is used over Alaska to assess the impact of the polar modifications over a polar region, not predominantly and permanently covered in snow and ice.

A brief description of the polar modifications made to the MM5 V3.4 is presented in Section 2. The experiment methodology is covered in Section 3. Forecast results are verified against surface observations and upper-air ROAB data. The results presented in Section 4 are analyzed by climatological region. Concluding remarks and recommendations for further work are given in Section 5.

2. PMM5 BACKGROUND

The application of mid-latitude physics parameterizations in the MM5 over Alaska generates persistent errors in output, specifically in the surface temperature field. Excessive longwave radiation from high ice cloud concentrations has been identified as the major contributor to this error (Bromwich, 2001; Tilley, 2001; and Manning and Davis, 1997). The MM5 produced poor representation of cloud cover and radiative fields over high-latitude ice sheets in simulations by Bromwich et al., 2001; Hines et al. 1997a, 1997b). Previous model versions (MM4) exhibited very warm biases due to excessive cloud cover production (Bromwich et al., 2001).

The PMM5 cloud and precipitation processes are represented by the Reisner 1 explicit microphysics parameterization (Reisner, 1998). This parameterization scheme predicts the mixing ratio of cloud water, rain water, snow water, and ice crystals and allows for the presence of mixed phase (partially frozen) clouds. Sub-grid scale clouds are parameterized with the unmodified Grell cumulus parameterization (Grell et al., 1995). Previous versions of the MM5 (MM4) were found to produce excessive cloud cover in the Polar Regions (Hines et al., 1997b) and (Manning and Davis, 1997). Manning and Davis suggested a solution of replacing the equation for ice nuclei concentration (Fletcher, 1962), with that of Meyers (1992), in the Reisner1 explicit moisture parameterization. The cold temperatures found in the Polar Regions exceed the limits of validity of the Fletcher equation (Manning and Davis, 1997). This Fletcher equation replacement is proposed to help mitigate the cloudy bias in polar forecasts with the MM5.

The PMM5 uses a modified version of the NCAR community climate model, version 2, (CCM2) radiation parameterization (Hack et al., 1993) to predict the radiative transfer of longwave and shortwave radiation through the atmosphere. Sensitivity simulations found that parameterizing cloud cover as a simple function of grid box relative humidity, with cloud liquid water path (CLW) determined from grid box temperature, resulted in a significant overestimate of CLW path. This excessive CLW produced large downwelling longwave radiation fluxes during the austral winter over Antarctica (Hines et al., 1997a, 1997b). This problem is resolved by using the modeled water and ice mixing ratios from the Reisner explicit moisture parameterization to determine the radiative properties of the predicted cloud cover. This modification provides consistency of radiative and microphysical properties of clouds while allowing for separate treatment of radiative properties of liquid and ice phase cloud particles.

The PMM5 uses the National Center for Environmental Prediction (NCEP) Eta model 1.5 order turbulence closure scheme to parameterize turbulent fluxes in the atmosphere and turbulent fluxes between the atmosphere and the surface. Land surface interaction modifications are necessary to account for the new sea ice surface type category. The thermal properties used in the soil model for snow and ice surface types are modified following Yen (1981). The number of substrate levels is increased from six to

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eight, increasing the resolved substrate depth from 0.47 m to 1.91 m.

The PMM5 is applied to an Alaskan domain, based on these findings. This is an attempt to mitigate the warm low-level temperature bias of the unmodified MM5.

3. METHODOLOGY

The PMM5 forecasts are verified using an inverse-weighted linear interpolation method using the four grid points surrounding each of the 63 surface stations and 7 upper-air stations. The ROAB data is log-linearly interpolated to the sigma levels for differencing. The 63 surface stations are separated into three climatologically discrete regions, labeled Gulf, Interior, and Bering. The lowest-sigma model values of temperature, wind speed and direction as well as derived mean sea-level pressure are verified against the WMO surface observations. Figure 1 shows the inner domain, distribution of the verification stations, and the regional classifications. Seven WMO RAOB reporting stations are used to verify model 3-dimensional fields of geopotential height, temperature, and normalized (against observed) relative humidity.

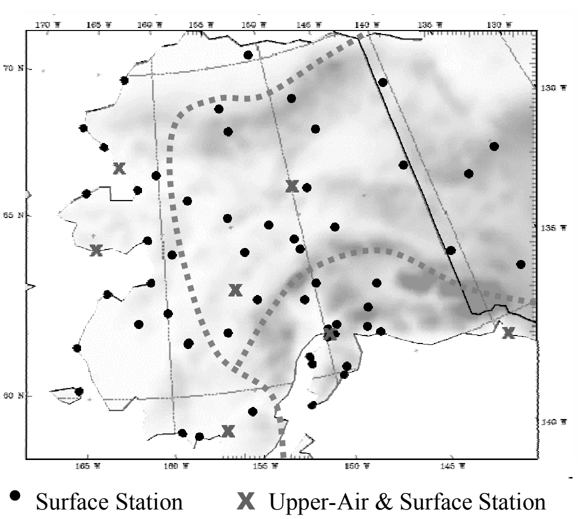

Figure 1. Verification station distribution. The dotted lines denote the 3 labeled regional divisions.

A vertical resolution of 41 levels is used with the lowest model level located at 20 m AGL. An outer nest with horizontal grid spacing of 45 km is used to create the boundary conditions for the inner domain. Observational data is assimilated into AVN model output background fields through a Multivariate Optimal Interpolation scheme, which is operationally employed by AFWA, and is used for the outer nest initial and boundary conditions. The inner domain, which is the region of interest, uses a horizontal resolution of 15 km over a domain covering an area of 1455 km x 1725 km, centered over the Alaskan Interior.

The PMM5 is used to make 67 27-hour duration forecasts for nonconsecutive week-long periods from September 2001 through December 2001. This period covers the complete transition from fall through a –40ºC arctic outbreak. The model is initialized at 21 UTC and 09 UTC using the previous AVN model run output. The unmodified original MM5 (control) is used to make parallel forecasts for comparison. The root mean square error (RMSE), root mean square vector error (RMSVE) and bias statistics are computed separately for the 21 UTC and 09 UTC runs to avoid dependence of overlapping integrations.

4. RESULTS

The PMM5 produced a maximum surface temperature domain-wide bias of +1.2ºC, which is an improvement over the original MM5 surface temperature bias of +2.5ºC for the same forecast time. The PMM5 surface temperature RMSE are considerably higher, around 4.5ºC, due to a few outliers and the particular weighting characteristics of RMSE. The PMM5 to MM5 comparisons of mean sea-level pressure and surface wind produced small differences that fall within measurement accuracy. The surface temperature RMSE produced consistent results within each region; 21 UTC initialization results are shown in Figure 2. The Interior Region contains a well-pronounced error, which deviated from the nominal error of the Bering and Gulf regions. This is consistent for all forecast times and both 12 UTC and 09 UTC initializations. The Regional surface temperature bias differences are consistently separated; 21 UTC initialization results are shown in Figure 3.

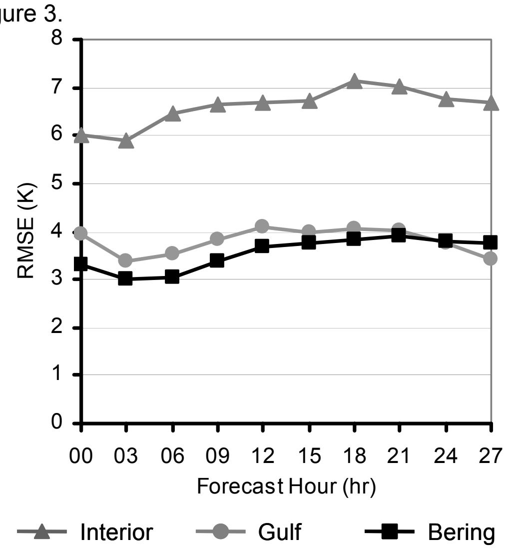

Figure 2. PMM5 regional surface temperature RMSE for 34 - 21 UTC initializations for all 63 surface stations.

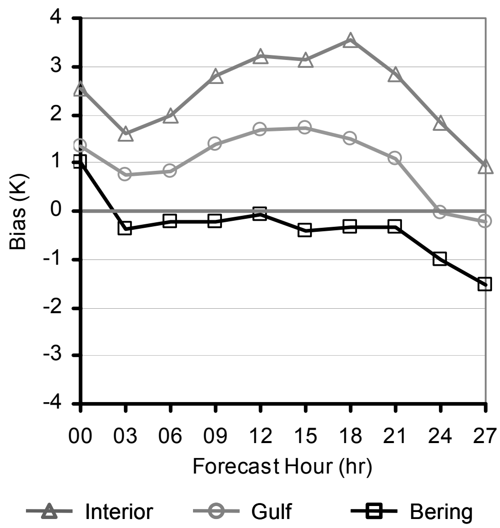

Figure 3. PMM5 regional surface temperature bias for 34 - 21 UTC initializations for all 63 surface stations.

The differences between PMM5 and control MM5 forecasts also maintained regional consistency. A surface temperature RMSE and bias improvement of PMM5 over MM5 by as much as 1.5ºC is found in the Gulf and Bering regions, however the Interior Region exhibits a greater PMM5 error than MM5 error. Similar results are found in mean sea-level and surface wind, although the degrees of error are very small, on the order of <2 mb and 3 m s^{-1} respectively.

The large warm bias found in the Interior stations may be due to the exclusion of an assimilated snow cover field in the MVOI scheme. This will be resolved with the implementation of the 3-Dimensional Variational Analysis System. Figure 4 shows the comparison of the observed, PMM5, and MM5 temperatures with snow cover for a single station, Eielson AFB. The same extreme warm bias of both models occurs when the temperatures fall very low and snow cover is present. An additional source of error is a discrepancy between the observed temperature at 2 m AGL and the model output at 20 m. During an arctic outbreak, a strong radiation inversion will produce some error.

The most significant upper-air results are found in the low-level moisture field. The RH difference between model and RAOB were normalized against the RAOB measurement. All verified forecast times and initializations produced the same relationship between the PMM5 and control MM5. Figure 5 shows the upper-air normalized RH bias for all 27-hour 21 UTC initialization PMM5 and MM5 forecasts for the lowest 500mb.

The PMM5 has a moist bias around 20% of observed in the lowest 100 mb, the MM5 moist bias was less than 10% of observed. This moist PMM5 bias is the only inconsistency between the results of this project and other PMM5 project results by Bromwich et al. (2001). Otherwise the error profiles between the two models are indistinguishable, likewise for temperature and geopotential height.

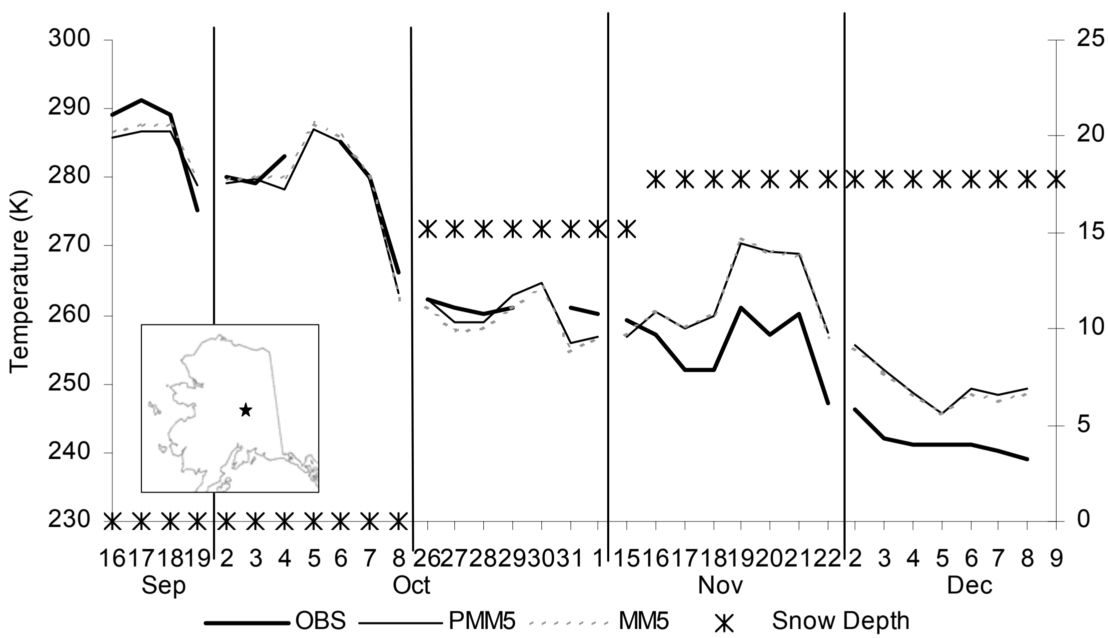

Figure 4. 21 UTC 27-hour lowest sigma level (20 m) temperature forecasts for Eielson AFB, AK (star location on inset) by valid time and observed surface temperature. Vertical lines denote breaks in week-long forecasts data sets.

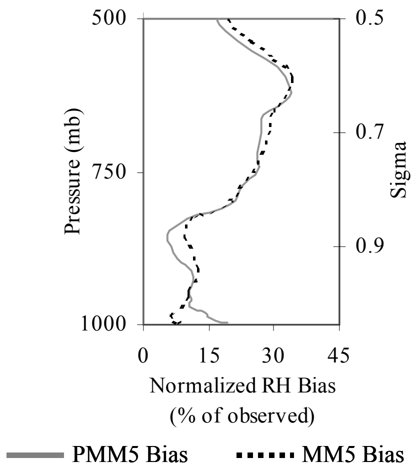

Figure 5. PMM5 and MM5 normalized RH bias, averaged over 34 – 21 UTC 27-hour forecasts.

5. CONCLUSIONS

The refinement of high-latitude specific or regionally tailored processes has proven valuable. The consistency of significant regional discrepancies found in this work illuminates the need for continued investigation. The moisture deficit typically found in the Interior may be a potential source of error. A potential source of the warm bias is the exclusion of snow cover in the data assimilation scheme due to software limitations. Subsequent model revisions allow for dynamic snow cover, which is a modification to the land surface model. The severe radiation inversions that occur during arctic outbreaks (when the largest warm biases exist) contribute to the error by using a 20 m model temperature verified with a 2 m observation.

The PMM5 modifications appear to be an improvement to the original MM5. The PMM5 results in this experiment closely compare to the findings of other PMM5 forecast projects. A more exhaustive comparison is still required for the Alaskan region. A specific investigation into the regional differences is needed. The large PMM5 regional discrepancy between the Interior and other regions may be due to the decreased moisture availability, or extreme radiation inversions. An assessment of the impact of the new snow cover forecast in MM5v3.5 on surface temperature as well as a validation of the 10 m temperature fields is required. Longer duration integrations covering all seasons would identify any other model disagreements or improvements.

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