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AN INVESTIGATION OF NEW YORK STATE FINGER LAKES SNOW BAND EVENTS

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1. Introduction

Much of the current understanding of winter lake-effect systems and the conditions that lead to their development is for large lakes (e.g., Great Lakes). Recent investigations of lake-effect systems over mid-sized lakes, such as the Great Salt Lake (e.g., Steenburgh et al. 2000), have resulted in an increased understand of these systems and their differences from large lake systems. Although there are a great number of small lakes located at mid-latitudes, very few studies exist that have examined their roles in the development of local lake-effect precipitation systems and the modification of regional atmospheric conditions.

Cairns et al. (2001) and Huggins et al. (2001) examined events over Lake Tahoe and Pyramid Lake in Nevada, Wilken (1997) described an event over Bull Shoals Lake in Arkansas, and more recently Schultz et al. (2004) presented an event that produced lake-effect snow bands over several small lakes in Oklahoma, Missouri, Arkansas, and Kentucky. While the spatial scale of these systems is smaller than those that develop over larger lakes, Cairns et al. (2001) showed that these small lake events have the ability to produce considerable snowfalls (53 cm within a two-day period).

Cosgrove et al. (1996) and Watson et al. (1998) used numerical simulations to demonstrate that the New York State Finger Lakes can produce lake-effect circulations and snowfall, as well as enhanced snowfall due to lake-effect precipitation originating from the Great Lakes. The Finger Lakes region within central New York State (NYS) includes 11 lakes of varying sizes and orientations (Fig. 1). The largest two lakes, Seneca and Cayuga, have lengths of 61 km and 64 km, respectively, with widths of approximately 5 km at their widest locations. These fetches are substantially less than those associated with the Great Lakes, making the region suitable for investigating the occurrence of lake-effect snow bands that develop in association with small lakes. The northern ends of the lakes are approximately 50 km south of Lake Ontario, allowing for an examination of the enhancement of Lake Ontario snow bands by the NYS Finger Lakes.

The current study presents the frequency, duration, timing, and the spatial distribution of lake-effect snow events which originate or are enhanced over the NYS Finger Lakes. In addition, typical surface weather conditions are examined for Finger Lakes lake-effect events and compared to regional climatological observations.

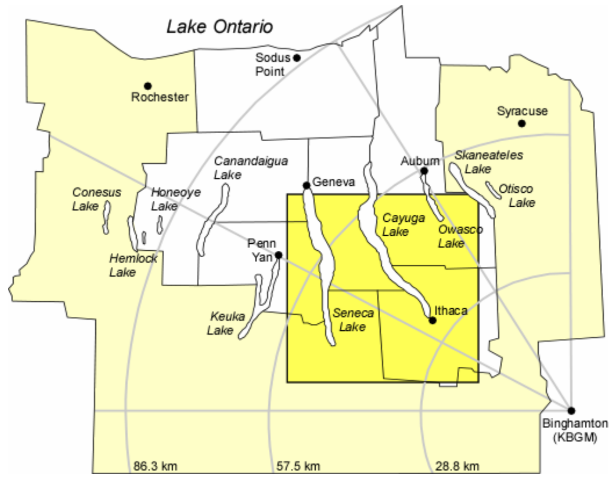

Fig. 1. Finger Lakes region of New York State with location of Binghamton WSR-88D radar shown.

2. Data & Methods

Level II WSR-88D radar reflectivity data collected by the National Weather Service office in Binghamton, NY (KBGM) for the winters (October-March) of 1995 through 2004 were used in this investigation. Level III radar reflectivity data was incorporated as a secondary source. Each 0.5° elevation scan and animations of the reflectivity data were viewed with Gibson Ridge Level 2 software (http://www.grlevelx.com). Data for a given date was considered missing if the number of hours of available radar data within the 24-hour period was less than the average duration of an event, 9.5 hours. Based on this criterion, missing data amounted to about 10 % of the study time period (197 days).

A database of events in the 10 year period was constructed which included information such as the date, start time, end time, event type, and the Finger Lakes associated with each event. Lakes within adequate radar range from KBGM (i.e., height of 0.5° elevation scan ≤ 1700 m) were included in the study. As shown in Fig. 1, these include Keuka Lake, Seneca Lake, Cayuga Lake, Owasco Lake, Skaneateles Lake, and Otisco Lake. Event type was classified as Finger Lakes lake-effect (LE), enhancement of Lake Ontario lake-effect precipitation by the Finger Lakes (LEO), enhancement of synoptic-scale precipitation by the Finger Lakes (LES), or an enhanced event (i.e., LEO or LES) which subsequently transitioned to a LE event.

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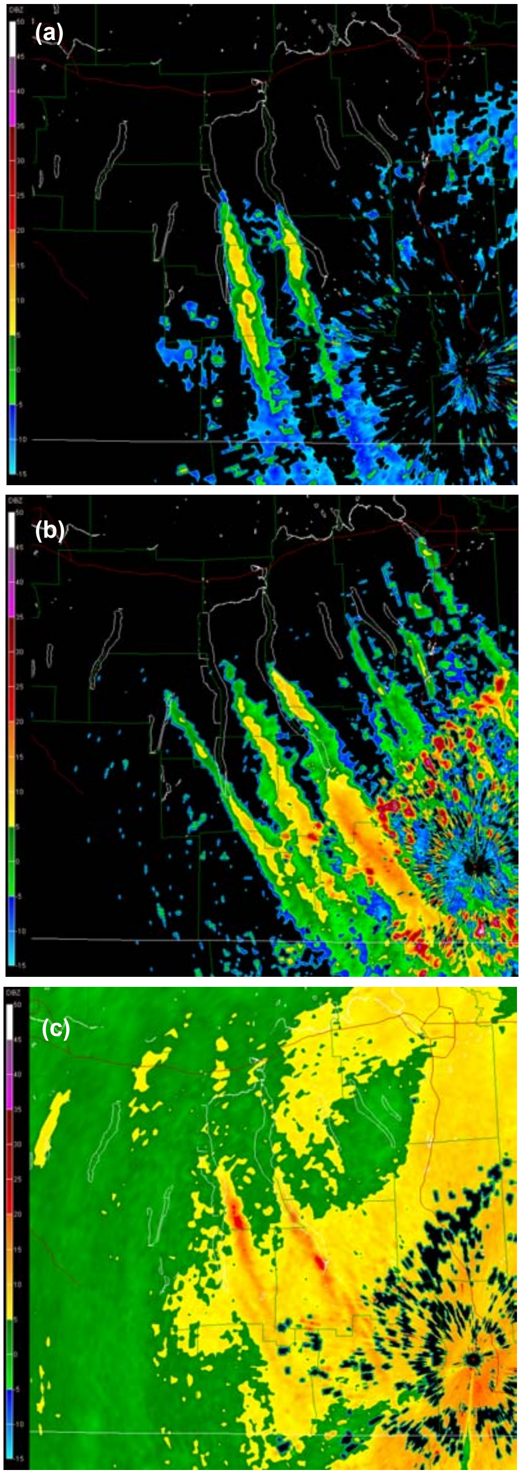

Fig. 2. KBGM radar reflectivity showing (a) Finger Lakes lake-effect (LE) event on 24 Feb. 2003, (b) enhancement of Lake Ontario lake-effect snowfall (LEO) event on 17 Jan. 2000, and (c) enhancement of synoptic snowfall (LES) event on 8 Mar. 1996.

Figure 2a shows an example of a LE event on 24 January 2003 which developed over and downwind of Seneca and Cayuga Lakes in the Finger Lakes region. An example of lake-effect bands from Lake Ontario that were noticeably enhanced by the Finger Lakes is shown in Fig. 2b. Enhancement is evident downwind of Seneca, Cayuga, and Otisco Lakes. Fig. 2c presents an LES event which occurred as lake-effect bands enhanced the snowfall in the vicinity of Seneca and Cayuga Lakes under widespread synoptic-scale precipitation moving through the region.

Hourly surface observations from Penn Yan, Syracuse, and Rochester, NY were used to examine the meteorological conditions during each event. Average temperature and wind conditions for each event were compared with monthly and 30-year climatological conditions to examine the seasonal and inter-annual variability in frequency of lake-effect snow events in the NYS Finger Lakes region. Information on accumulated snowfall during an event was obtained from the KBGM snow spotter network and Northeast Regional Climate Center daily reports.

3. Results

A total of 107 events were found in the 10 year period with varying types, times, and durations. The graph in Fig. 3 represents the duration of all the events found. The range of the events spanned between 1.5 and 36.9 hrs although the majority of the events, 71%, lasted less than 12 hrs, and 96% lasted less than 24 hrs. The LEO enhanced events ranged from 2 - 30 hrs with the duration of most LEO events being 3 - 15 hrs. The LE events lasted the shortest amount of time, all were less than 18 hrs.

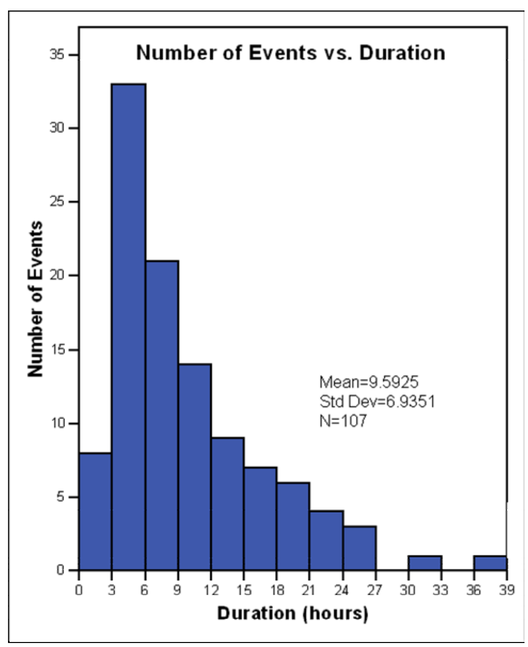

Fig. 3. Duration of lake-effect events occurring in NYS Finger Lakes region.

Figure 4 shows that the number of events starting between 0 and 12z (nighttime and morning hours) was much greater than the events developing later in the day. The end time for each event is shown in Fig. 5 with the highest frequency of events ending in the afternoon hours, between 12 and 20 UTC. These findings are consistent with results from a recent study of lake-effect events for Lakes Superior and Michigan by Kristovich and Spinar (2005) which found a distinct morning maximum and afternoon/evening minimum in lake-effect precipitation frequency.

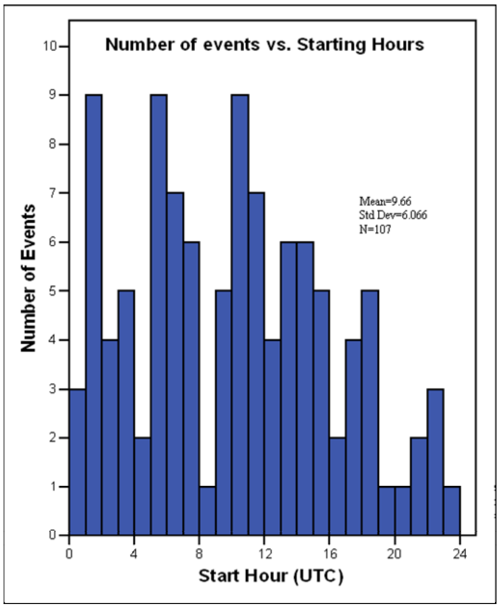

Fig. 4. Start time of lake-effect events occurring in NYS Finger Lakes region.

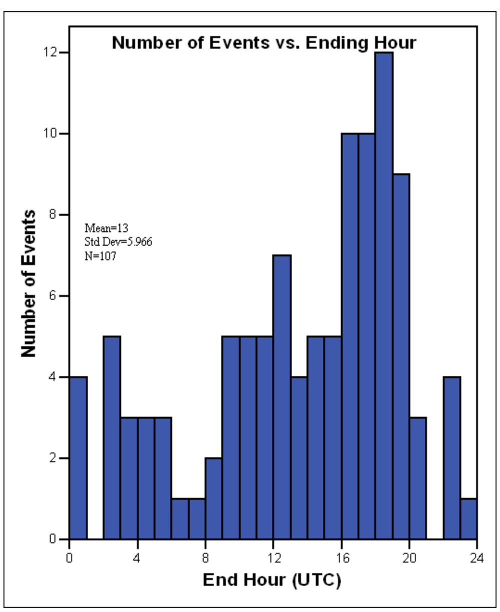

Fig. 5. End time of lake-effect events occurring in NYS Finger Lakes region.

Figure 6 presents the monthly number of lake-effect events which occurred over the 10-year study period. Overall, December and January had the largest number of events. Note the inter-annual variability of NYS Finger Lakes lake-effect events during the period (each color represents a different winter). Departure of average event temperature from monthly and daily climatological averages shows a strong correlation to monthly event frequency. Further discussion of these results will be provided during our conference presentation.

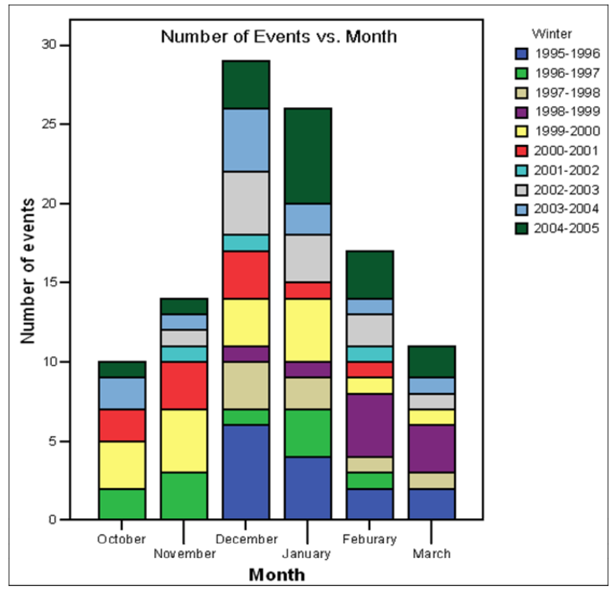

Fig. 6. Number of lake-effect events during the 10-year period (1995 – 2004) for each winter month.

Figure 7 shows the average frequency of occurrence for lake-effect events over each of the NYS Finger Lakes studied. The highest event frequency occurred in December for each lake. Results indicate that from 1 to 3 lake-effect events occur during December in the eastern and central NYS Finger Lakes region. Preliminary results suggest that lake size and lake axis orientation are the primary factors leading to variations in event frequency over the 6 Finger Lakes examined. The two largest lakes, Cayuga and Seneca, had the greatest frequency of events. This is likely associated with the larger fetch and capacity for these lakes to remain relatively warm and ice free during each winter. Additionally, the southern portion of Cayuga Lake and northern portion of Seneca Lake are oriented from northwest to southeast while the other sections of each lake have a north-south orientation.

Average event temperature at Syracuse, NY was examined for each case (Fig. 8). The typically shorter duration LE events are shown to occur during time periods with colder air temperatures. Surface data at Syracuse, Rochester, and Penn Yan demonstrated

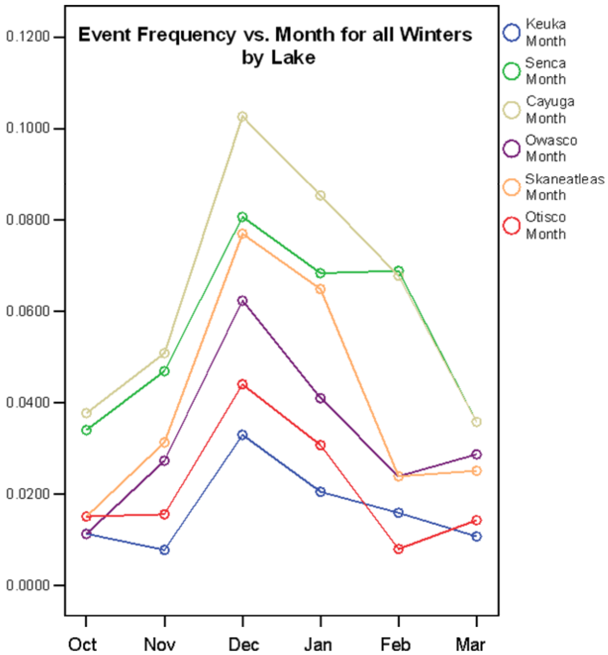

Fig. 7. Average frequency of lake-effect event occurrence during the 10-year period (1995 – 2004) for each NYS Finger Lake included in the analysis.

similar characteristics (colder temperature events) when compared to Finger Lakes snow events of different types. This suggests that LE events require a larger lake-air temperature difference (stronger environmental forcing) to develop than the other event types.

Figure 9 shows NYS Finger Lakes snow events typically have an average wind direction of 280-360 degrees. This is a reflection of the predominant NNW-SSE orientation of the central and eastern Finger Lakes. Several events have average wind directions with a short fetch across the lakes. These events typically have durations of < 10 hrs and weaker wind speeds.

For all winters, the average monthly temperature departure at Ithaca, NY was compared with the number of observed events to investigate the inter-annual variability of events. During the winter of 2001-2002, only 3 events were observed. Associated temperature departures showed that average monthly temperatures were 4.4 °C warmer than normal during December 2001 and January 2002. The winter of 1995-1996 saw 13 lake-effect events. Temperature departures were colder by as much as 2.8 °C during December 1995.

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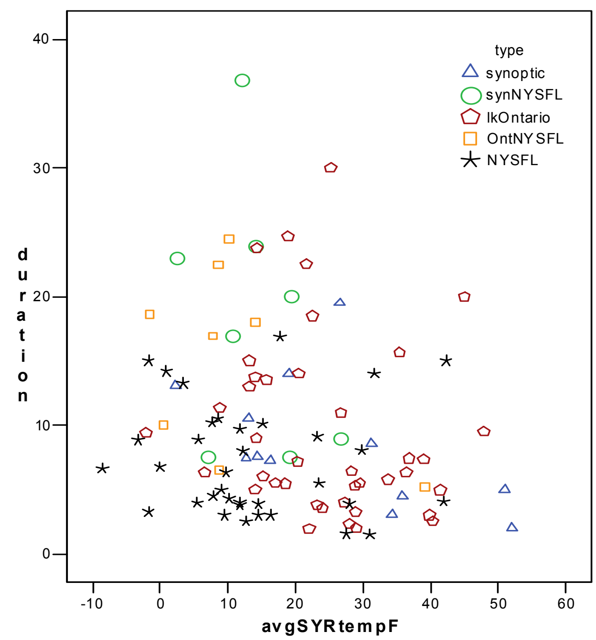

Fig. 8. Average air temperature at Syracuse (SYR) versus event duration. Symbols identify event type.

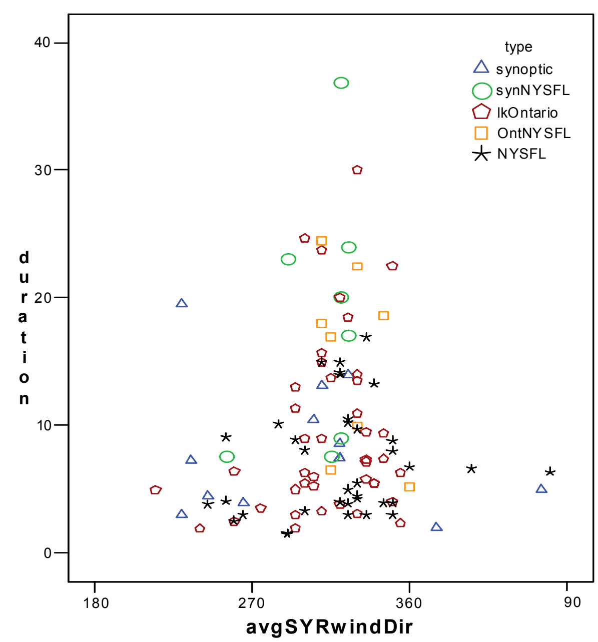

Fig. 9. Average wind direction at Syracuse (SYR) versus event duration. Symbols identify event type.

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