Talking Points for VISIT Lake-effect Snow II session

1. Title
2. Objectives
3. Mesoscale model limitations
4. Horizontal Resolution - The “delta X rule” refers to the width of the feature divided by the model grid spacing, for example to simulate a band 20 km wide, you need 2 km grid spacing; this is referred to as the 10 delta X rule. This corresponds to 10 grid points being needed to span the feature horizontally to adequately represent it.
5. Horizontal resolution - In general the lack of sufficient resolution will result in an underestimate of lake-effect snow QPF values. However, QPF fields should NOT be used to assess if a model can resolve some small scale feature. The feature will be smoothed out or blend in with the accumulated precipitation field for the period of time the QPF field is output. Instantaneous fields should be used to assess if the model can resolve a feature, examples include low-level omega or condensate fields.
6. Omega / radar - Here we compare Eta12 native grid instantaneous fields (866 mb omega and total condensate) (frame 1) with the radar reflectivity (frame 2) at that time as an example of what the model cannot resolve due to the lack of horizontal resolution. Notice the detail that is present in the radar imagery is being smoothed out in the model fields. The snowfall shown on radar over northwest Lake Ontario is not present in the model fields. Also, small scale features such as the wave on the southwest portion of the Lake Erie snowband is absent in the model fields.
7. AWIPS display issues - Lack of sufficient horizontal resolution in the model is not the only source for smoothing out the band too much or missing small scale features. The way the model output is displayed on AWIPS can also cause this problem. AWIPS model grids generally display the output at a resolution lower than the model native grids. Also, they only display the data 3 or 6 hourly. Grid #218 is one exception that does display the Eta12 at its native resolution, but is still not output hourly (3 hourly instead). Running local models such as the workstation WRF allow us to view the native grids at hourly intervals and allow us to experiment with various convective parameterization schemes. Next, let’s consider how the various convective parameterization schemes perform with regard to lake-effect snow.
8. Convective schemes - Convective parameterization schemes do not perform well with model grid spacing finer than 10 km. The schemes for the various operational models are listed.
9. Comparison of schemes - Color codes correspond to representative for LES (green), unrepresentative for LES (red) and neutral (yellow). Let’s compare the various schemes used by the operational models in how they predict precipitation.
    a. Grell-Devenyi (RUC) - Uses an ensemble approach where the following are varied (108 variations) within the scheme:
        i. Removal of CAPE over a specified time (e.g. 30 minutes) or CAPE never completely consumed
        ii. Low-level vertical velocity
        iii. Integrated vertical transport of water vapor
        iv. Precipitation efficiency (precip vs downdraft/evaporation)

Variations of these are treated as members of the ensemble, and the ensemble mean of these yield the QPF amount, this is done for each grid point. Some variations are representative of LES (i.e. CAPE never completely consumed) while others are not (i.e. removal of CAPE over a specified time). The idea is that the probability of getting the “correct” QPF value increases if it is in the envelope of solutions, however, ensemble member outliers may contribute to more diffuse precipitation patterns.

b. Explicit (Workstation WRF option) - Directly predicts convective precipitation (not through paramaterization as in the other schemes). This scheme is run at a finer scale grid spacing (finer than 5 km), therefore it begins to resolve convective motions. Clouds are developed through vertical motion so precip is coupled to convergence and ascent over the lake. The scheme allows for a more realistic redistribution of heat and moisture than the convective paramaterization schemes. It also enables the winds and vertical motion to be modified directly by the convection.

c. Kain-Fritsch (Workstation WRF option) - Makes assumptions that are tuned so the scheme doesn’t crash then uses a limited 1-D cloud model to compute precipitation.

d. Betts-Miller-Janjic (NAM and Workstation WRF option) - Scheme adjusts towards an end profile that assumes CAPE is exhausted. This is not representative of shallow, long-lived convection (which lake-effect snow is). Therefore this scheme is physically unrealistic for lake-effect snow.

Where the model draws its moisture is another important facet of the models to consider. The BMJ scheme does NOT draw moisture from directly below cloud base. This is a critical limitation because in lake-effect snow the moisture below cloud base is essential to maintaining the snowband. The other schemes do take moisture from below cloud base. Another issue is the convective cloud depth needed to trigger deep convection in the schemes.

The BMJ and KF schemes both require a minimum of 200mb convective cloud depth before the deep convective scheme is triggered. The result is that shallow LES bands (less than 200 mb deep) are not represented as precipitation in the BMJ and KF schemes.

10. Shallow Convective Portion - Another problem with the 200mb requirement in the BMJ and KF schemes is that if the deep convection portion of the scheme is not triggered, then the shallow convective scheme is. This acts to dry the boundary layer unrealistically (for LES) as moisture is released through the top of the PBL.
11. Explicit vs convective parameterization - The Kain-Fritsch run showed a smoother look to the QPF field and lower amounts. Buffalo, NY recorded 24" during this event, more than the forecast QPF amounts from the model. Of course there are no observations over the lake to verify the maximum amounts from the model.
12. Comparison of schemes - In summary, the QPF fields have known problems, therefore they should be used with the understanding that the precip amounts will likely be too low, the patterns too smooth meaning that small scale features are absent.
13. Boundary layer winds / fluxes
14. Observations vs model for 24 December 2001 case - Note the model diagnosed 10 m wind field (dark blue), the values over the lake are significantly lower than observed

(cyan). This will have a major impact on fluxes vertically mixed into the boundary layer, as well as convergence.

15. Locked thermal convergence zone - One example of model wind speeds being too light is in the case of a single band that remains stationary for an extended period. The models have a tendency to move the band too quickly because the convergence assoicasted with the LES band is too weak. During these stationary single band events, be sure to check model vs observed surface winds if the model moves the snowband for no apparent reason.
16. RUC forecast surface winds
17. Initialization and model spinup
18. GLERL dataset
19. GLERL water temperatures November 21 through December 6, 2001 - Note the analyzed lake surface temperature (LST) does not change drastically during much of November, but then suddenly drops for the December 6 analysis. This is due to prolonged periods of cloud cover over the Great Lakes region which prohibits the satellite from making observations of lake surface temperature. The bottom line is that during an LES event, the model may be initialized with lake surface temperature data that is quite old and perhaps much warmer than observed.
20. Lake surface temperature sensitivity (eastern lakes) - Workstation Eta run at 8 km grid spacing, Kain-Fristch scheme, 15:1 snow ratio. Ovals are observed snowfall (inches) from the storm. The implications of an incorrect LST analysis in the model initial analysis are shown in this slide and the next. As it can be seen, slight changes in LST can have a profound effect on model QPF values. The effects of extended periods of cloud cover will lead to older GLERL LST data in the initial analysis, this older data will likely be warmer than reality. This problem of old GLERL data in the initial analysis will result in higher forecast QPF amounts due to higher than reality LST values. Recall convective parameterization schemes generally underestimate QPF amounts.
21. What to be aware of when the model initializes during a lake-effect snow event.
22. RUC accumulated snowfall for 20 November 2000. Buffalo, NY had 2 feet of snow from this event.
23. RUC accumulated snowfall (using 15:1 ratio) for 20 November 2000. Small scale motions dominate the signal, especially early on. The model still does not have sufficient resolution to resolve individual horizontal convective rolls associated with the multiple bands (readily seen off Lakes Michigan and Superior), rather, we are looking at gravity waves or features along grid lines. Also not the diffuse precipitation patterns, this may be caused ensemble member outliers.
24. Visible loop for 20 November 2000 - This should go along with the previous two slides. Note the multiple bands occuring over Lakes Superior and Michigan. The multiple bands affecting northwest lower Michigan are northwest to southeast oriented. Recall in the model output the lines of QPF early on were east-west, this is a good indicator that what we see is features along grid lines in the model, not the multiple LES bands themselves.
25. Aggregate Lake Effects - Relatively warm air from multiple lakes in a cold environment modifies the sub-synoptic boundary layer, especially over the western lakes.
26. Lake aggregate schematic - The aggregate effects of the warm lakes in a cold air mas can induce locally lowered pressure. Frame 1 – Here blue lines indicate a lake aggregate

induced sea level pressure trough. Dashed yellow oval shows an approaching mid-level shortwave prior to its interaction with this low level trough. Frame 2 – surface trough intensifies as the shortwave phases with the lake induced trough.

27. 18 - 20 December 1996 Analyses - Frame 1) (12:00 UTC 18 Dec.) Example of lake-induced MSLP trough with approaching 500 mb shortwave/trough. Frame 2) (00:00 UTC 19 Dec.) Surface and 850 mb troughs remain in place. Heat plume lofted above the surface locks the 850 mb thermal ridge in place. Meanwhile, as 500 mb trough continues moving east, lapse rates in the 850-500 mb layer begin to increase. Frame 3) (12:00 UTC 19 Dec.) Deepening surface pressures form an aggregate low over MQT. A mesoscale, mobile trough begins to pivot around this low through Wisconsin. At the same time, the 500mb trough continues intensifies as it interacts with the mobile trough. Additionally there is further destabilization and a weakening of the inversion over the southern and central Great Lakes region. Frame 4) (00:00 UTC 20 Dec.) At the surface, the mobile trough pivots into western Michigan. The 850 mb thermal ridge and pressure trough begin to move east.
28. Water vapor 13:32 19 December - 5:40 UTC 20 December 1996 - The position of the 500 mb trough is clearly seen. Note that the mobile trough is not evident, since it is a lower tropospheric feature
29. IR 02:40 - 15:40 UTC 19 December 1996 - (Bring up the RAMSDIS IR color table). This channel allows us to see the lower tropospheric mobile trough. South of Lake Superior note the increase in cloud cover due to northeast flow off the Lake. As the mobile trough begins to move through Wisconsin, a slightly colder cloud deck can be seen forming. Light snow flurries are reported with this band of clouds. Notice that a multiple band event is already in progress over southwest lower Michigan.
30. Visible 14:45 - 19:40 UTC 19 December 1996 - The cloudiness associated with the mobile trough arrives over southern Lake Michigan. Note that the associated innocuous clouds are more difficult to see on the visible than they are on the IR. The multiple bands along the eastern shore of Lake Michigan can be easily seen in this channel.
31. IR 15:55 19 December - 7:40 UTC 20 December 1996 - In the first third of this loop the cloud deck associated with the mobile trough moves across southeast Wisconsin. As it arrives in western Michigan, it interacts with the multiple bands LES event in progress, and intensifies the snowfall.
32. Grand Rapids, MI radar reflectivity from 14:57 UTC 19 December - 10:00 UTC 20 December, 1996 - During the first half of the loop the radar data confirms the multiple band nature of the LES event. However, as the mobile trough arrives, the mode of convection can be seen to transition from multiple bands in the low-20's dBz, to a single intense band with maximum dBz values in the high thirties.
33. Snowfall totals (inches) 24 hours through 7:00 CST 20 December 1996
34. Lake aggregate summary
35. Lake aggregate summary (2)
36. Application of principles - Now we will apply principles learned during this session in a case study from late December 2001, a significant LES event for the Great Lakes region.
37. Above average Lake Surface Temperatures (LST) for Lake Erie - The above average LST's were a major factor in the late December 2001 LES event being significant. The city of Buffalo received 82 inches of snow from this event, a location on the east end of

Lake Ontario received 127 inches.

38. Eta 850 mb HT/T/Wind forecast from 12:00 UTC 28 December 2001. At the initial time we have southwest flow (favorable fetch for BUF) but winds are forecast to veer through the forecast period over Lake Erie which means an unfavorable fetch for BUF, but more favorable south of BUF.
39. MM5 (20 km grid spacing, Grell scheme), precipitation, surface wind from 12:00 UTC 28 December 2001. The simulation shows the snowband over Buffalo early but then moving southward as winds veer. In good agreement with the Eta 850 mb forecast. Remember this scheme will underforecast QPF amounts and smooth and broadens the precip pattern.
40. Workstation-Eta (15 km grid spacing, Kain-Fritsch scheme) 900 mb Omega from 12:00 UTC 28 December - If we are trying to find a small scale feature, the QPF field from the previous slide would not show it. Here, we have an instantaneous field (omega) as well as the advantage of somewhat finer horizontal resolution. The pattern still looks similar to the QPF field in this case, with a snowband over Buffalo early that moves southeast. The horizontal resolution of the model may still be inadequate to resolve small scale features, in this case, a feature less than 150 km in width would not be completely resolved. To help find small scale disturbances, we use satellite data next.
41. IR for 8:15 to 12:15 UTC 28 December 2001 - Notice the disturbance moving eastward along the southern Michigan border towards Lake Erie. What effect will this have on the Lake Erie single band in progress as shown in the model forecast? Is the cloud cover central Ohio and Indiana associated with a jet? (See next slide)
42. 500 mb isotachs at 12:00 UTC overlaid with IR image - Notice the mesoscale jet max over Ohio. The small disturbance noted above is directly beneath the left front quadrant of this jet. This jet will add additional curvature vorticity to the mesoscale disturbance, acting to intensify it.
43. IR 12:45 - 18:15 UTC 28 December 2001 - The jet streak mentioned in the previous slide adds vorticity to the mesoscale disturbance on the west end of Lake Erie (the circulation can be clearly seen on this IR loop and even better on the visible loop next). The vorticity center moves along Lake Erie towards the northeast.
44. Visible for 28 December 2001 - The mesoscale disturbance can be seen to clearly have vorticity with it, and it disrupts the single band in progress that is affecting BUF.
45. Radar reflectivity from BUF 15:53 - 22:49 UTC 28 December 2001 - Shows the complete evolution of what took place in Buffalo. Early in the loop, a single intense band with 3" per hour snowfall rates was affecting the city. However, the mesoscale disturbance comes along and disrupts the snowband, putting an end to the heavy snow in BUF. Using the satellite data in combination with the model data, we were able to identify this disturbance well before it was in the range of the BUF radar. The radar shows that after the disturbance passes, multiple bands form well south of BUF, then by about 22:00 UTC the single band re-establishes itself further south. Compare this with the MM5 output we were looking at earlier that simply moved the snowband towards the southeast. Monitoring satellite/radar data allowed the forecaster to see what the actual evolution would be, and to anticipate the event well in advance.
46. GRR CWA - This case study covers a lake-effect snow that occured on 26-27 December, 2001

47. Eta 500 HT/T/Vorticity/Wind from 12:00 UTC 26 December 2001 - 18:00 UTC 27 December 2001 - A moderately strong short wave trough is exiting the area at the initial time. Notice that between 00:00 and 12:00 UTC on 27 Dec a jet max intensifies to the northwest of the forecast area. As the winds increase an associated vorticity max intensifies. This intensification may be a reflection of the Eta's detection of aggregate low effects. By being aware of the aggregate low, and approaching shortwave, the forecaster can anticipate the possibility of a developing mobile trough.
48. Visible satellite loop for 26 December - Shows a multiple band snow event in progress over Lake Michigan during this time period, that is affecting the Grand Rapids CWA. Notice the innocuous cloud mass approaching from the northwest through central Wisconsin.
49. 212 Eta Grid of MSLP/Sfc temperature and wind from 12:00 UTC 26 December 2001 - 18:00 UTC 27 December 2001 - Recall the Eta is re-mapped to 80 km grid therefore, features are probably smoothed out or absent. The sea level pressure is forecast to decrease throughout the period over the western Great Lakes, and remember that the pressure trough is probably sharper than shown. Notice also that the isotherms generally reflect the aggregate shape of the western lakes (e.g. 06:00 UTC 27 December). There is an elongated north-south ridge adjacent to Lake Michigan. Note baroclinic zone north of Lakes Superior and Huron. This is a region where lows are likely to spin up. Part of the aggregate effect is being masked at the surface by diurnal effects. 850 mb temperatures may be better to look at.
50. Eta 850 HT/T/Wind from 12:00 UTC 26 December 2001 - 18:00 UTC 27 December 2001 - The cold pool over Wisconsin is upwind of our forecast area at the initial analysis, but throughout the forecast period we see the cold pool pass to the south and east of the CWA, with temperatures warming more than 2 degrees by 12:00 UTC 27 December. A het plume dominates the entire region by the end of the forecast period – advecting as far north as southern Ontario. Even at this coarse grid the 850 winds increase over southern WI. What are some possible reasons for this increase?
51. BUFKIT Eta from 12:00 UTC 26 December valid for Grand Rapids - Model forecast lake-induced CAPE values are around 600 J/kg through early evening, with somewhat lower values thereafter. Note the wind speeds just above the top of the PBL increase from 20 to 30 knots. The trend is for an increase in wind speeds and temperature/dewpoint for the forecast profile. Notice that the depth of the PBL is decreasing.
52. BUFKIT Eta from 12:00 UTC 26 December valid for Grand Rapids - Cross section of omega with snow growth region (pink indicates region favored for dendritic growth; yellow represents dendritic area growth *with* RH greater than 75 %), red omega is rising motion, blue is downward motion. Yellow line is the lake-induced equilibrium level. Notice the lake-induced equilibrium level is lowering in time. The most favorable time for LES seems to be through the first half of the forecast period. During the second half of the period vertical motions are less favorable and inversion height lowers. However, at the end of the period the Eta seems to be increasing the vertical motion and raising the top of the inversion height. The effect is subtle, but this may mean the Eta is responding to the aggregate low.
53. Water vapor with Eta MSLP and surface observations. Water vapor from 08:45 UTC,

MSLP and surface obs from 08:00 UTC on 27 Dec 2001. Note the surface low locked over the northern Great Lakes. This is due to the lake aggregate effect. We can expect warming of the PBL up to and probably higher than 850 mb. Notice also the upper level trough swinging around from the northwest. This trough appears to have a greater amplitude than what we were seeing forecast at 500mb earlier.

54. Hand drawn surface analysis at 09:00 UTC 27 December 2001. Note the lake aggregate low as well as the hint of a pressure trough and a second trough just east of Lake Michigan (indicated by dashed lines).
55. RUC forecast of MSLP from the 00:00 UTC, 27 Dec 2001 run. Forecast times shown are 03:00, 06:00, 09:00 and 12:00 UTC. Aggregate low is forecast to remain in place. In this case, the two mesoscale troughs shown in hand analysis are also seen (40 km resolution grid). Note that the diurnal effect is probably reducing the amplitude of the Wisconsin (mobile) trough, since it is moving through the area overnight. The Eta failed to find the trough in this run. As will be shown below, this mobile trough can be readily tracked on IR satellite imagery.
56. Water vapor 08:45 27 December - 16:32 UTC 27 December 2001 - This loop shows the synoptic scale trough rotating across the northern Great Lakes. Also notice a smaller embedded trough (indicated by darkening) moving from northeast Wisconsin into central Michigan. There is an enhanced region at the southern edge of the mesoscale trough. This may be a mobile trough due to the aggregate effects.
57. IR 00:15 - 16:02 UTC with surface observations overlaid 27 December 2001 - As an exercise, see if you can identify the signs of the mobile trough passage. (Answer: – The enhanced cloudiness associated with the mobile trough can be seen in the IR channel as it moves across Wisconsin. Several surface stations in central Wisconsin show decreasing pressure with the approach of the trough and light snow occurs as the clouds cross the region. Also, notice that pressures increase following its passage, and winds veer for a short period. However, the winds quickly return to the synoptically driven direction and speed when the mobile trough leaves the area.
58. Grand Rapids, MI radar reflectivity from 06:19 - 11:26 UTC on 27 December, 2001. The effects of the mobile trough can be seen beginning around 09:00 northwest of GRR. The higher reflectivities moved southeast and intensify with time and is through the area sometimes after 11:00 UTC.
59. 24-hour snowfall total (in inches) ending 07:00 CST, 27 Dec 2001 over the Grand Rapids CWA. Observations include co-op reports. Note the maximum snowfall over the area where the multiple band event and the mobile trough phased.
60. Summary of 26-27 December 2001 case
61. 27 December 2001 visible loop – neat stuff. Bay and peninsula enhanced band over northwestern Lake Huron, Saginaw Bay/lower Michigan thumb band weakens, multiple band events over Lake Michigan and Georgian Bay,
62. 29 December 2001 visible loop – Band over northwestern Lake Huron and the Saginaw Bay band strengthen and elongate. Lake Huron band stretches from SSM to western Ont. Intense single band over Lake Ontario, and multiple bands developing downwind from Lakes Superior and Michigan.
63. 30 December 2001 visible loop – Multiple lake band enhances LES band over northern Lake Huron, Ontario band persists, band develops over Lake Erie, enhancement over

southern Michigan (Lake aggregate?).

64. 31 December 2001 visible loop – the Lake Superior/Lake Huron band now extends across Iberian Peninsula onto Lake Ontario (phasing?), What is happening over souther Michigan?
65. 01 January 2002 visible loop – multiple bands Lakes Superior and Huron, Lake vortex southern Lake Michigan, mesoscale disturbance northern Lake Michigan.
66. Conclusions