ON THE SENSITIVITY OF SIMULATED SUBARCTIC WINTERTIME INVERSIONS TO PBL PARAMETERIZATION

Jeffrey S. Tilley and Cynthia Weatherby
Geophysical Institute, University of Alaska Fairbanks, Fairbanks, Alaska

1. INTRODUCTION AND MOTIVATION

During the winter in Arctic and subArctic latitudes, surface-based or boundary layer (BL) inversions are common and persistent features (e.g., Kahl, 1990). Such inversions, though often formed through radiational cooling near the surface, also occur within an overrunning environment or through a combination of the two effects.

In midwinter, persistent radiational cooling of a frigid air mass often leads to the formation of an exceptionally strong shallow surface inversion (> 20 C/km as seen in Figure 1.) accompanied by ice fog. Under warmer conditions (e.g., -25C < T < -5C), ice fog does not form but a pronounced brownish haze is visible over populated areas. Air quality within the inversion is severely degraded during such an event, due to trapping of CO and various hydrocarbons emitted by vehicles and by homes utilizing wood-burning stoves.

Operational numerical weather prediction (NWP) models can often provide guidance that an ice fog/strong inversion episode will occur with lead time of at least a day. However it is still difficult to provide local air quality officials more than general forecasts of onset and duration of such episodes. Episode duration has proved particularly difficult to forecast with much accuracy, as past events have occurred over a wide range of timescales. Diverse processes, such as an increase in cloud cover (changing the radiative regime, turbulent momentum transport downward from the mid-troposphere, or local topographic effects can be associated with the inversion breakdown, resulting in the wide range of episode duration.

Many NWP parameterization schemes for BLs have been developed with the aid of field datasets of BL turbulent and mean flow variables for locations in lower latitudes. While these locations experience stable BLs from time to time, situations such as that depicted in Figure 1, which was maintained for over a 120 hour period, are virtually unrepresented in those datasets. It is reasonable to expect that the resulting schemes would have more difficulty simulating Arctic stable BLs; this has been our experience (Tilley and Wilkinson 1998) in previous simulations on larger scales.

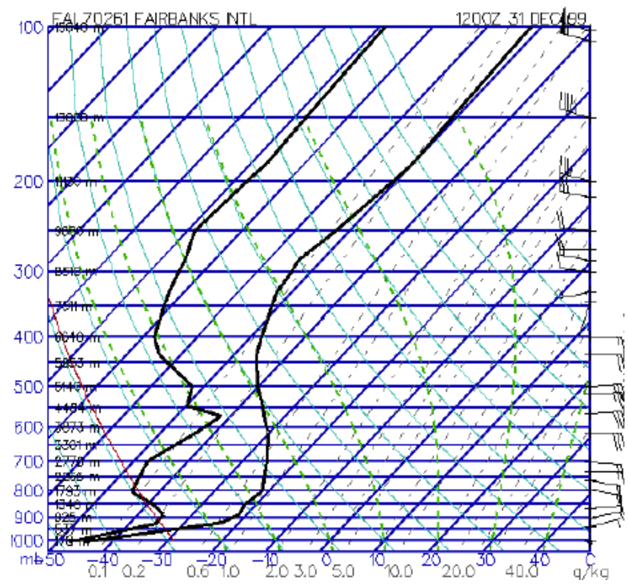

Figure 1. Fairbanks sounding for 12 UTC 31 December 1999.

Considerable work (e.g., Fairall et. al, 1999) has gone into better understanding of the BL, and its interactions with clouds, over the Arctic sea ice pack via the SHEBA program. Little work has been done to consider the stable BL environment endemic to interior Alaska inversion episodes. In this study, we present early simulations of a recent inversion episode over the Fairbanks area using the current BL schemes available in MM5. This preprint focuses in particular on the background and overview of the event. Detailed results will be presented at the workshop.

2. OVERVIEW OF EVENT

As part of a coordinated effort with a separate project, our initial simulations focus on an inversion episode from the most recent winter. The winter of 2000-2001, unfortunately, was one of the mildest winters in the entire observational record, with only a handful of days with

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

temperatures below -20°F(-28.9°C) and no temperatures colder than -32°F (-35.6°C) recorded. Strong inversion episodes were relatively rare and we have chosen the event of 23-24 January 2001 as representative of this rather unusual winter. In addition, it should provide some guidance as to the robustness of the BL schemes for a more extreme case; if a certain scheme performs poorly for this relatively mild event then poor performance would be expected as well for more extreme events.

Soundings taken during the event are shown in Figures 2a-c. At 12 UTC 23 January (Figure 2a), a very shallow surface-based inversion is present, bounded above by an 85hPa deep isothermal layer which is itself capped by a 15hPa deep weak inversion layer. 12 hours later (Figure 2b) a more mixed profile appears near the surface, bounded above by an elevated inversion that appears to have developed through a merging of the two separate inversions seen 12 hours earlier. By 12 UTC on 24 January (Figure 2c), the surface based inversion has been re-established with increased strength (17°C) and extends upward for approximately 50 hPa. This inversion is now bounded above by a shallow mixed layer which is again bounded above by a very shallow, weak inversion (10hPa deep). Over the following 12 hours (not shown) the surface based inversion again breaks down but is not re-established due in part to increased cloud cover and winds from an approaching cyclone system.

3. EXPERIMENTAL DESIGN

In this study we have utilized MM5V3.3 (e.g, Chen and Dudhia 2000) for our experiments. In all simulations, the Grell (1993) cumulus, Dudhia (1989) 2-stream radiative transfer and Reisner et. al (1998) microphysics scheme are included. Simulations using the bulk, Blackadar, MRF (Hong and Pan 1996), Eta (Janjic 1994), Burk/Thompson (1989), and Gayno/Seaman BL schemes constitute the experiments, which are all conducted on a hierarchy of 4 nested grids at resolutions of 45, 15, 5 and 1.66 km. The model domains are shown in Figure 3a, while Figure 3b shows the topography associated with Domain 4, which covers the immediate Fairbanks vicinity.

The three inner nests are initialized, respectively, at 6, 8 and 10 hours into the simulation from its parent domain's grid fields. No four-dimensional data assimilation to either the analysis or observations is performed for these initial simulations, in order to examine the

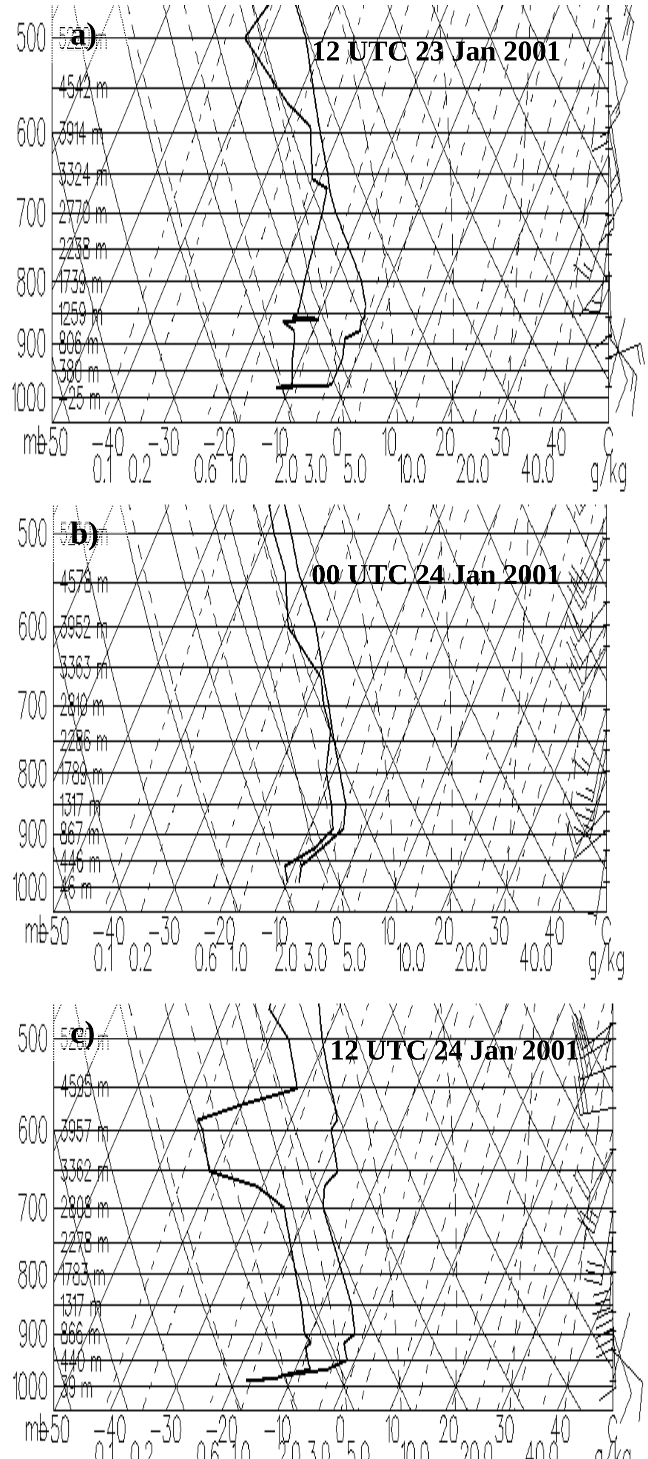

Figure 2. Fairbanks soundings (surface to 500 hPa) for a) 12 UTC 1/23/01; b) 00 UTC 1/24/01; c) 12 UTC 1/24/01

differences in the BL scheme performance without complications introduced by the addition of the nudging terms in the tendency equations. All

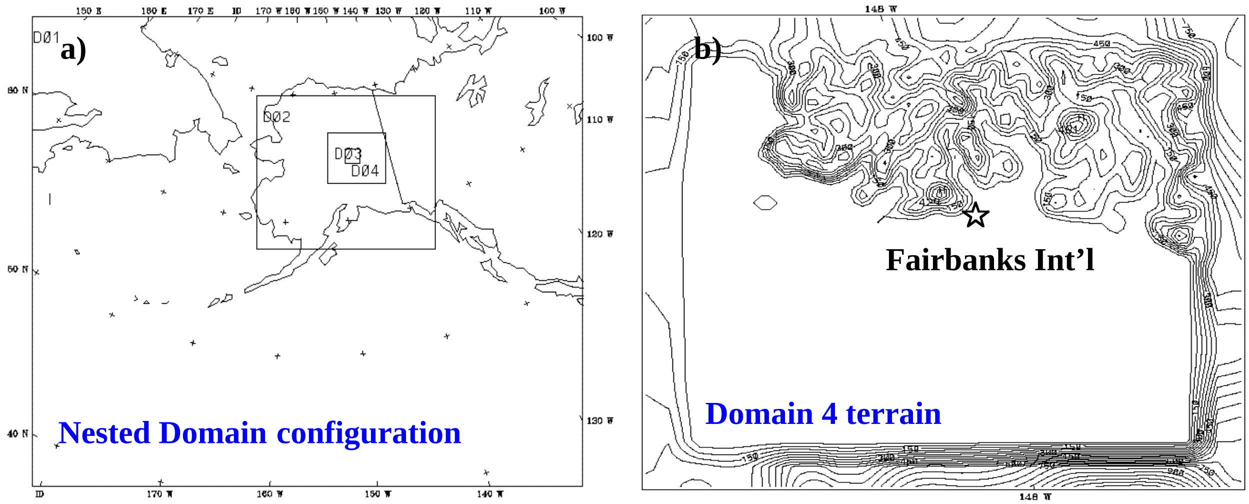

Figure 3. a) Grid configuration for MM5 experiments. b) Terrain for Domain 4. Contours @ 50m intervals starting from 150m. Star indicates location of Fairbanks International Airport (sounding location).

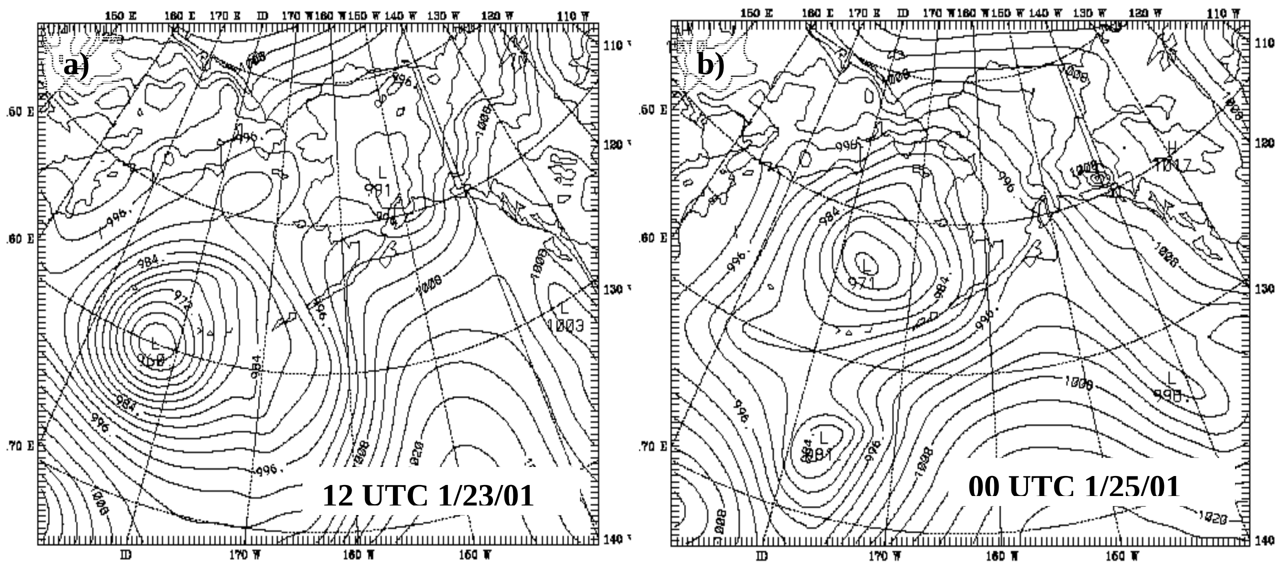

Figure 4. Analyzed sea level pressure fields (hPa), contoured at 3 hPa intervals, for the a) initial time, 12 UTC 1/23/01, and b) ending time, 00 UTC 1/25/01, of all MM5 simulations.

simulations are initiated at 12 UTC January 23 and continue for 36 hours, in order to examine the degree to which the BL schemes can capture the transitions suggested by the Fairbanks soundings in Figure 2.

4. MM5 SIMULATION RESULTS

Figures 4a and b illustrate the large-scale sea level pressure fields at the beginning and ending times of the simulations. Initially (Figure 4a) a deep synoptic cyclone is centered in the western Aleutian Islands. A weak trough is located over the Susitna valley area north of Anchorage, while little pressure gradients exist between the Alaska and Brooks Ranges in interior Alaska. By the end of the simulation, the synoptic cyclone has moved northward into the southern Bering Sea; its sphere of influence is now including most of interior Alaska as well as parts of the North Slope region. Concurrently with these changes, an anticyclone has developed with a center south of Great Slave Lake in the Northwest Territories. The combination of these developments over the period results in the establishment of an overall W to E pressure gradient over interior Alaska and specifically the Fairbanks area.

A small sample of the results is presented here. Other results and more in-depth discussion will be presented at the workshop.

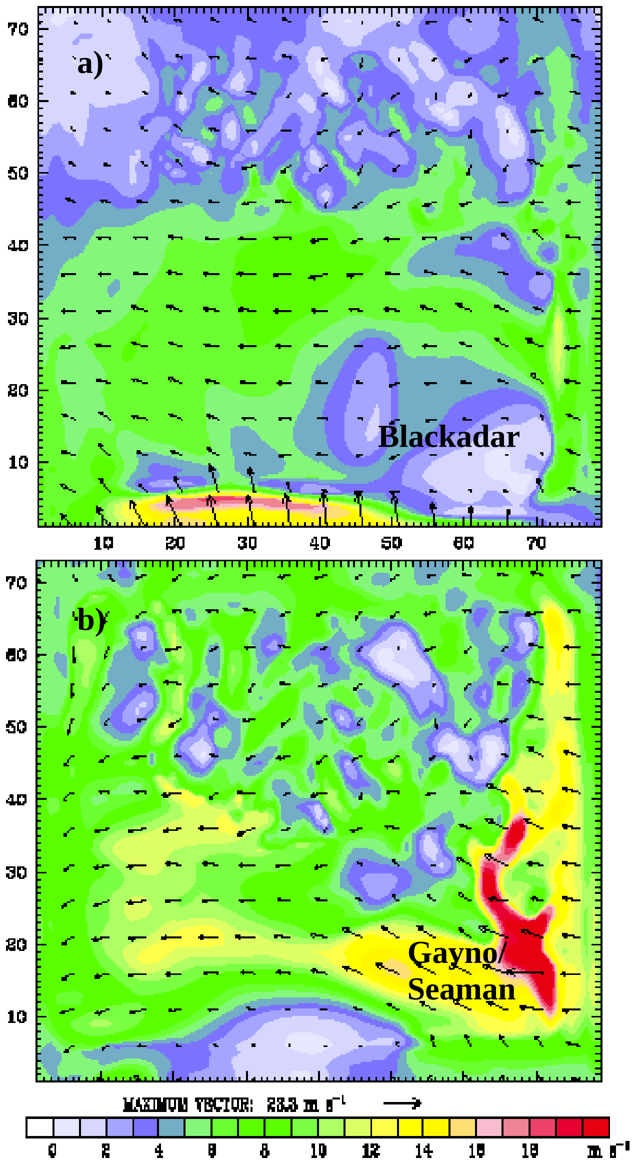

Figure 5. 975 hPa wind speed and vectors at 12 UTC 24 January for the a) Blackadar and b) Gayno/Seaman BL experiments, Domain 4.

Figures 5a and b show 975 hPa domain 4 wind fields at 24 hours into the respective simulations. These simulations represent much of the range of variability seen between the K-theory-type schemes (e.g, Blackadar) and the 2/2.5-order closure schemes (e.g, Gayno/Seaman). Results from the Bulk scheme, not surprisingly, differ considerably from either of these classes of solutions though there are elements, particularly of the Bulk solution (not shown), that appear in the Blackadar solution. Most notable of these is the southerly downslope flow from the Alaska Range seen at the southern boundary, though in the Bulk solution this flow is much stronger and penetrates much farther northward into the domain. The second-order schemes generally show no such inflow from the south, but rather substantial inflow from the east and southeast along the Tanana River and from the uplands to the east.

5. REFERENCES

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