Operational Forecasting of Lake Effect Snowfall in Western and Central New York

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ABSTRACT

Lake effect snowstorms frequently produce heavy snow in western and central New York State during the late fall and winter months when the waters of Lakes Erie and Ontario are relatively ice free. Mesoscale snowbands account for most of the snow. The depth of the snowfall can vary as much as 100 cm in 50 km. An overview is presented of some of the procedures that the National Weather Service Office in Buffalo uses to forecast lake effect snow. Forecasters at the office developed a computer program for the Automation of Field Operations and Services (AFOS) that provides guidance for forecasting lake effect snow. The program includes the compilation of forecasts for wind direction and temperature in the lower troposphere at Buffalo. It also calculates the fetch across each lake, and the change in wind direction through the lower troposphere. The program requires input parameters that are computed from one of the two operational numerical models of the National Meteorological Center, and the average surface temperature of each lake. The output is used as guidance by the forecasters to determine the potential for lake effect snow and the most likely location of the snowbands.

1. Introduction

Lake effect snow is a term that is used to describe localized snowfalls that occur downwind of the Great Lakes during the late fall and winter months. These events develop when very cold air crosses the relatively warmer waters of the lakes.

The National Weather Service Forecast Office at Buffalo, New York has forecast responsibility for a large part of New York State immediately downwind of Lakes Erie and Ontario (Fig. 1). This area includes major cities with large populations that border the lakes. Lake effect snow events can occur in many forms, ranging from light flurries to heavy snowbursts with little wind to wind-driven localized blizzards (Bahr, 1980). Because of the mesoscale nature of lake effect snow, sunny skies can prevail over one location, while a second location only 20 km away experiences a raging snowstorm that produces well over 1 m of snow (Fig. 2). In order for a forecast to have any value, extremes such as this have to be predicted to some extent. The forecast must take into account the onset time, location, and duration of the snowband, as well as the motion of the band. Large-scale numerical models such as the Limited Fine Mesh (LFM) or Nested Grid Model (NGM) of the National Meteorological Center (NMC) are not yet capable of predicting these mesoscale events (20–200 km). Certain model forecast parameters, however, can aid in the prediction of lake effect snow.

The purpose of this paper is to present the operational forecast procedure that is used to predict lake effect snow at the National Weather Service (NWS) office in Buffalo, New York. The forecast procedure consists of selected forecast parameters from the large-scale NMC models and special guidance products that have been developed at the station. These include a forecast decision tree, snowband location table, and a computerized guidance product that aids in the prediction of onset, location, and movement of the snowbands. A case study will also be presented to explain how some of the on-station guidance products are used.

2. Example of a lake effect snowstorm

Wiggin (1950) outlined the conditions necessary for prolonged lake effect storms that occur at the eastern end of Lake Erie. His basic conditions, modified over the years by forecasters at Buffalo, include

1) The presence of a stationary or very slow moving low at 500 mb centered in the vicinity of James Bay, Canada.

2) A strong flow of arctic air over the Great Lakes associated with a surface low that has moved into eastern Canada. In most cases the surface low center tracks from west to east between the Great Lakes and James Bay, Canada.

3) A southward extension of the parent surface low in the form of a trough across the Great Lakes, which assures an extended period of southwest winds over the long axis of Lake Erie.

A good example of a stationary lake effect snowstorm at the eastern end of Lake Erie occurred from 29 November to 1 December 1983. The synoptic-scale weather pattern revealed a closed 500 mb low centered just south of James Bay that remained nearly stationary during the period (Fig. 3a). An elongated trough trailed

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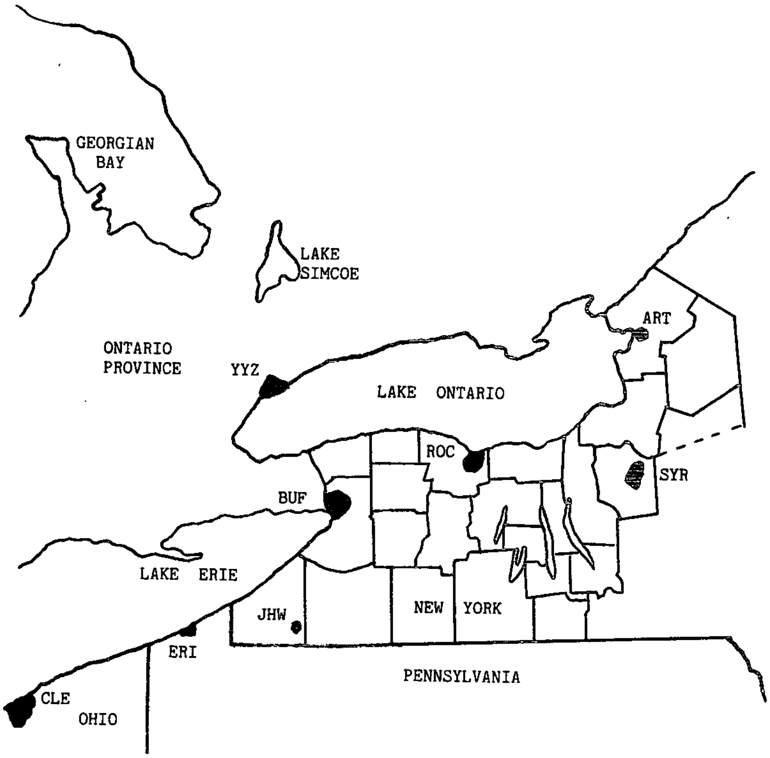

FIG. 1. Counties in New York State under the responsibility of the National Weather Service office at Buffalo, New York.

to the southwest of the low. The 850 mb and surface low centers shown in Figs. 3b and c indicate similar features. An upper air sounding (Fig. 3d) taken at Buffalo during the height of the storm, is typical of an arctic air mass, with a shallow layer of very cold air and a corresponding low-level inversion (Petterssen, 1956). In this event, up to 100 cm of snowfall were reported in a narrow 40 km band across the suburbs immediately southeast of Buffalo over a 2-day period.

A synoptic-scale weather pattern, with an elongated trough established over the lower Great Lakes, produces an extended period of southwest winds at the eastern

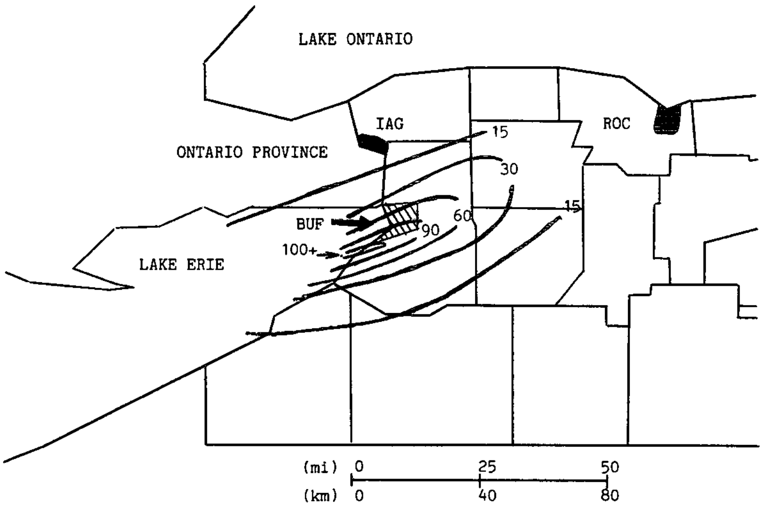

FIG. 2. Snowfall totals (cm) from the lake effect storm of 16–19 December 1983. Note the extremes that occurred in less than 40 km.

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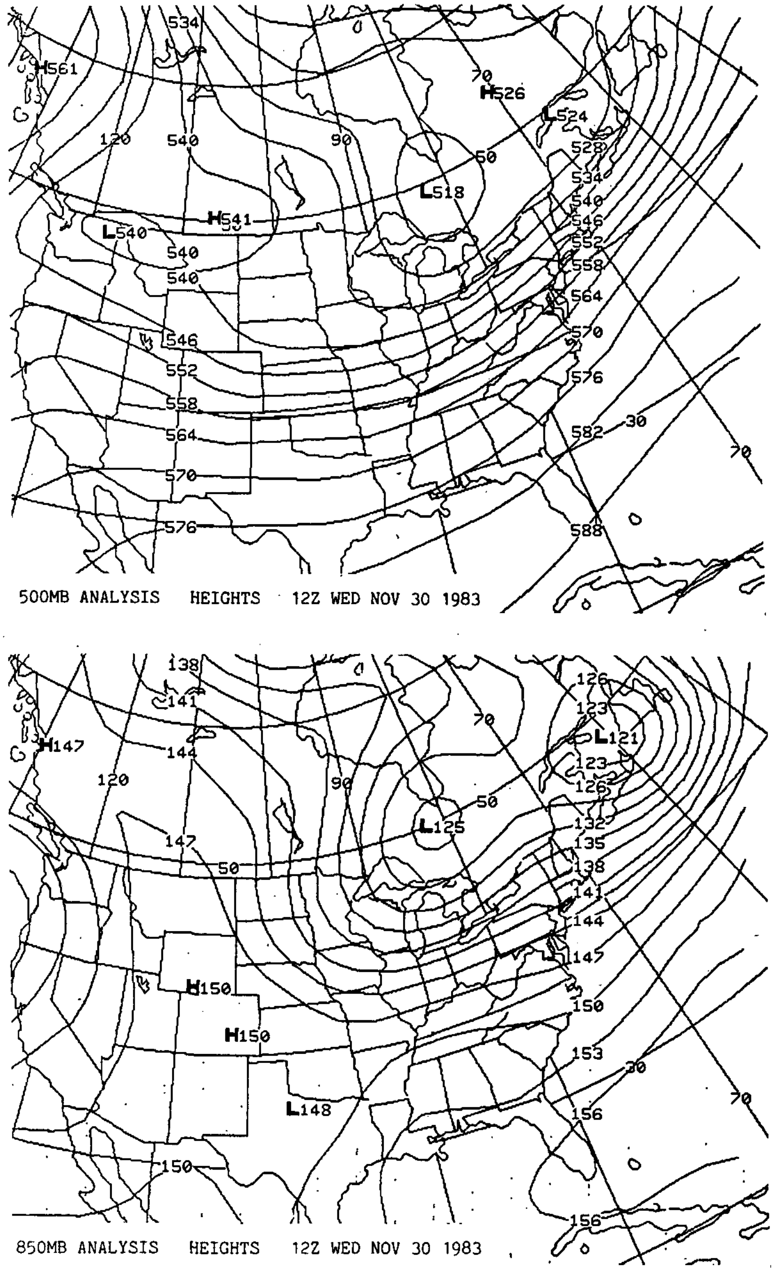

FIG. 3. An example of the synoptic-scale weather pattern for a typical single-banded lake effect snowstorm off Lake Erie. This pattern shows the extended period of southwest flow at (a) 500 mb, (b) 850 mb, and (c) the surface at 1200 UTC 30 November 1983. The temperature and dewpoint profiles are shown in (d) at 0000 UTC 30 November 1983 during heavy snowfall at Buffalo. The solid lines in panels a and b are geopotential heights in decameters, and in panel c are isobars with the thousand and hundred digits omitted.

end of Lake Erie. This, in turn, leads to narrow stationary snowbands that produce heavy snowfalls in a very localized elongated area.

Lake Ontario is roughly the same shape as Lake Erie, and its long axis lies in about the same direction as Lake Erie (west–east vs southwest–northeast). Therefore, the rules developed by Wiggin (1950) for Lake Erie are also valid for Lake Ontario, although there are exceptions to the basic rules. Lake Ontario, for example, is in closer proximity to New England, and some of the worst lake effect storms on Lake Ontario have been the result of Atlantic coastal lows, or "Nor'easters," that have stalled over the Gulf of St. Lawrence (Sykes, 1966). It is very important to examine the full synoptic weather picture; the "typical" lake effect snow weather pattern can develop in a number of ways.

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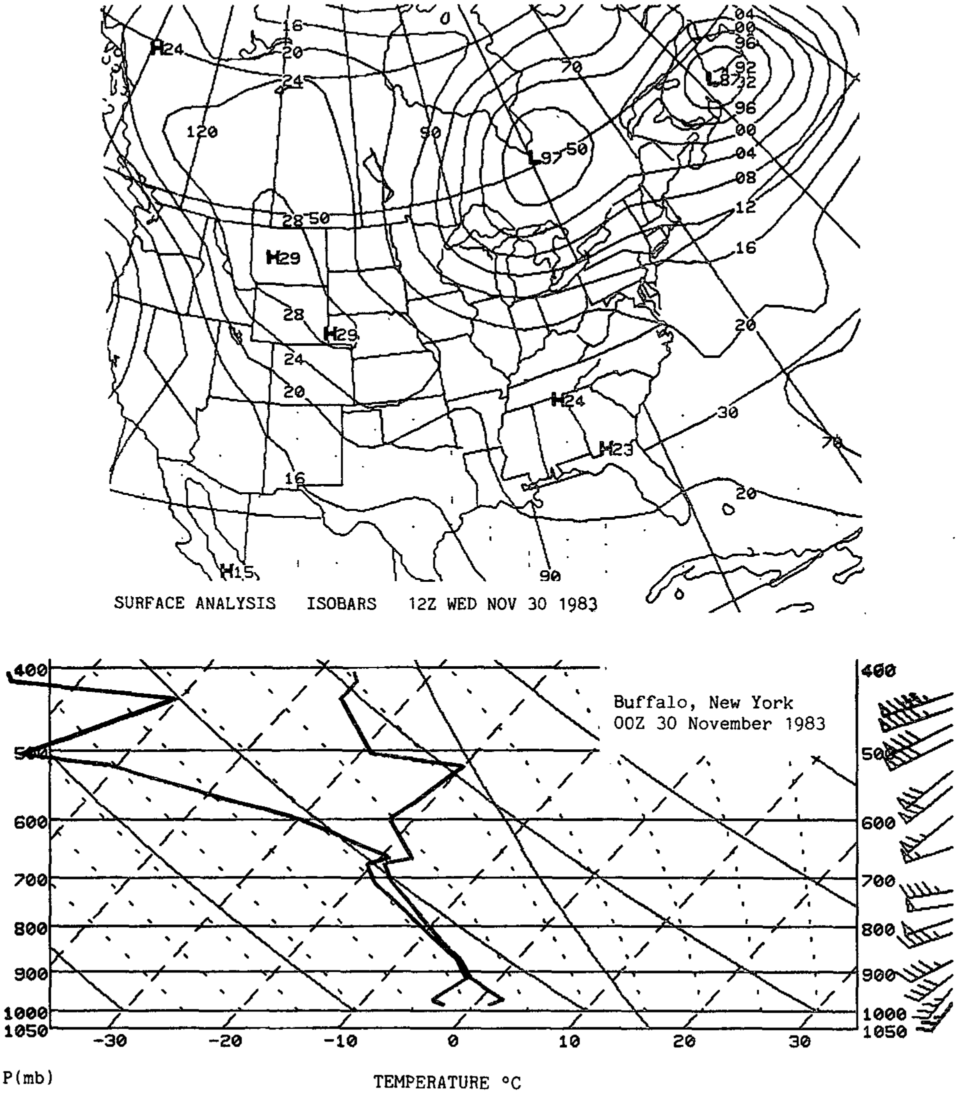

FIG. 3. (*Continued*)

3. Forecast procedure

The synoptic-scale weather pattern outlined by Wiggin (1950) defines conditions necessary to produce single-banded snows at the eastern end of Lake Erie and to some extent at Lake Ontario. Forecasters at Buffalo selected forecast parameters based on those conditions to quantify the meteorological variables important for all types of lake effect snows. Some of the more important variables are listed and discussed below. They include

1) The temperature difference between the water at the surface of the lake and 850 mb.
2) Wind direction from the boundary layer (first 50 mb) through 700 mb. (This layer is sometimes referred to as the "steering" layer for snowband orientation.)
3) Change in wind direction with height through the steering layer.
4) Existence and height of the low-level inversion.

An arctic outbreak across the warm Great Lakes can be quantified by determining the temperature difference between the lake and some level where cloud development is expected to occur. The potential for snowfall from the lakes is most dependent upon the temperature difference between the lake and the overriding airmass (Lavoie, 1972). Operationally, a 13°C difference between the lake and the 850 mb layer (i.e., the dry adiabatic lapse rate) is considered the minimum difference to initiate "pure" lake effect snow (Holroyd, 1971).

The location and movement of the surface and upper air features also determine the air parcel trajectory over

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the lake. The wind direction in the layer below the inversion determines the location, orientation, and movement of the snowband (McVehil and Peace, 1966). The wind direction from the boundary layer through 850 mb is the best operational forecast parameter for general snowband orientation and location. However, mesoscale features such as the shape of the shoreline, topography, and convergence, no doubt contribute as well (Peace and Sykes, 1966). Airflow parallel to the long axis of the lakes generates single bands that can produce intense snowfalls, while the flow of low-level air along the short axis leads to multiple bands that produce less-intense snowfalls.

Over many years of operational forecasting, the staff at the Buffalo office has noticed through empirical evidence that significant change in wind direction (>30°) with height in the mesoscale environment of the snowband is detrimental to well-organized activity. The more aligned the winds are from the surface through 700 mb, the better organized the snowbands. The alignment of winds throughout the depth of the lake effect disturbance could contribute to the confluence zone associated with single-banded storms. Directional wind shear leads to three possibilities:

1) For a prevailing wind direction over the long axis of the lake, single intense bands break into multiple, less-intense bands.
2) Snow bands tend to spread out.
3) If shear is extreme (>60°), banded structure breaks down completely. A widespread deck of stratocumulus may result and produce only a few embedded flurries.

The reviewer of this paper and others familiar with the procedure have commented that the changes in wind direction with height may be important in the synoptic scale as well. For example, geostrophic cold air advection is occurring when the geostrophic wind backs with height. When the winds finally align themselves in the vertical, geostrophic cold air advection ceases, and the column of cold air has grown to a sufficient thickness to support the development of lake effect snow. This relationship is certainly worth studying during the coming snow season, but it must be emphasized here that in our forecast scheme we have followed the simple empirical relationship that well-aligned winds through the snowband's environment (surface through 700 mb) will contribute to organized activity.

The arctic air mass that is responsible for lake effect snow is most often accompanied by a low-level frontal (cold) type inversion as shown in Fig. 3d (Petterssen, 1956). The height of the "capping" inversion is the limiting factor for cloud depth, and therefore precipitation rate. Generally, the inversion is usually found within the first 1 to 2 km of the surface. In some cases, the inversion may exist at higher levels or not be present at all. In fact, the most convectively active snowstorms have occurred with inversion heights topping 3 km, when heavy snowfall was accompanied by lightning and thunder (Niziol, 1982).

Some of the forecast parameters previously mentioned are part of a decision tree that is used as a "first look" for lake effect snow potential to the lee of Lakes Erie and Ontario (Fig. 4).

4. Other forecast parameters

The existence of a secondary trough embedded in large-scale flow over the forecast region has been shown to enhance lake effect snow activity greatly (Jiusto et al., 1970). Cyclonic vorticity advection at 850, 700, and 500 mb contributes to quasi-geostrophic ascent and is a good indicator for enhanced lake effect snow activity. Only 500 mb forecasts of vorticity are available, but they are usually considered representative of lower layers as well.

The amount of ice cover on the lake reduces the amount of heat and energy available to the overriding air mass, and therefore must be monitored by the forecaster. Ice charts prepared by the NOAA Great Lakes Environmental Research Laboratory in Ann Arbor, Michigan, are used by the forecaster to make some determination of the amount of open water on each lake. Lake Erie is a very shallow lake and usually freezes over by midwinter, while Lake Ontario, a very deep lake, does not develop appreciable ice cover (Saulesleja, 1986). Therefore, most lake effect snow activity ceases off Lake Erie by midwinter, whereas lake effect snow is possible throughout the entire winter downwind of Lake Ontario.

Although not a direct part of the forecast scheme, topographic features significantly affect the amount of snow that falls to the lee of each lake. Forced orographic ascent enhances the snowfall rate. Studies to the lee of the lake indicate that, at the very least, there is a 25–50 cm increase in annual snowfall for every 100 m of elevation (Hill, 1971). The operational forecaster at Buffalo subjectively increases the forecast of snowfall amounts for the higher elevations to the east of Lakes Erie and Ontario.

5. Forecast products

a. General outlook

The installation of computers at all NWS offices allows the forecaster to develop automated guidance products and procedures tailored specifically for local weather conditions. At Buffalo, a locally developed, computerized lake effect guidance product has been in use for the past 6 years on the AFOS system. The program utilizes relevant parameters from the large-scale numerical models as guidance in the preparation of a lake effect snow forecast. Numerical information is compiled from subsets of the LFM or NGM models the FOUS (6 h numerical output of the LFM model

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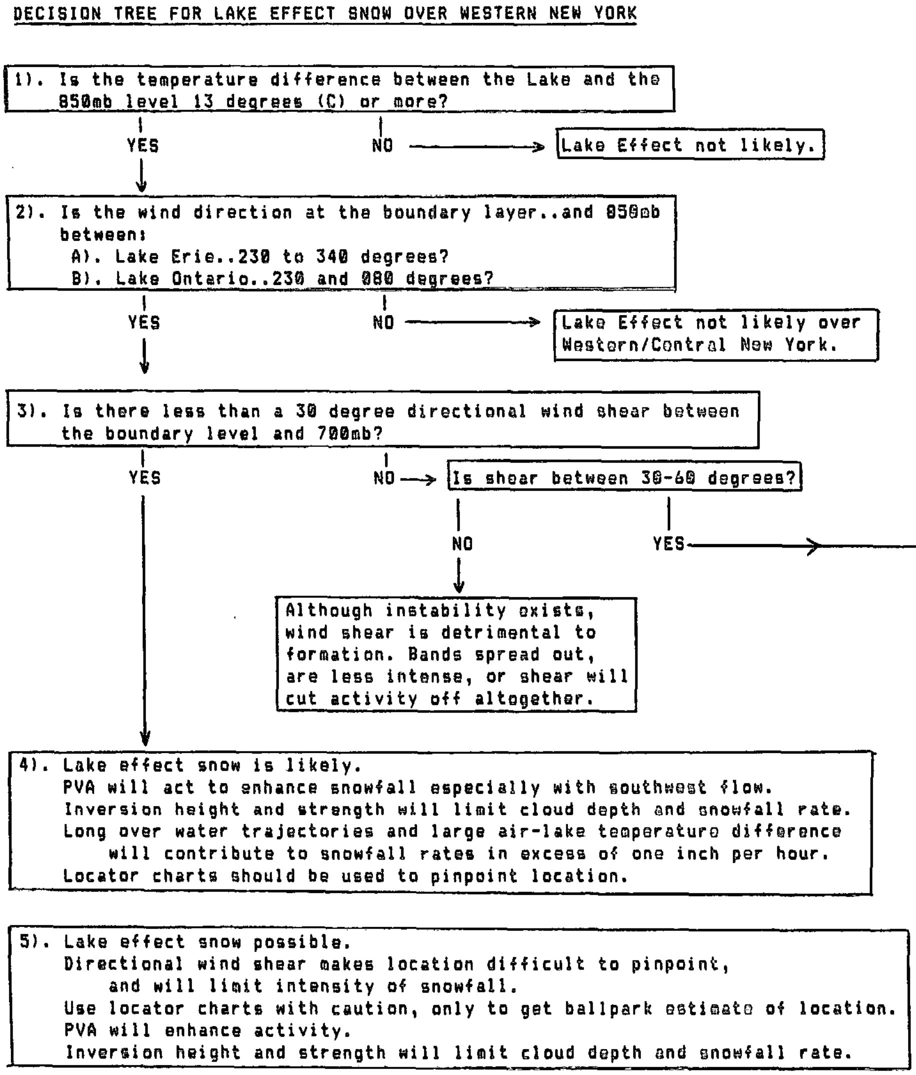

SUMMARY:
Total snowfall is a combination of snowfall rate, and the total time that a snowband remains over an area. Therefore, be very aware of wind shifts at the surface and aloft. Surface mesoanalyses are imperative!
Remember, orographic effects will enhance snow amounts greatly.

FIG. 4. A simple decision tree for lake effect snowfall potential on Lakes Erie and Ontario.

interpolated to cities) and the FD-wind (6, 12, and 24 h output of winds from the boundary layer to about 700 mb from the NGM model). Originally, both FOUS and FD-wind guidance were only available from the LFM model. The program is in the process of being changed so that it uses only NGM forecast products.

An example of the output generated by the AFOS computer is shown in Fig. 5. Wind direction is listed for three levels in the lower atmosphere: the boundary level (first 25 mb), 850 mb and 700 mb. The program calculates the directional wind shear through this layer to determine the relative alignment of the forecast winds to the axes of the lakes. It also determines the maximum fetch across the lake based on the 850 mb wind direction, which is considered the best steering wind for the snow bands.

Temperature forecasts are listed for the three levels. With the LFM model, the temperatures must be interpolated for some of the levels, because the forecast data are not directly available over AFOS. The local observation of the lake temperature is entered by the forecaster and assumed to remain constant through the 2-day forecast, since the lake warms and cools very slowly.

Vertical velocity is also compiled from the LFM FOUS product. This parameter is a useful indicator of

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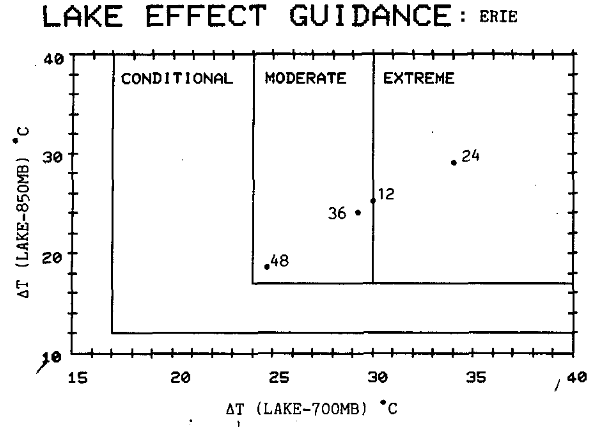

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INITIALIZED 17/12z
FORECAST PARAMETERS
VARIABLES      12HR 24HR 36HR 48HR
WIND DIR..
   700MB       260  270  300  310
   850MB       250  280  290  300
   B.L.        250  290  240  250
CHANGE OF WIND DIR. (DEGREES)
   850/700MB 010  010  010  010
   BL/700MB  010  020  060  060
FETCH(km)
   850MB       360  150  110  100
TEMPS(°C)
   700MB       -24  -28  -23  -19
   850MB       -19  -23  -18  -12
   B.L.        -08  -20  -20  -17
   LAKE         06   06   06   06
VERTICAL VELOCITY (μB/SEC)
   700MB       00.7 -0.5 -1.3 -0.7
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12HR MODERATE INSTABILITY..010 DEGREE SHEAR FROM
     700MB TO SFC..AND 360 KM FETCH AT 850MB.
24HR EXTREME INSTABILITY..020 DEGREE SHEAR FROM
     700MB TO SFC..AND 150 KM FETCH AT 850MB.
36HR MODERATE INSTABILITY..060 DEGREE SHEAR FROM
     700MB TO SFC..AND 110 KM FETCH AT 850MB.
48HR MODERATE INSTABILITY..060 DEGREE SHEAR FROM
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FIG. 5. Lake effect snowfall guidance product generated on the AFOS computer system. This product was initialized from LFM data at 1200 UTC 17 December 1985 (Note that B.L. indicates the boundary layer.)

the synoptic-scale forcing that exists. Rather than analyzing the absolute value of the vertical motion, the forecast procedure determines trends in the motion. The greater the increase in the upward motion, the better the potential for enhanced lake effect snow. With the changeover to the NGM FOUS product it is anticipated that vertical motion will be treated in a similar manner. Although the NGM's derivation of vertical motion is somewhat different than that of the LFM, it is the trend in the vertical motion forecast that is most important to the forecast procedure.

The forecast data are compiled at 12-h intervals, 48 h into the future. To the left of the table is a graph that was developed in the 1960s by forecasters at Buffalo to chart the forecast temperature of an airmass vs the temperature of the lake. The x-axis is the temperature difference between the lake and the 700 mb level. The y-axis is the temperature difference between the lake and the 850 mb level. By graphing these temperature differences on one chart, the forecaster can evaluate the airmass instability through the forecast period. Broumas (1977) reported that if each stability category was combined with other factors such as overwater trajectory and synoptic-scale forcing (cyclonic vorticity advection) at the standard 500 mb level, the forecaster could predict the potential for heavy snow (> than 2.5 cm per hour). The forecaster categorizes the outlook for heavy snow as conditional, moderate, or extreme. These terms have the following meanings:

1) *Conditional.* Heavy snowfall rates are possible when airmass trajectories are along the longest fetch of the lake (approximately 80% of maximum fetch on Lakes Erie and Ontario), and there is cyclonic vorticity advection at 500 mb

2) *Moderate.* Heavy snowfall rates can occur with moderately long trajectories (≥50% of the maximum fetch), and cyclonic vorticity advection at 500 mb

3) *Extreme.* Heavy snowfall rates possible with little dependence on fetch or cyclonic vorticity advection at 500 mb.

If the airmass attains a 13°C difference between the lake and 850 mb, then a summary of the instability, change in wind direction with height, and fetch are listed below the graph.

At the eastern end of Lake Erie, FD-wind and temperature data for Buffalo are used at predictors. At the eastern end of Lake Ontario, the forecasts of wind direction and temperature are taken from FD-data for Syracuse.

b. Location of snowbands

Along with the general outlook, the forecaster uses a set of locator tables, based on the 850 mb wind direction, to determine the location and type of snowbands that will occur for each lake.

The locator tables were adapted from a series of forecast charts that were developed at Buffalo and have been in use at the office for over 30 years (Kolker, 1978). The charts have worked exceptionally well in delineating potential areas that might be affected by the snowbands. The locator table takes the chart one step further, so the forecaster can transfer the affected areas into public forecast. The Lake Ontario table is shown in Table 1.

c. Other operational forecast tools

The computerized lake effect snow guidance product must be used with care. It is only a forecast aid, based

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TABLE 1. Locator table for western/central New York for snowbands off Lake Ontario. This forecast tool is most valuable when there is little directional wind shear within the steering level.

Lake Ontario wind direction (850 mb)	Fetch (km)	Structure and location
230/240	110	Single band. Northern Jefferson County. North shore of Lake Ontario from Trenton to Kingston in Ontario.
250	190	Single band. Watertown, mainly Jefferson County. Similar to Lake Erie band that affects largest population.
260	240	Single band. Southern Jefferson/Lewis counties. Long fetch and orographic enhancement at Tug Hill Plateau cause intense snows. Route 81 closes with this fetch. Oswego Peninsula is also affected with this fetch.
270	225	Single band. Southern Jefferson/Lewis, northern Oswego counties mainly north of Syracuse. Also Oswego Point.
280	180	Single band. Oswego County and areas just north of Syracuse. South shore of Lake Ontario mainly east of Rochester.
290	140	Multiple bands. Areas between Rochester and Syracuse mainly north of Thruway and around east end of lake to Pulaski.
300–340	130/100	Multiple bands. South shore of lake between Rochester and Syracuse. Potential for snows off Georgian Bay with well-aligned flow.
360–090		Rare. Single to multiple bands. Usually capped by a strong low-level inversion. South shore of lake.

on point forecast data. Other forecast aids developed on-station over the past 30 years are also routinely used to prepare the lake effect snow forecast.

Before any forecast is made, the forecasters on duty must study the synoptic-scale weather pattern across the Great Lakes, and upstream, to get a good feel for the current weather pattern. One product used quite often is the three-dimensional trajectory forecast (Reap, 1978). In its present form, the trajectory model computes three-dimensional trajectories from smoothed wind forecasts of the LFM. Based on the air parcel trajectory forecast, upstream soundings are selected and plotted on the AFOS system to get a better idea of forecast inversion heights and strength.

The weather radar is a short-term forecast tool used to monitor and predict the movement of precipitation echoes associated with lake effect snows. In standard use on NWS network radars, snow is coded and reported only as level 1 [No linear attenuation on the DVIP (Digitized Video Interpretation Processor).] At Buffalo, the radar operator uses linear attenuation of the radar signal from the WSR-57 radar to plot relative snowfall intensities for on-station use (Fig. 7). This has proven to be an extremely valuable tool for following the development of lake effect snows. Unfortunately, because precipitation tops associated with lake effect snows are generally less than 3000 m, and snow provides a weaker signal return than raindrops, radar is of little use beyond a 90 km radius.

The Geostationary Environmental Operational Satellite (GOES) is routinely used to monitor the development and movement of lake effect snow clouds. Ferguson (1971) noted that where radar coverage was inadequate, the satellite could be most helpful in delineating areas of lake effect snow. Visible imagery can be used to pinpoint activity; snowband detection is somewhat limited with infrared imagery. Cloud tops associated with lake effect snows are quite low, and cloud top temperatures are often similar to surface temperatures, so at times it is difficult to separate the snowband from other terrestrial features with infrared imagery. Operational forecasters at Buffalo routinely use satellite imagery to cover "blind" spots in surface reports and radar coverage, especially with bands that occur at the eastern end of Lake Ontario, which is at least 180 km from the closest network radar.

6. Forecast of lake effect snow

a. Interpretation of the guidance—a sample forecast

The lake effect snow of 17–19 December 1985 illustrates the use of the output from the computer program written by the Buffalo forecasters. This event involved a snowband that oscillated back and forth across the region during a 2-day period. These snowfalls can be especially frustrating for the forecaster and the general public, because of the rapid changes in weather conditions at one location over relatively short periods of time.

Surface and 500 mb charts from 1200 UTC 17 and 18 December are shown in Fig. 6. The snowband formed during the afternoon of 17 December and dissipated during the early morning hours of 19 December. At 500 mb, a closed low tracked eastward across the province of Ontario, just south of James Bay, Can-

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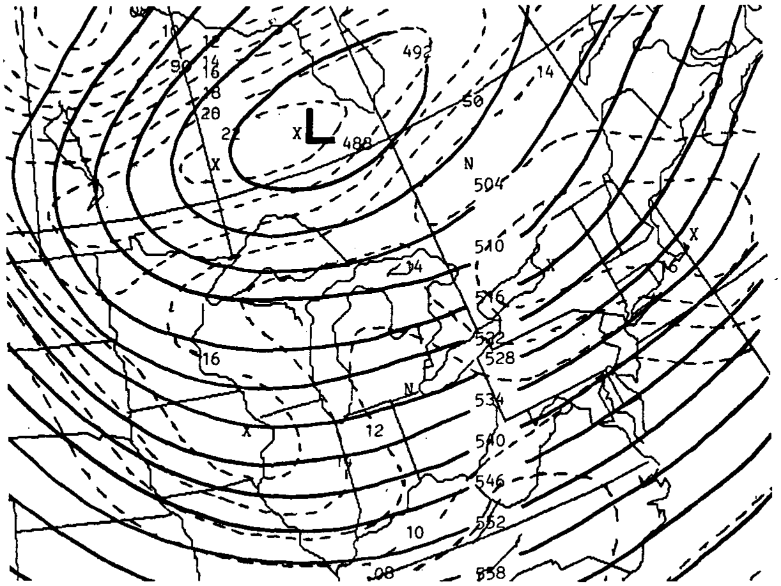

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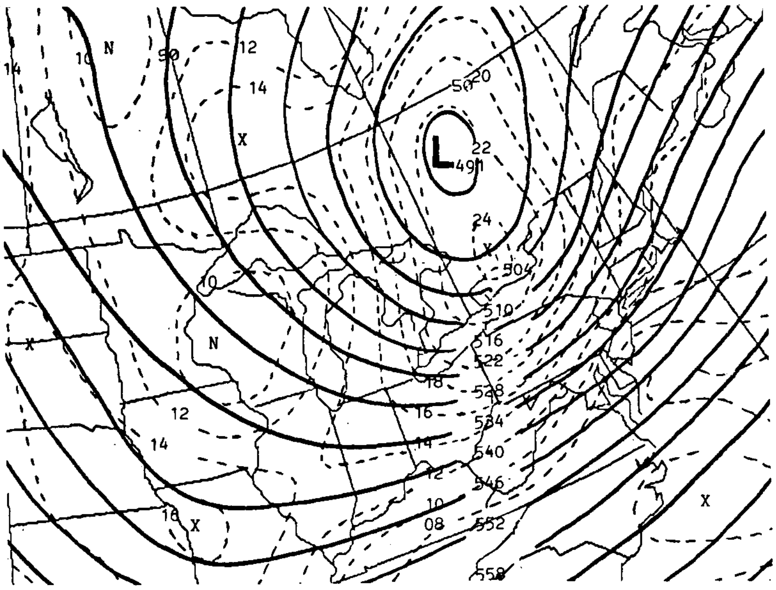

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FIG. 6. Synoptic-scale weather pattern associated with the lake effect snowstorm during 17–18 December 1985. (a) 500 mb, 1200 UTC 17 December 1985; (b) 500 mb, 1200 UTC 18 December 1985; (c) surface, 1200 UTC 17 December 1985; and (d) surface, 1200 UTC 18 December 1985. In panels a and b the solid lines are geopotential heights in decameters and the dashed lines are absolute vorticity in units of 10^{-5} s^{-1}. In panels c and d the solid lines are isobars with thousands and hundreds digits omitted and dashed lines are 1000 to 500 mb thickness lines in decameters.

ada (Fig. 6a). A strong vorticity maximum associated with the low passed a bit north of Lakes Erie and Ontario, just before 1200 UTC on 18 December. Quasigeostrophic theory suggests that cyclonic vorticity advection across the lakes was increasing the relative humidity and destabilizing the midtropospheric air mass. At the surface, an arctic outbreak was associated with a low that tracked just north of Lakes Erie and Ontario. The southwest winds produced by the track of the low funneled up the longest fetch of Lake Erie, spawning an intense single-banded storm at the eastern end of the lake. As the surface and upper air troughs moved

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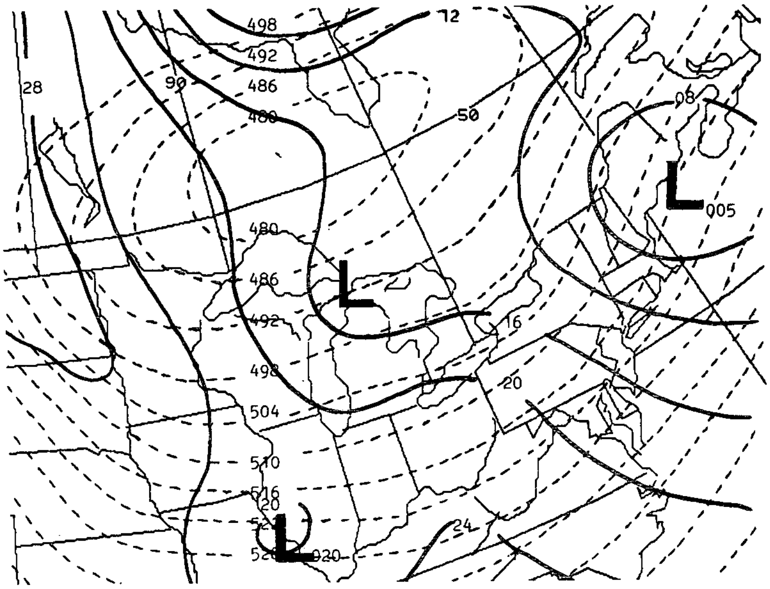

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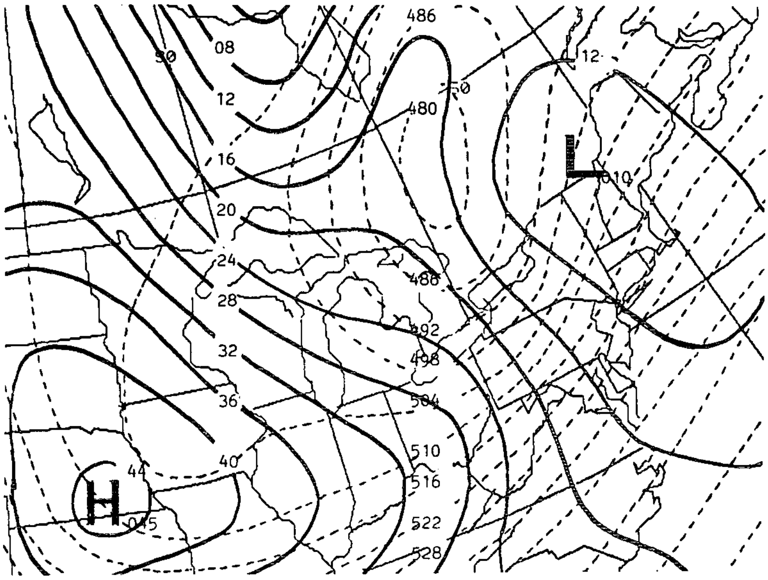

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FIG. 6. (*Continued*)

to the east coast, winds backed to west, then northwest, the snowband migrated south of Buffalo, spread out, and eventually dissipated. A similar scenario also took place to the east of Lake Ontario.

The guidance product in Fig. 5 was compiled at 1200 UTC 17 December 1985, a few hours before the lake effect snow event began. The 1200 UTC LFM forecast, verifying at 0000 UTC 18 December, indicated favorable conditions for lake effect snow. It predicted the air mass to have moderate to extreme lake instability, winds aligned parallel to the longest fetch of the lake, with little directional wind shear, and synoptic-scale upward vertical motion. Although the air-lake temperature difference was predicted to be a maximum 12 h later, Lake Erie at this time was under the greatest cyclonic vorticity advection at the 500 mb level. The snowband developed 3–4 h earlier. By 0000 UTC, a single intense band of snow was roughly 50 km wide and 200 km long. The band was parallel to the 850 mb wind, and the heaviest snowfall extended inland across the north side of Buffalo and its adjacent northern suburbs (Fig. 7).

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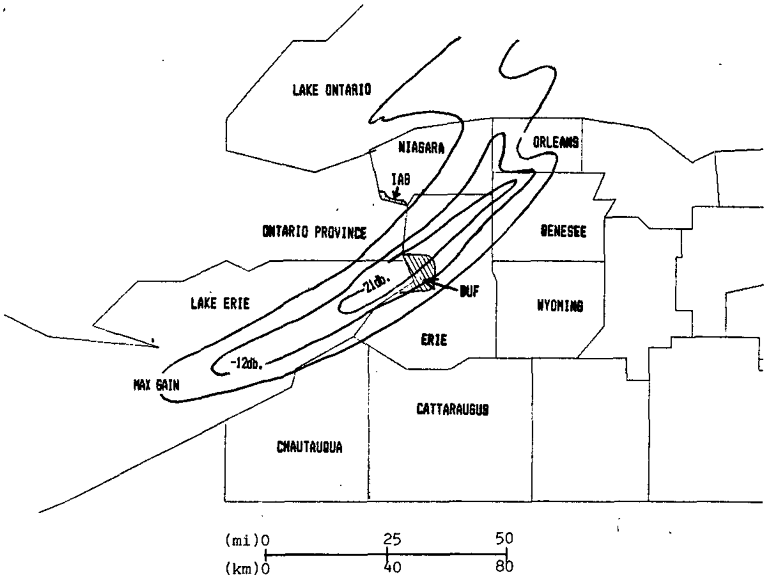

FIG. 7. Precipitation echoes from the WSR-57 radar at Buffalo for the Lake Erie snowstorm on 2330 UTC 17 December 1985. Snowfall intensities are contoured for local use, with linear attenuation, to depict the areas of heaviest snowfall more accurately.

The 24 h forecast, verifying at 1200 UTC 18 December, indicated that there would be cold air advection from the surface through 700 mb and the air–lake temperature difference would be categorized as extreme. The guidance predicted that short over-lake trajectories and weak downward vertical motion would offset the extreme thermodynamic instability. At 1200 UTC, the band actually weakened a bit, although it still produced heavy snowfall, and migrated to the south of Buffalo.

The 36–48 h forecast indicated warming of the air mass and greater directional wind shear within the steering layer. Negative vertical motion was also predicted. During that time, the area of snow continued to weaken in intensity, and spread out, before dissipating altogether.

Snowfall totals for the storm varied greatly across the region. The differences in snowfall were caused by variations in the intensity of the snowband and the total time that the band spent over a particular area. Suburbs to the north of Buffalo reported nearly 40 cm of snow during 17 December. The Buffalo airport received over 10 cm of snow in a couple of hours on the evening of 17 December. Areas to the south of Buffalo reported about 40 cm of snowfall, from late on 17 December through about midday on 18 December.

b. Wording the forecast

At the NWS forecast office in Buffalo, most emphasis is placed on the first 12 h of the lake effect snow forecast. The large-scale numerical models have been greatly improved over the past few years, but much of the data from these models must be used with some caution. As an example, a wind shift as small as 10° can cause the heavy snow area to move a lateral distance greater than the width of the band. This is one reason why forecasts of snowband location are usually limited to the first 12 to 24 h. Only estimates of general location are made thereafter. Exact snowfall amounts are nearly impossible to predict because of widely varying snow to water ratios (more than 50:1 at times; Hill, 1971), and a variety of mesoscale effects induced by migrating and pulsating bands in conjunction with terrain features. Researchers have attempted to predict lake effect snowfall totals through statistical techniques on Lakes Erie and Ontario, but as yet these methods have not been tested operationally (Dewey, 1979a,b).

In western and central New York, the NWS categorizes snowfall forecasts. As an example, a forecast might read "1 to 3 inches (2.5 to 7.5 cm) of snow, but 6 inches (15 cm) or more tonight in persistent squalls over southern Erie and Genesee counties." For extreme events, such as the single-banded "megastorms" that persist over one locale for an extended period of time, categorized amounts of "another foot (30 cm) or more" might be included in the first or second period of the forecast. In practice, there is little additional value in a forecast that goes out on the limb and predicts extreme snowfall totals. In fact, extreme snowfall forecasts have been known to cause panic situations for the general public. By categorizing amounts, in terms of additional snowfall in discrete periods, and leaving the upper end of the snow amounts open, the Buffalo NWS office alerts the public and local government agencies to the potential for significant snowfall without causing undue panic.

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An advisory is issued for a lake effect snow event that produces less than 15 cm during a 12 h period. When more than 15 cm of snow is predicted, a snow squall warning is issued. If the squall is expected to be accompanied by strong winds that produce blowing and drifting snow, and will occur over a particular locale for an extended period of time, a blizzard warning may be issued.

7. Possible improvements using the NGM model

The NGM model may be an improvement over the LFM model for the prediction of lake effect snows, mainly because of the increased resolution in the horizontal and vertical scales. Temperature forecasts are available at three layers below 700 mb in the NGM FOUS forecast. These correspond to average temperatures near 800, 900, and the first 18 mb above the surface.

The NGM represents the Great Lakes, with 15 to 20 grid points. The LFM has only one or two grid points over the Great Lakes, and ignores sensible or latent heat flux from the water to the air. The NGM incorporates sensible and latent heat fluxes from water to air, as well as a boundary layer with a realistic diurnal cycle. The NGM may therefore forecast some synoptic conditions, such as lagging, thermally induced, surface troughs that are often observed over the Great Lakes with arctic outbreaks, and are important for lake effect snowfall.

8. Conclusions

A brief discussion of some of the operational forecast procedures for lake effect snows in western and central New York has been presented. A relatively new forecast aid, developed for use on AFOS, allows the forecaster to compile and calculate select predictors for the development, location and movement of these mesoscale snow events.

The location, shape, and orientation of each of the Great Lakes makes it difficult to use a standard technique to forecast lake effect snow for the entire region. As an example, land-breeze lake snows, which are common on Lake Michigan during weak synoptic-scale wind patterns, would not be handled as well by this forecast scheme (Passarelli and Braham, 1981). The same can be said for mesoscale vortices that develop across Lakes Huron and Michigan during fall and winter (Forbes and Merritt, 1984).

Lakes Erie and Ontario are about the same shape, are located in close proximity to one another, and their long axes are oriented in roughly the same direction, so the forecast scheme works relatively well for these lakes.

In the future, forecast offices will be making much more use of on-station computer resources. One step in this direction now being pursued at the NWS office in Buffalo is the use of mesoscale numerical models to predict lake effect snow. Unfortunately, even the most sophisticated numerical models cannot predict mesoscale weather phenomena accurately from a synoptic-scale database. Tools of the future, such as vertical sounding profilers, may improve short-term forecasting. The combination of a mesoscale data network and on-station mesoscale numerical modelling capabilities should take the forecast office one step closer to accurate short-term predictions of lake effect snows.

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