P2.16 NUMERICALLY SIMULATED INTERACTIONS BETWEEN A PRECIPITATING SYNOPTIC SYSTEM AND LAKE-EFFECT SNOWBANDS OVER LAKE MICHIGAN

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1. INTRODUCTION

During the last century, lake-enhanced precipitation has been well documented over the Great Lakes Region (eg. Wiggin 1950). Arctic air masses protruding downward from Canada over these relatively warmer bodies of water are the basic ingredient for the increase in snowfall amounts now coined "lake-effect snows". As a result, various papers have been written concerning the simulation of lake-effect morphologies and general mechanics of these snowstorms. (eg. Lavoie, 1972; Hjelmfelt, 1990)

On 05 December 1997, another variable was added to these wintertime snow events over the southeast portion of Lake Michigan. A precipitating low-pressure system enhanced the lake-effect snow through the process of natural seeding. Conveniently, the Lake-Induced Convection Experiment (Lake-ICE; Kristovich *et al.* 2000), which was designed to observe a wide range of atmospheric phenomena associated with lake-enhanced snow events during the winter of 1997/1998, initiated their operations on the morning of 5 December.

2. BACKGROUND

2.1 – Synoptic Conditions

A precipitating synoptic low pressure system, centered over northeastern Wisconsin at 500mb, was observed moving southeast towards Lake Michigan on 4 December 1997. Upon its arrival (and eventual traversal) over the central portion of Lake Michigan early on 5 December, the upper level low-pressure system proceeded to naturally seed the snowbands. This process increased the amount of precipitation on the leeward side of Lake Michigan due to the growth of the convective boundary layer (CBL; Schroeder *et al.* 2002). At 12 UTC on 5 December 1997, the 500 hPa low pressure center was centered over eastern Michigan as can be seen in Figure 1.

2.2 Natural Seeding and Data Collection

The growth of the CBL as a result of the natural seeding of the pre-existing lake-effect clouds is an important feature of the 05 December 1997 case (Shroeder *et al.*, 2002). The "seeder-feeder" process involved in this enhancement has been previously documented primarily in land-based cases (eg. Herzegh and Hobbs, 1981); however, an observational summary of the "seeder-feeder" process involved in this case-study is detailed by Shroeder *et al.* (2002).

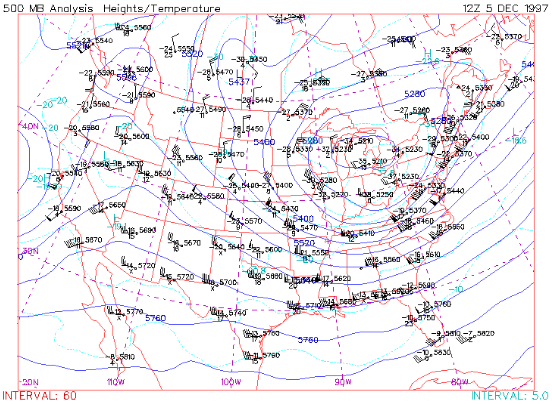

Figure 1 – 500mb Analysis at 12 UTC on 05 December 1997

Flights made from 16 UTC to 20 UTC as a part of Lake-ICE permitted observations to be made of the "seeder" clouds aloft. Visual confirmation that the fallstreaks from clouds at 500 hPa were not evaporating before reaching the low-level lake-effect clouds was made during these flights.

3. MODEL SET-UP

Numerical simulations of the natural precipitation enhancement were made utilizing the Penn State University/National Center for Atmospheric Research Fifth Generation Mesoscale Model (PSU/NCAR MM5). This in part is due to the MM5's ability to be easily modified by the user, as well as its non-hydrostatic features. For this simulation, four domains were used with spacing set so the finer-scale features can be seen, particularly during the primary time of interest (16 UTC to 18 UTC on 5 December 1997).

The four domains used in the simulation consisted of spacings of 13.5km, 4.5km, 1.5km, and 0.5km. Initialization of the domains were staggered in order to allow the model to spin-up as necessary. The outer domain was initiated at 00 UTC on 5 December 1997.

The second domain was initiated after 12 hours. The inner two domains were primarily focused on the primary time of interest. Accordingly, the third domain began at 16 UTC, and the fourth domain commenced at 17 UTC. A depiction of the nesting used in the four domains can be seen in Figure 2. The simulation used 45 vertical levels. The model's physics options and time-frame are listed in Table 1.

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Table 1 –Physics options activated for the simulation.

Physics Option	Domain(s)	Scheme Chosen
Explicit Moisture Scheme	ALL	Goddard Microphysics
Cumulus Parameterization	1	Grell Convective
Cumulus Parameterization	2, 3, 4	None Used
Planetary Boundary Layer Scheme	ALL	Eta-Mellor-Yamada
Atmospheric Radiation	1	Rapid Radiative Transfer Model
Soil Temperature Model	ALL	NOAH Land-Surface Model
Shallow Convection	1	N/A
Forecast Length	ALL	1440 minutes (05 December 1997 00Z to 06 December 1997 00Z)

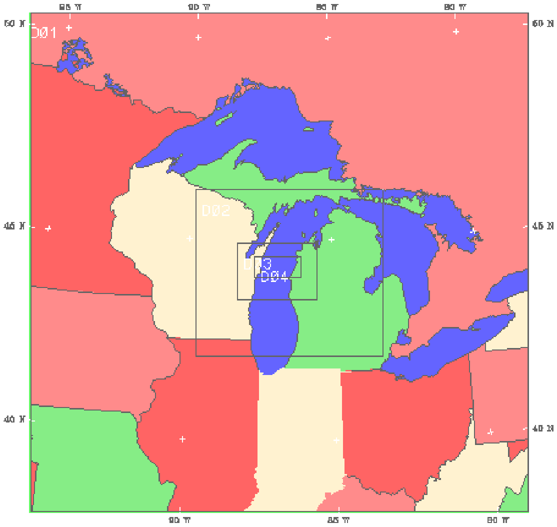
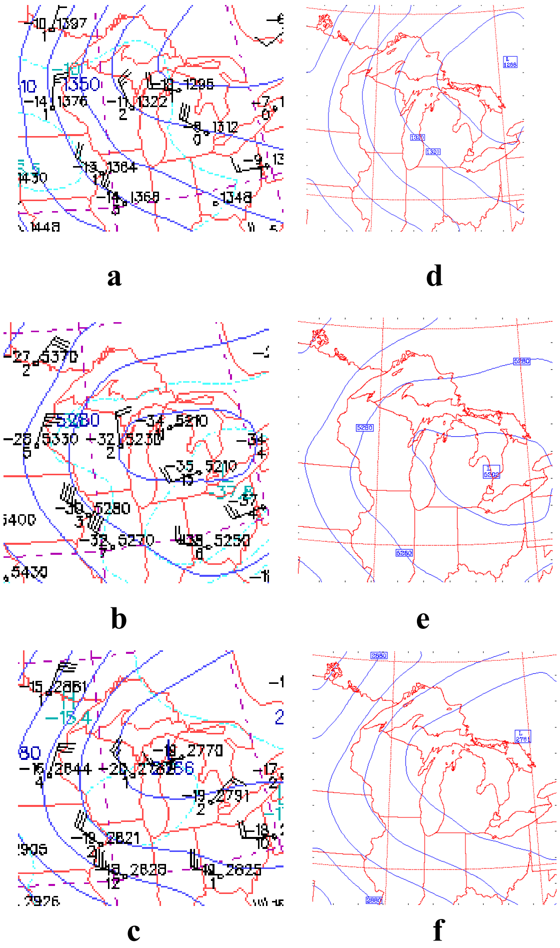


Figure 2 – Domain Nesting and Spacing Used in Simulation

4. RESULTS

In order to ensure accuracy in the simulation, verification between model output and observations were made. Figure 3 depicts the comparisons of observations from the Lake-ICE archive maintained by the Joint Office for Scientific Support (JOSS) and the MM5 output. These plots indicate the geopotential heights for 850 hPa, 700 hPa, and 500 hPa. These plots indicate that the model accurately represented the placement of the low pressure center at 12 UTC.



a d

b e

c f

Figure 3– (a,b,c) Observed Analyses at 12 UTC from Joint Office of Scientific Support and (d,e,f) Analyses obtained from MM5 simulation output at 12 UTC

Locations of potential natural enhancement were obtained by plotting the snow mixing ratio (q_{sn}), for the 1000 hPa level over-laid with the q_{sn} from the 900, 700, and 500 hPa levels in contrasting colors. Dense areas of coincident ratios of q_{sn} were plotted in cross-section to check for precipitation. Looking at this overlay indicated different zones of natural enhancement from the 500 hPa low, and two areas of potential seeding were focused on (one at 1645 UTC and one at 1730 UTC). Details of these two areas follow. Figure 4 gives a view of what was happening vertically through the use of soundings (taken at 12 UTC), and also an image of base reflectivity from 17 UTC. The sounding taken from the MM5 output (Fig. 4.b) show a similar stability profile as that taken from the National Weather Service (NWS) office in Green Bay, WI (KGRB) (Fig. 4.a), and the base reflectivity radar image indicates areas of precipitation approximately over the area where the seeding is found in the model output.

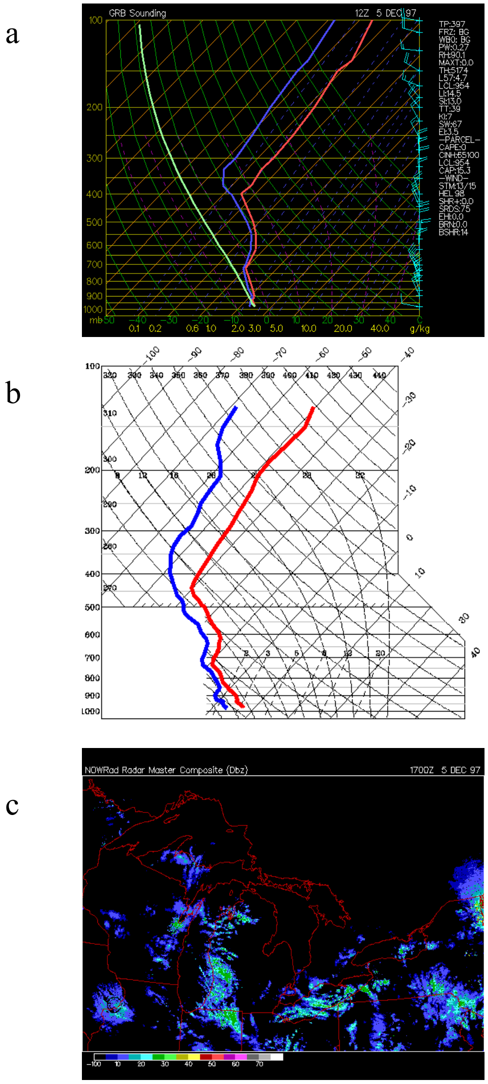


Figure 4– a) National Weather Service Sounding; b) MM5 Sounding; c)Base Reflectivity Radar Image

Natural seeding at 1645 UTC was found in the southwestern portion of the third domain. A horizontal plot was made to confirm the enhancement of lower-level clouds from the system located at 500 hPa. Figure 5 shows the location, and corresponding vertical cross section plots (with 4 contours ranging from $5.0X10^{-4}$ g kg^{-1} to $1.0X10^{-2}$ g kg^{-1} of the seeding. Both horizontal and cross section plots demonstrate three specific cloud decks located at 500 hPa, 700 hPa, and approximately 900 hPa. The seeded levels (700 hPa and 900 hPa) have contours of increased densities below the areas of upper-level precipitation. The precipitation at 900 hPa and 1000 hPa contain the highest densities of q_{sn} contours.

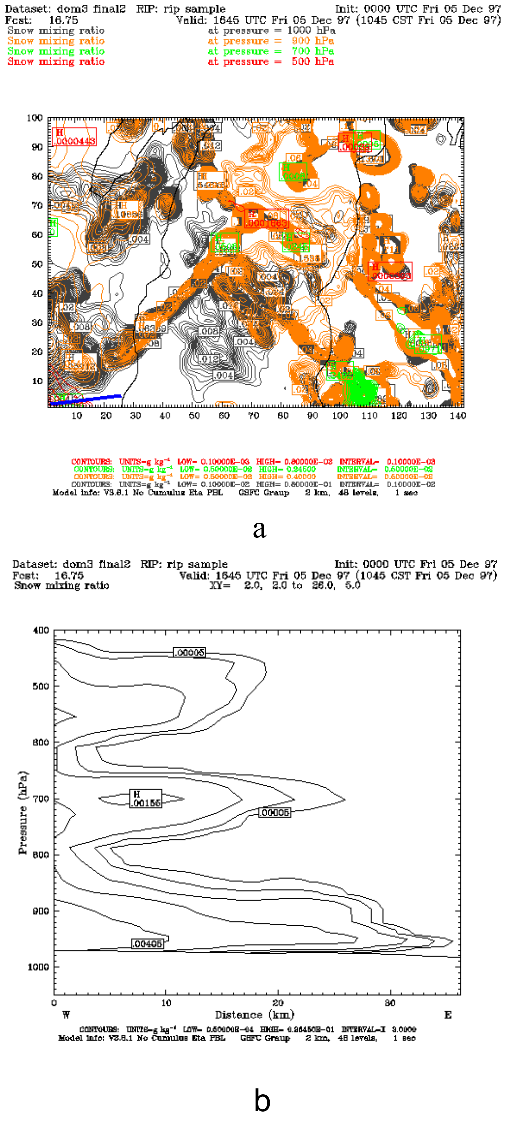


Figure 5–Seeding at 1645 UTC a) Location (think blue line in lower left) and b) Vertical Cross-Section of snow mixing-ratio

Additionally, the areas receiving the enhancement have deeper cloud-deck depths, demonstrating an increase in their boundary layers (as discussed in Schroeder *et al.*, 2002).

The location of natural enhancement, and vertical cross-section plot of the snow mixing-ratio at 1730 UTC can be seen in Figure 6. A combination of four contours ranging from 1.00 X 10^{-5} g kg^{-1} to 1.00 X 10^{-1} g kg^{-1} of q_{sn} are utilized to allow for the large range of snow intensities, not otherwise possible from using the smallest contour interval (used to detect specific feeder portion of cloud). Using the higher interval in the lower-cloud deck also demonstrates the increased mixing ratios in the seeded portions of this cloud-deck. The depth of the lower cloud-deck is, again, deeper in the seeded regions indicating a deepening of the boundary layer as discussed by Schroeder *et al.* (2003). Also shown in the vertical cross-section plot is an area where the upper-level deck is less intense (the right side of the plot) resulting in a non-seeding portion of the cloud-deck. It can also be noted the thickness of the lower clouds below this portion are not as deep as those areas being seeded at this time.

Further work with this simulation will directly compare areas where the 500 hPa deck is not seeding the snowbands as a tool for further verification of the simulation results. This will be done by locating areas of no precipitation and looking at the vertical cloud structure above them to ensure no seeding is occurring. Additionally, areas of precipitation will be closely examined to show there is no evaporation occurring between the upper and lower cloud decks. Additionally simulations where physical processes are adjusted (no precipitation, no latent heat of evaporation, etc) will also be done.

The simulations thus far completed of 05 December 1997 have been successful in demonstrating natural enhancement of lake-effect snows over Lake Michigan. Further use of the parameterizations used in this numerical simulation can be used in models run by forecasters to better predict the level of enhancement discovered with the coupling of precipitation synoptic events and lake-effect snows

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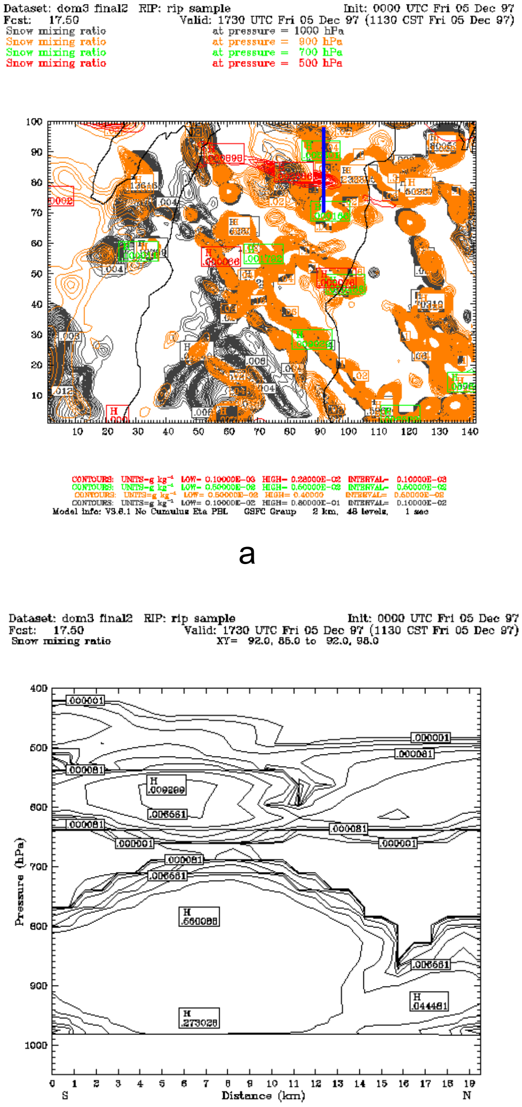

Figure 6 – Seeding Event at 1730 UTC a) Location (think blue line at center of the top) and b) Vertical Cross-section of mixing ratio

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