P4.2 GAUGING MESOSCALE PREDICTABILITY OF AN UNUSUAL HIGH LATITUDE SNOW EVENT VIA A MULTI-MODEL INTERCOMPARISON

Jeffrey S. Tilley
Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska

Richard Thoman
National Weather Service Forecast Office, Fairbanks, Alaska

1. INTRODUCTION

An unusually strong winter storm impacted the northern Arctic coast of Alaska on 8 January 2001. In association with this storm, wind gusts of 100 km/h and more than 18 cm of snow were reported at Barrow (71.3N, 156.2W; Figure 1). Though not large by mid-latitude standards, this was the greatest mid-winter snowfall in more than 75 years of observations at Barrow.

While synoptic scale forcings related to this event were relatively well forecast, mesoscale structure and forcings in the vicinity of the Alaska Arctic coast were not as well captured. As such, this case is a good candidate for examining the degree of mesoscale predictability possible with current NWP models for such unusual winter Arctic systems.

In this study we focus on intercomparing the meso-α- and β- scale solutions (at various lead times) provided by not only the standard NCEP model suite available within NWS/Alaska Region but also MM5 (e.g, Grell et al 1994; Chen and Dudhia 2001) forecasts conducted at the Air Force Weather Agency (AFWA) and the University of Alaska. We anticipate examining the utility of a multi-model ensemble solution constructed from the forecasts of the aforementioned models.

In this paper we set the stage for the remainder of the study by providing a meso-α scale overview of the event and discussing aspects of one of the model solutions, that being the MM5 forecast simulations conducted at the University of Alaska. Details of the full multi-model intercomparison and other aspects of the study will be presented at the conference.

2. MESO-α SCALE OVERVIEW OF EVENT

Figures 2a- 2d show NCEP analyses of the sea level pressure (SLP) field for the Alaskan region at various times between 00 UTC 8 January and 12 UTC 9 January 2001. At 00 UTC 8 January (Figure 2a), the region is dominated by a large and exceptionally vigorous cyclone, with central pressures ~ 957 hPa, centered over the Alaska Peninsula. Though cyclones of this intensity are not uncommon during the winter months in the Bering Sea and Aleutian Islands, this one was unusual for maintaining its intensity upon landfall with a circulation covering a nearly five million square kilometer area.

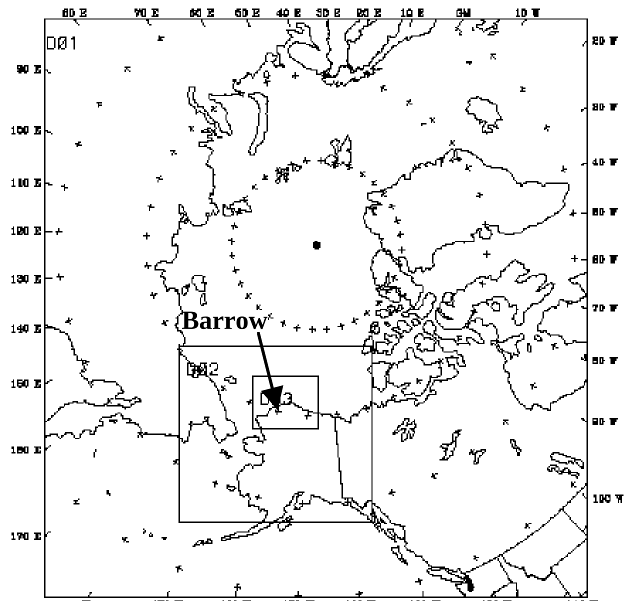

Figure 1. Domains of nested MM5 simulation. Location of Barrow indicated by arrow.

Over the next 18 hours this cyclone weakens significantly as a secondary development occurs in western Alaska near the Seward Peninsula. By 18 UTC (Figure 2b), both cyclones have central pressures near 969 hPa and there is evidence of a third trough developing eastward from the secondary low through the Yukon River valley. This trough develops farther northeastward into the Yukon Territory by 00 UTC 9 January (Figure 2c) while both the primary and secondary cyclones slowly weaken, drifting slowly eastward and northwestward, respectively.

Corresponding author address: Jeffrey S. Tilley, University of Alaska Fairbanks, Geophysical Institute, Fairbanks, AK 99709; Email: jeff@gi.alaska.edu

During the period the Barrow vicinity is under the influence of a strong surface north-south pressure gradient and strong easterly to northeasterly surface winds. Only after 00 UTC 9 January does this gradient slowly relax with the development of a pronounced surface ridge along the Alaskan coastal plain east of Barrow. This coastal ridge development occurs concurrently with a tertiary cyclone development in the Mackenzie River Valley (cf. Figure 2d) along the trough evident earlier.

These surface developments are possibly associated with smaller scale features apparent in the 700 hPa geopotential fields. At 06 UTC 8 January 2001 (Figure 3a), the geopotential height pattern largely reflects the surface structure, with a cyclonic circulation dominating the Bering and Chukchi Seas, most of Alaska as well as the southern Beaufort Sea. However, by 00 UTC 9 January (Figure 3b), a pronounced trough has appeared at 700 hPa which is quasi-parallel to the Brooks Range and with an axis just south of Barrow. The analysis suggests a possible meso-β scale circulation center near Prudhoe Bay at 00 UTC. The trough maintains its identify near the coast for the next 6 hours before modifying its orientation and extending northeastward from the primary 700 hPa cyclone as a larger scale feature.

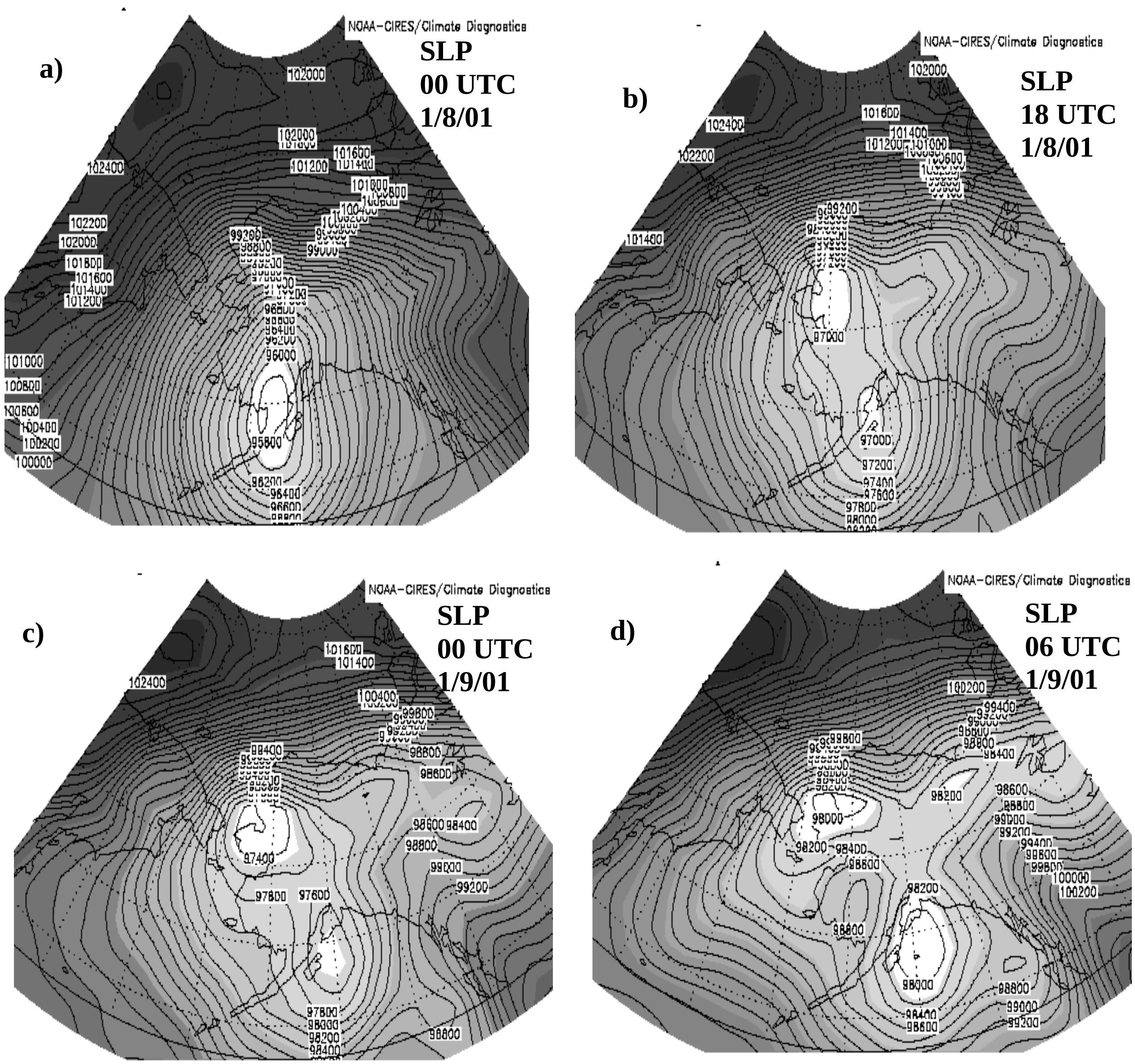

Figure 2. NCEP Analysis of Sea Level Pressure (Pa) over the Alaskan Region for a) 00 UTC 1/8/01; b) 18 UTC 1/8/01; c) 00 UTC 1/9/01; d) 06UTC 1/9/01.

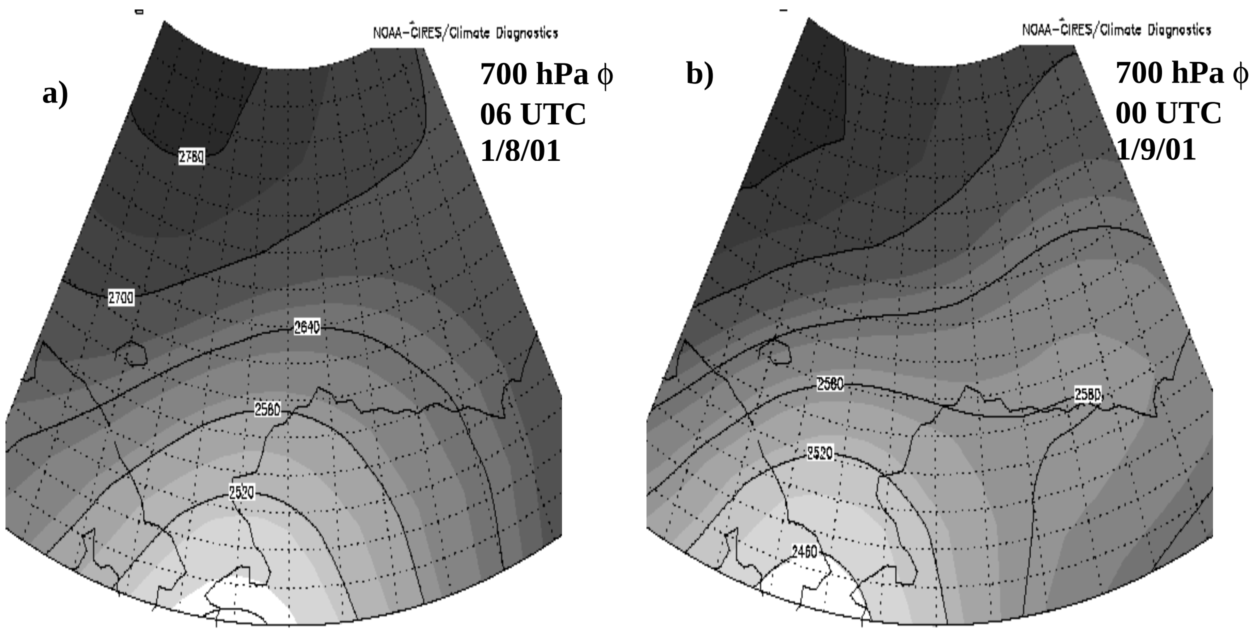

Figure 3. NCEP Analysis of 700 hPa geopotential height (f) for northern Alaska, Beaufort and Chukchi Seas a) 06 UTC 1/8/01 and b) 00 UTC 1/9/01

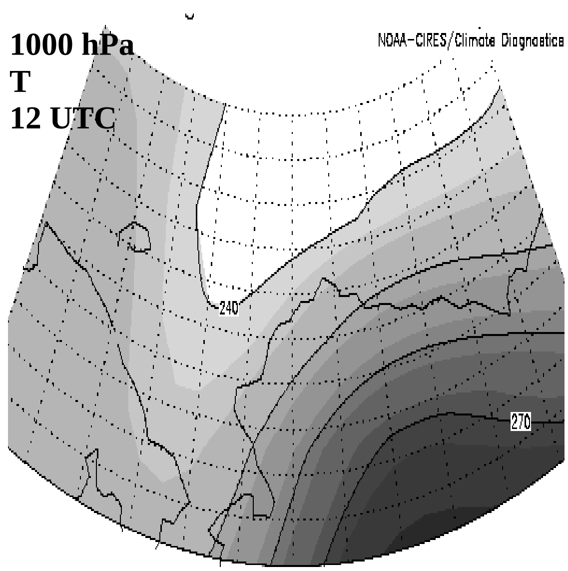

Figure 4. NCEP 1000hPa temperature (K) analysis at 12 UTC 1/8/01

Despite the strength of the circulation pumping warm maritime air northward over much of continental Alaska, a cold pool of air remained entrenched near the surface over the western Arctic coast of Alaska and over the adjacent sea ice. Figure 4 shows the NCEP analysis of surface temperature at 12 UTC 8 January 2001. A pool of cold air (T < -30C) is centered offshore over the sea ice pack at this time, but with -30C temperatures extending into the Barrow vicinity. Figure 5a, the 00 UTC 8 January sounding [the 12 UTC sounding was not launched due to the strong 100 km/hr gusts noted earlier] shows the cold air to be accompanied by a strong surface-based inversion extending upward to the 850 hPa level (approx. 1.2 km AGL). An isothermal layer lies above between 700 and 850 hPa. There is only modest erosion of the cold air at Barrow through the event. Evidence of such warming is visible in the 00 UTC 9 January sounding (Figure 5b), which shows surface temperatures near -24^{o}C and a weaker, though deeper, inversion layer that extends upward to nearly the 650 hPa level.

3. MM5 EXPERIMENTAL DESIGN

As noted in the Introduction, this study involves examining output from a number of different models, including two realizations of the PSU/NCAR MM5 model. In our realization, we utilize different initial conditions (the NCEP/NCAR reanalysis plus conventional observations) on the coarse grid plus include an additional 8km grid centered on the Barrow area, as seen in Figure 1. The outer nested domains have grid resolutions of 72 and 24 km and 45 vertical computational levels are used in all simulations, which are run for a total duration of 60 hours beginning at 00 UTC 7 August 2001. For all domains, the Reisner (e.g, Reisner et. al 1998) mixed phase microphysics scheme is utilized, as is the Burk/Thompson (Burk and Thompson 1989) boundary-layer scheme, the

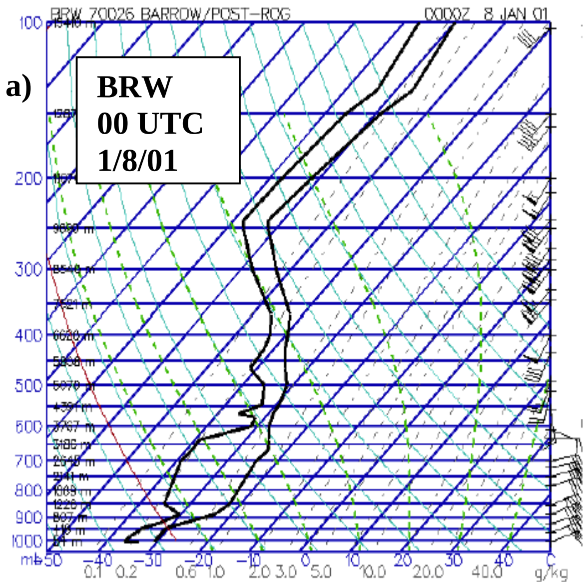

Figure 5. Sounding data at Barrow for a) 00 UTC 1/8/01 and b) 00 UTC 1/9/01

Grell (1993) cumulus scheme and the Dudhia (1989) 2-stream radiative transfer treatment. Note that the two inner nests are initialized, respectively, at 6 and 9 hours into the simulation from its parent domain's grid fields. Note that no four-dimensional data assimilation to either the analysis or observations is performed in this MM5 simulation, in order to simulate a real-time forecast for comparison with the other models available to the NWS forecasters.

4. MM5 SIMULATION RESULTS

The MM5 simulation reproduces most of the structure in the fields shown in the previous section, though there are the expected differences due to enhanced representation of mesoscale structures and processes in the model. This fact is particularly on the 5 km mesh, which we choose to focus on for the remainder of this paper.

Figure 6 shows the accumulated precipitation for the 5 km domain at 12 UTC 9 January. This time represents, effectively, a storm total accumulated precipitation (liquid water equivalent). Large amounts are clearly visible over the northern slopes of the Brooks Range, but an area with > 10 mm accumulation is present in the immediate Barrow vicinity. Assuming the normal wintertime ratio of at least 15:1 between liquid water equivalent and snowfall accumulations in Northern Alaska (NWS Alaska Region, pers. comm.), the MM5 forecast appears to agree well with the reported 18 cm snowfall accumulation.

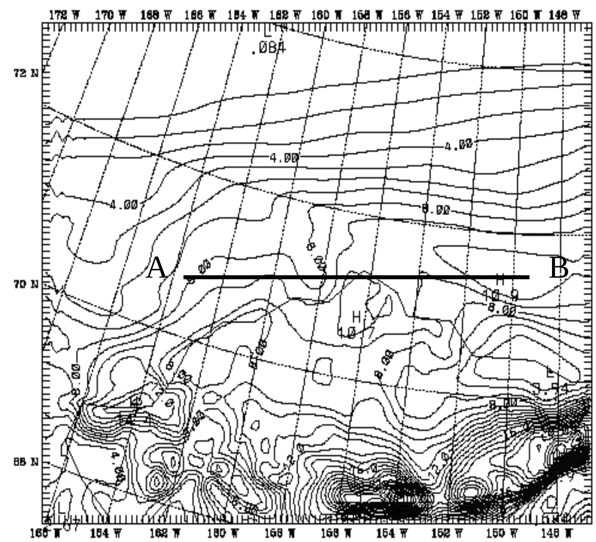

Figure 6. MM5 accumulated precipitation (mm) at 12 UTC 1/9/01 for the 5 km domain. Line AB represents the cross sections in Figure 7.

Agreement with the warming indicated in the 00 UTC 1/9/01 Barrow sounding (Fig. 5b) was not as good. The simulated soundings (not shown) indicate that the strong (20-30^{o}C) inversion in the lower troposphere present early in the simulated is maintained throughout the event; virtually no warming takes place in the boundary layer. More positively, the MM5 simulation does produce sustained 35-55 kt winds in the boundary layer during the period on 8 January when the 100 km/hr gusts were reported in Barrow.

Although the number of reporting stations relative to the number of MM5 grid points is small, local reports from the Barrow area suggest that from a precipitation and wind speed standpoint, the MM5 forecast captured key aspects of the mesoscale structure. This result suggests further that the MM5 forecast reproduced important mesoscale processes that may be the key to the mesoscale predictability of the event. It is thus prudent to examine the MM5 solution in more detail to look for mesoscale structure and processes which may or may not have been reproduced in the other operational NWS models examined in our study.

For this purpose we briefly examine cross sections through Barrow of two variables at 12 UTC 8 January: the potential vorticity and the vertical motion. The cross section is denoted by line AB in Figure 6.

Figures 7a and 7b show cross sections of the omega vertical motion (dPa/s) and potential vorticity (PVU) fields at 12 UTC 8 January. In addition to deep, spatially broad overrunning ascent over the surface -based cold dome, there are also mesoscale updrafts and downdrafts above the boundary layer within the overrunning inversion in the Barrow vicinity. Further, localized potential vorticity maxima are evident not only at the surface at Barrow, but also in the lower part of the overrunning inversion layer near Barrow and farther upstream. We suspect that these structures are a key element of the localized heavy snowfall event at Barrow. At the conference we will present a more detailed analysis of these results as well as examine the other model forecasts for evidence of such features.

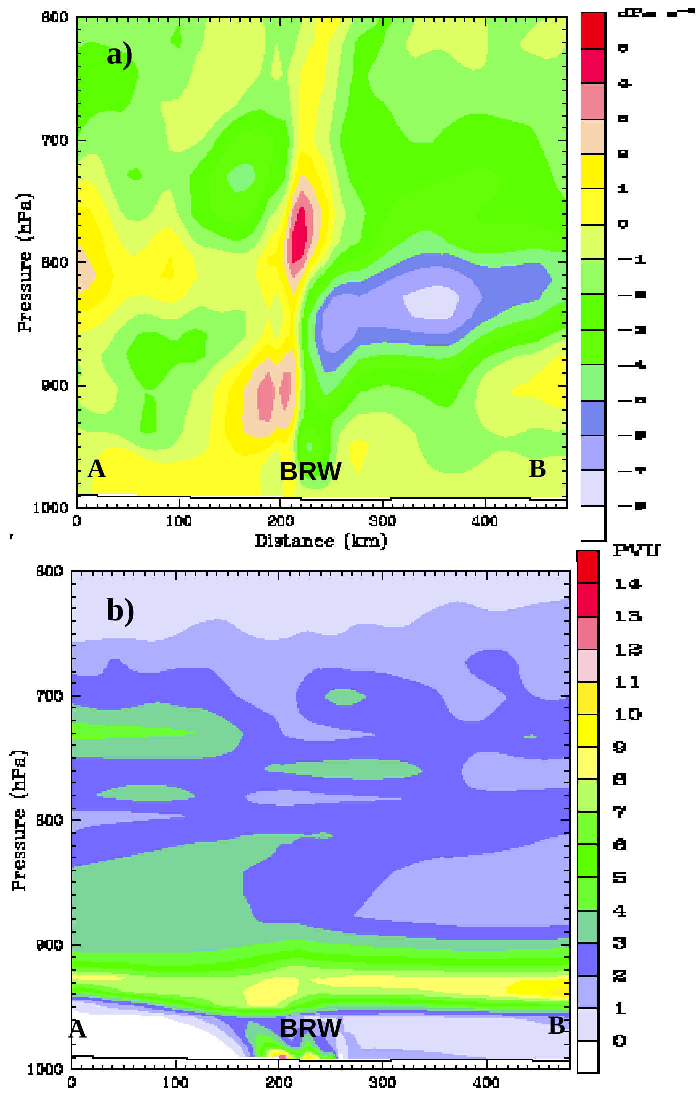

Figure 7. Cross sections through Barrow (marked 'BRW') of the a) vertical motion (dPa/s) and b) potential vorticity (PVU) fields at 12 UTC 1/8/01.

5. REFERENCES

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