5B.6 A CASE STUDY OF POLAR MM5 USAGE FOR MESOSCALE NUMERICAL WEATHER PREDICTION IN THE ANTARCTIC: UPPER BOUNDARY CONDITION

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1. Introduction

In limited area modeling, the upper boundary condition was not addressed extensively until nonhydrostatic models became widely available for numerical weather prediction (Mesinger, 1997). Ideally, the boundary conditions should be imposed in such way which makes the flow behave as if the boundaries were not there.

There are two most commonly used upper boundary conditions. One is the rigid lid, which requires $\omega = \frac{dp}{dt} = 0$ at the model top. This condition has the undesirable effect of reflecting vertically propagating waves. Reflection does not allow the wave energy to exit the model domain; reflection traps the waves in the domain where they can erroneously interact with other waves. The other one is the radiation boundary condition proposed by Klemp and Durran (1983). This condition permits internal gravity waves to exit the domain. It is more physically based. However there are some constraints when it is applied. Firstly, it must be applied spectrally. It is difficult to employ in more generally applied numerical models because the vertical wavenumber and frequency of the radiated waves must be specified. Secondly, it also requires a relatively deep model domain so that the vertical radiation of gravity wave energy is of secondary importance at the model top, otherwise the spurious momentum flux is not negligible (Klemp and Durran, 1983).

The Antarctic continent has high and steep terrain. Internal gravity waves induced by topography are stronger than over relatively flat regions. So if the model top is not set high enough to provide a deep model domain, large biases are found near the model top. However when the model top is set within the stratosphere, not only must more vertical layers be added at the expense of computational resources but also the interaction between troposphere and stratosphere has to be considered in the model physics. This interaction may be important for climate simulation but will bring extra complexity for weather prediction. Alternatively Klemp and Durran (1983) suggested truncation of the radiation condition at the small-wavenumber end. The cutoff wavenumber is determined using a reasonable estimate for ω.

In this study, Polar MM5 is applied to simulate the synoptic and mesoscale evolution of the atmospheric state over Marie Byrd Land and Siple Coast, West Antarctica, for 9-16 October 1995 with different upper boundary conditions. GPS/Met (Global Positioning System / Meteorology) soundings are adopted to validate model results.

2. Model description and experimental design

Polar MM5 is a version of NCAR MM5 specifically adopted for polar regions (Bromwich et al, 2000). The main modifications try to get better representation of the cloud cover and radiative fields over extensive ice sheets. The ice nuclei concentration equation (Meyers et al., 1992) is implemented in the explicit microphysics parameterization of the Polar MM5. The cloud ice and water content predicted by the explicit microphysics parameterization is now used to determine the radiative properties of clouds in the CCM2 radiation parameterization. Two additional substrate levels [which increases the substrate depth to 1.91 m (Compared to 0.47 m in the unmodified version)] are added to the multi-layer soil model proposed by Dudhia (1996). A final modification to MM5 is the addition of variable fraction sea ice surface type. This surface type allows a fractional sea ice cover to be specified for each oceanic grid point in the model domain. The surface fluxes for sea ice grid points are calculated separately for the open water and sea ice portions of the grid points and averaged before interacting with the overlying atmosphere.

For the simulations discussed in this extended abstract, the Polar MM5 is used with the nonhydrostatic option. 9-16 October 1995 is chosen as the simulation period. During this period a number of synoptic scale low pressure systems crossed the Marie Byrd Land coast and moved inland over West Antarctica. The initial and boundary conditions are generated by ECMWF TOGA data [European Centre for Medium-Range Weather Forecasts (ECMWF) Tropical Ocean-Global Atmosphere (TOGA)].

Two upper boundary conditions are available in standard MM5, and the default model top is set at 100 hPa. In this study, we have carried out several simulations with different upper boundary conditions. The experiments are designed as in Table 1 to

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investigate the effects of upper boundary condition on mesoscale simulation in the Antarctic.

Case	Upper Boundary Conditions	Truncated Wavenumb -er	Model Top (hPa)
Control	Radiation	6	100
Top10	Radiation	6	10
Lid	Rigid lid		100
Wave3	Radiation	3	100

Table 1 Experiments

In standard MM5, the truncated wavenumber for the radiation condition is 6. As mentioned in the first section, in order to eliminate the spurious momentum flux generated at the model top, the wavenumber should be truncated at the small end over the Antarctic. So in case of Wave3 the truncated wavenumber for the radiation boundary condition is 3. This case is anticipated to yield the best results among these four experiments.

3. Preliminary Results

(1) Control Run

Figure 1 shows ten GPS/Met points whose observed time is just within one hour from our model simulation output times. The first three points are located in continent and the other points are over the ocean. And points 8-10 are close to the coast.

Figure 2 depicts the vertical temperature sounding for Control simulation and GPS/Met. The values of the model simulation are interpolated to GPS/Met height coordinate. It is clear that the simulated soundings over the ocean area have a pretty good agreement with GPS/Met, however the warm biases are found at the top of those soundings over the continental Antarctic or the ocean close to the coast. The largest bias is as high as 10°C. The possible reason is that strong internal gravity waves are generated over these areas due to the topography, and the model top is not set high enough to make these waves become weak when they vertically propagate to the upper boundary. Therefore when a relatively large truncated wavenumber (here is 6) is applied to the radiation condition, there are still some waves reflecting back to the model from the upper boundary, which results in warm biases.

(2) Sensitivity Runs

Figure 3 presents temperature sounding for all experiments over number 1, number 5 and number 10 GPS/Met locations. For the cases with the same model top (100 hPa), the soundings in the lower troposphere are almost identical. When the model top is raised up to 10 hPa, the model seems to have a cold tendency. From Figure 2 we can see the model has 10°C warm biases over number 1 and number 10 GPS/Met points.

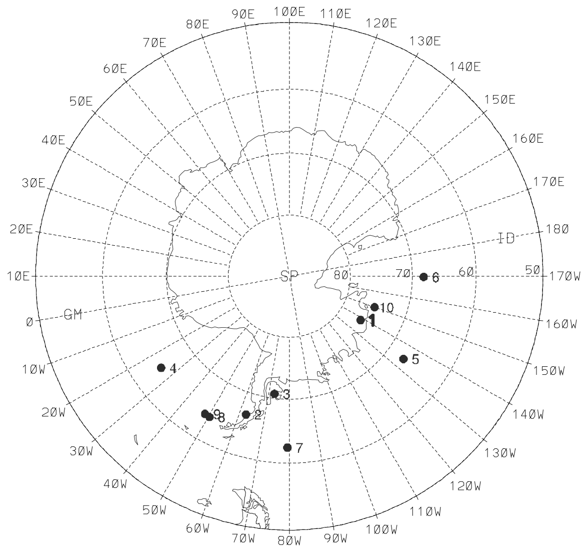

Fig.1 The locations of GPS/Met data during the simulation periods.

As shown in Figure 3, Wave3 generates 10°C colder temperature than the Control run. Therefore the modified radiation boundary condition yields better results.

Again it is still found that the difference generated by different cases is larger over the continent than those over flat area (Ocean). Since internal gravity waves over flat areas are weak, they are almost totally damped before they reach the upper boundary. In this situation both rigid lid and radiation boundary conditions achieve $\omega = \frac{dp}{dt} = 0$ at the boundary. As expected they do not show any large difference (Figure 3b).

4. Conclusion and discussion

In this study the effects of upper boundary conditions on mesoscale modeling over the Antarctic have been investigated. When using radiation upper boundary condition it is found that:

(1)Because the Antarctic has high and steep terrain which easily generates internal gravity waves, the model top should be set to relatively high so that these waves have enough space to reduce their magnitude when they propagate toward the upper boundary.

(2)If the model top is kept as the same level, an alternate way to eliminate the biases generated by reflection of gravity waves at the upper boundary is to truncate the radiative waves at the small wave- number end.

Though there is not a significant difference for the

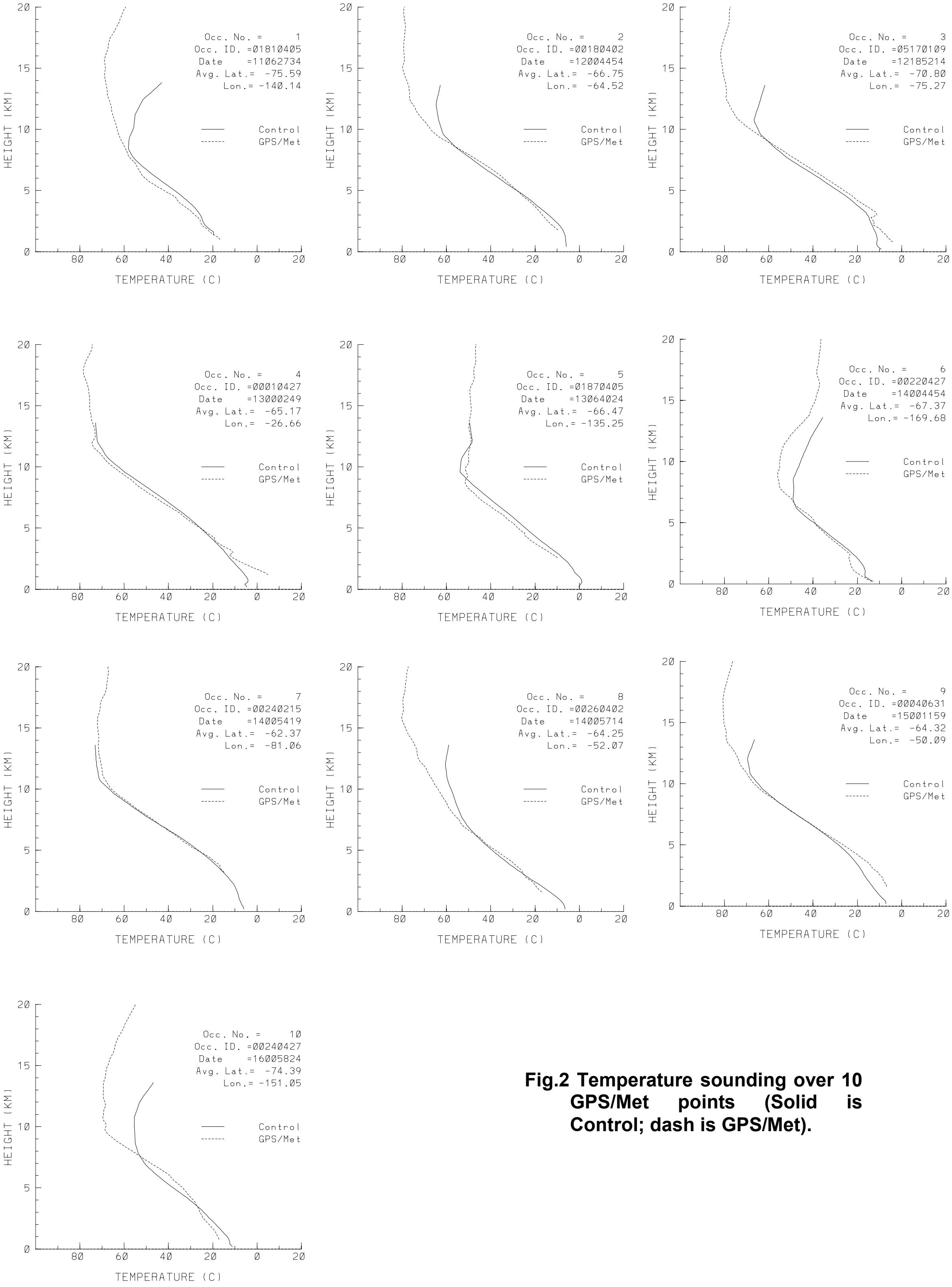

Fig.2 Temperature sounding over 10 GPS/Met points (Solid is Control; dash is GPS/Met).

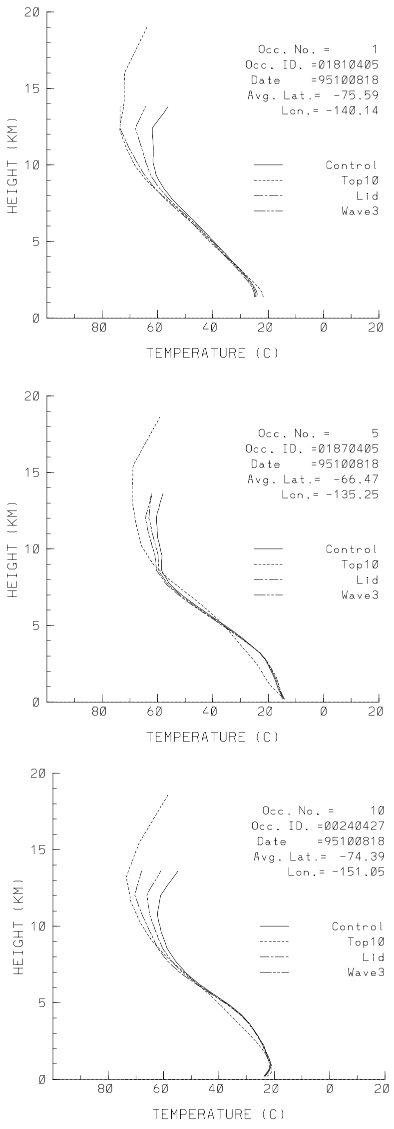

Fig.3 Temperature sounding simulated in different cases.

temperature soundings in the lower troposphere when using different upper boundary conditions, the effects could be amplified when integration of the model becomes longer. The upper boundary condition may be more critical for climate simulations.

Only the effects of the upper boundary condition on temperature soundings have been studied. We plan to further investigate their influences on other important fields such as the high level jet.

5, Acknowledge

This work was supported by NASA grant NAG5-9518.

6, References

Bromwich, D.H., et al., 2000: Bipolar modeling over ice sheets with MM5. The Tenth PSU/NCAR Mesoscale Model Users' Workshop, 21-22 June 2000, Boulder, Colorado. 150-154.

Dudhia J., 1996: A multi-layer soil temperature model for MM5. Preprints, MM5 Users' Workshop, Boulder, Colorado.

Klemp, J. B., and D.R. Durran, 1983: An upper boundary condition permitting internal gravity wave radiation in numerical mesoscale models. *Mon. Weather Rev.*, **111**, 430-444.

Mesinger, F., 1997: Dynamics of limited area models: Formulation and numerical methods. *Meteorol. Atmos. Phys.*, **63**, 3-14.

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