SURFACE WIND DIRECTIONS ASSOCIATED WITH SNOWFALL IN UPSTATE NEW YORK

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Abstract

Hourly observations of snowfall, recorded during the months of November through April for thirteen seasons, 1981-82 through 1993-94 at National Weather Service stations mostly in New York State, were used to analyze the wind directions observed during those hours. It was found that wind directions were not uniformly distributed from 10° to 360°. The preferred wind directions were consistent with snow resulting from synoptic-scale systems and from lake-effect. At stations located near the Great Lakes, most snowfall hours occurred with winds which had a fetch over one of the lakes and a smaller number of hours apparently from synoptic-scale snow events. At New York City and Boston, Massachusetts, most snowfall hours were consistent with coastal snowstorms in that winds were from the north or northeast. Albany and Binghamton, two New York State inland stations located some distance from the lakes, showed characteristics of both regimes, as well as one with southeast winds which may have been due to warm-air advection. Separating the seasons into those, which could be identified as El Niño, La Niña, or neutral resulted in some differences in the wind distributions. At all stations, El Niño tended to show slightly more snowfall hours with east or northeast winds than the two other seasonal types. El Niño winters produced fewer snowfall hours with west and southwest winds than La Niña or neutral winters. This was especially pronounced at the three stations closest to the Great Lakes.

1. Introduction

Most parts of western and central New York State experience a weather phenomenon commonly known as "lake-effect." This is mesoscale, convective precipitation that occurs in regions downwind from the Great Lakes, in particular Lake Erie and Lake Ontario (Niziol et al. 1995). When the air temperature is close to or below freezing (32°F), the precipitation is in the form of snow and can be quite heavy, causing severe winter conditions such as hazardous driving and closings of roads, airports, businesses, and schools.

In hourly weather observations, snow from lake-effect is reported using the same nomenclature as snow which results from synoptic-scale systems. From weather maps, one can subjectively classify the meteorological situation and make the distinction, but it would be useful to be able to make the determination objectively. In an earlier paper (Blechman 1996), a possible relationship between mean monthly temperatures and lake-effect snow was examined in an attempt to distinguish lake-effect snow from snow associated with larger-scale systems. However, the correlation approach used there was unable to establish any cause and effect and the monthly data were unsuitable for studying individual lake-effect events. An analysis of the wind directions during these events seemed to be the next logical approach. The use of hourly observations instead of monthly data could allow more definitive conclusions.

2. Background: Lake-effect Snow in New York State

Figure 1a, obtained from the Northeast Regional Climate Center, shows the average annual snowfall of New York State. The lake-effect maximum to the lee of Lake Ontario, when combined with orographic uplift, such as in the Tug Hill Plateau, exceeds 200 inches. The snowfall maximum in extreme western New York, to the lee of Lake Erie is smaller, but still surpasses 150 inches, impressive for a place so far from the ocean.

The three largest cities in the upstate region of Fig. 1b are Buffalo, Rochester, and Syracuse. Chaston (1986) found Buffalo to have the greatest average seasonal snowfall among the fifty most populated metropolitan areas in the nation. Rochester was the second snowiest city. Chaston pointed out that Syracuse was slightly too small to make that list but if Syracuse had more people, its greater average snowfall would rank it as the snowiest metropolitan area in the U.S., ahead of Buffalo and Rochester. It is safe to say that no other region of the country has the combination of intense snowfall in so many large population centers that upstate New York can claim. Clearly, it is of great importance to learn all we can about forecasting lake-effect snow, which affects millions of people in the upstate New York region and elsewhere.

Lake-effect is most pronounced when there is a significant difference between lake water temperatures and air temperatures and a long fetch of strong surface wind over the open water surface (Reinking et al. 1993; Niziol et al. 1995). In addition, there are factors such as the shape of the lake, vertical wind shear, the height of the subsidence inversion, and synoptic-scale vertical motion that may enhance or inhibit lake-effect precipitation. For example, the passage of an upper-air trough is often accompanied by a surface low-pressure trough with convergence and

Table 1. Average seasonal snowfall (inches) November through April of 1981-94 at cities used in this study. Data from NCDC, obtained from EarthInfo, Inc.

Season	Buffalo	Rochester	Syracuse	Binghamton	Albany	NYC (JFK)	Boston
1981-82	112.4	128.3	136.5	78.7	97.1	24.9	61.8
1982-83	52.4	59.9	66.0	80.3	74.9	32.1	32.7
1983-84	132.5	118.0	113.6	70.9	65.2	22.0	43.0
1984-85	107.2	87.1	116.4	62.5	41.3	27.3	26.6
1985-86	114.7	70.7	104.9	75.0	62.5	19.3	18.1
1986-87	67.5	67.1	93.5	78.8	80.6	23.1	42.5
1987-88	56.4	69.8	111.4	81.6	70.2	19.7	52.6
1988-89	59.0	75.6	92.1	41.5	19.0	8.2	15.5
1989-90	93.7	105.8	162.0	74.7	57.9	9.6	39.2
1990-91	57.5	68.3	96.7	66.7	28.7	20.4	19.1
1991-92	92.6	110.6	166.9	56.0	30.7	10.5	22.0
1992-93	92.6	131.5	190.7	120.8	94.2	20.0	83.9
1993-94	109.8	123.6	167.9	119.7	88.1	45.2	96.3
13-yr Average	88.3	93.6	124.5	77.5	62.3	21.7	42.6

strong northwest winds on its backside. This can enhance lake-effect significantly.

It can be seen from Fig. 1b that Syracuse would get the best wind fetch over Lake Ontario with a strong west-northwest wind. In the late fall with the lake still relatively warm and the air masses cold, lake-effect conditions should be optimal. Rochester's position on Lake Ontario's south shore leads to a similar situation with those conditions. Buffalo, on the other hand, would seem to get maximum fetch and thus maximum lake-effect from a surface southwest wind over Lake Erie, although moisture can travel all the way from Georgian Bay and Lake Huron to give Buffalo snow with northwest winds. These arguments describe the general situation in western and central New York, but an hourly wind analysis could add important details such as, for a given city, how many times during the winter does snow fall and with exactly which wind directions does it occur?

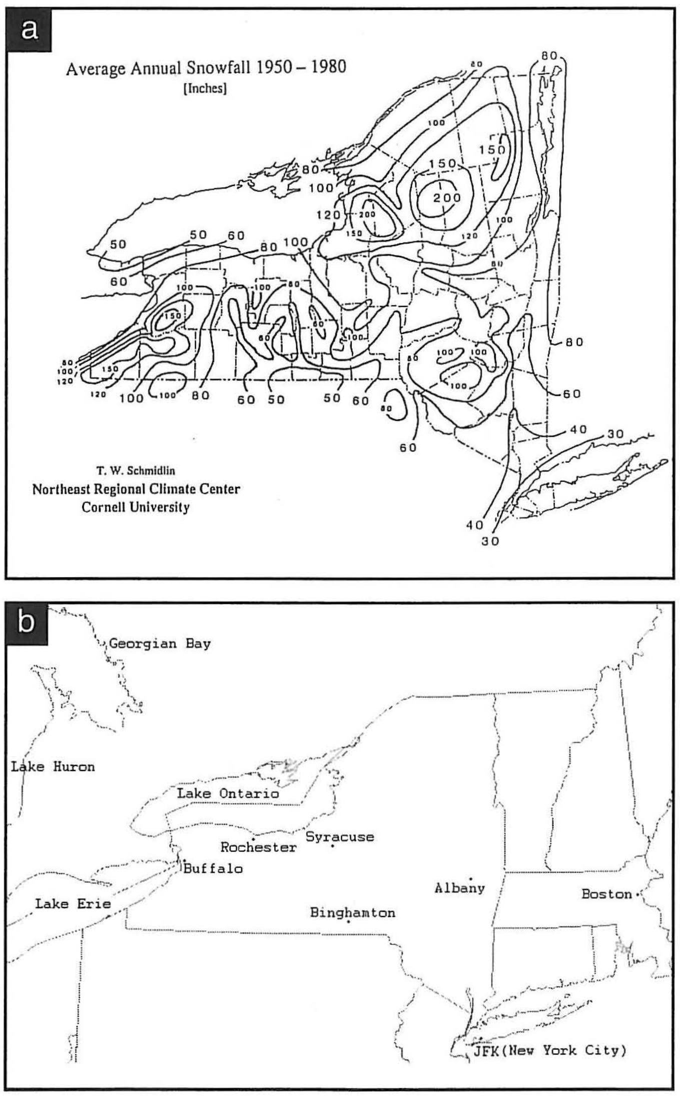


Fig. 1. (a) Average Annual Snowfall (inches) in New York State, 1950-1980. Source: Northeast Regional Climate Center (b) Locations of stations used in this study.

3. Method of Analysis

Data for this study were obtained from Earthinfo, Inc. on compact disc for which the NOAA/National Climatic Data Center (NCDC) was the original source. The surface airways disc included hourly observations of wind direction and "present weather," i.e., snow, snow showers, snow grains, etc. Each hourly observation, which reported some type of snowfall and also had a corresponding wind direction reported was included in this study. Blowing snow was not considered. If either the present weather or the wind direction were missing, the entire hour was discarded, but those instances were very infrequent. These snow-and-wind data couplets were then organized in order of direction 0° to 360°. A wind from due north was reported on the disk as 360° while 0° was used to report calm wind conditions.

Snowfall in upstate New York is possible in October, but unlikely. The snow season essentially begins in November. Snow may occur as late in the season as May but April is the latest one can usually expect it. Therefore, the months of November through April were used in this study. Thirteen seasons, beginning with 1981-82 and ending with 1993-94 were considered. These included years with both above and below average snowfall as shown in Table 1. It is important to note that Table 1 shows accumulated amount in inches but in this study the measured amounts were not used. Instead, the number of times that snow was reported in the regular hourly observations together with the wind directions when snow was observed were counted. The amounts would not be totally independent of the observation count since any time period with many snow observations would probably (but not necessarily) have a high snow accumulation.

The advent of ASOS (Automated Surface Observing System) in the 1990's may have introduced an element of nonstationarity in the observations. Machines don't observe snow the same way people do. ASOS for Syracuse, Buffalo, and Rochester were commissioned on 11/1/93, 12/1/95, and 7/1/96 respectively. Syracuse data in 1993-94 was augmented by National Weather Service observers and, therefore, could be included with those from previous years. Nevertheless, the 1993-94 season was the last one used in this study as after that the other two stations began using ASOS. Restricting the analyses to the pre-ASOS era insured that the potential differences between observations made by humans and those made by machines would not add an additional degree of freedom. If the results prove to be robust with the 1981-94 data, a future study using snowfall observations after 1994 could test any hypotheses or conclusions reached here. In fact, ASOS observations are likely to be more self-consistent than human measurements since the machines at all stations measure snowfall using identical objective methods. Therefore, data after 1994 have been reserved as a valuable resource.

Prior to 1981, Rochester and Syracuse reported their "hourly" observations on the compact disc in three-hour intervals, at least for some years. Buffalo's data was also recorded once every three hours prior to 1970. While the wind analysis could still be done, comparisons to the full 24-hour records were avoided since it was unknown how to fill in the two hours between each reported observation.

4. Results

a. Entire period (1981-1994)

In Figs. 2a-g the distributions of the number of hours with snowfall at each station are shown as bar charts using 0° for a calm wind, 90° for an east wind, 180° for a south wind, 270° for a west wind, and 360° for a north wind. The charts for Buffalo, Rochester, and Syracuse (Figs. 2a-c) show preferred wind directions which differ from station to station. There is an obvious minimum with southeast and south winds at all three stations. These winds would not travel over the Great Lakes and south winds would mean that synoptic-scale low pressure systems would be passing to the west of a station so it is not surprising to find little snow in that part of each chart. There is a structure to the distributions on each of the three charts in that snowfall occurring with east and northeast winds at each station is clearly separated from the more numerous southwest, west, and northwest wind snowfall hours. In fact, the changes in snow event numbers are quite abrupt on each of these three graphs. For example, at Syracuse, there were only 187 observations of snow with a wind of 230° but when the wind came from 250° there were 714 observations during the period of study.

The chart for Buffalo shows a large number of hours of snowfall with west-southwest and southwest winds. This should be expected, given Buffalo's location at the northeast end of Lake Erie. However, Buffalo also had a large number of snowfall observations with northwest winds. If we consider a range of southwest winds from 210° to 260°, on average it snowed 277.9 hours per season with surface winds in that range. Considering northwest winds to be from 280° to 340°, snow occurred with winds from those directions, on average, 229.4 hours per season. West winds (270°) are near the peak on Fig. 2a. Buffalo can experience snow with west or northwest winds for a variety of reasons, including so-called backlash or wraparound snow after a cyclone has passed to the east or northeast, snow showers after a cold frontal passage, and lake-effect from the west end of Lake Ontario or even from Lake Huron.

It is interesting to note from Table 1 that Buffalo averaged 88.3 inches of snow from November to April in the years 1981 to 1994 while Rochester and Syracuse both averaged more, 93.6 and 124.5 inches respectively. Yet, of the three cities, Buffalo reported the greatest number of hours in which snowfall was observed. Assuming that all stations were using the same reporting criterion, Buffalo saw snow more often during the period of study, but that snow apparently did not accumulate as much as it did at the other two cities.

Rochester is located on the south side of Lake Ontario and Fig. 2b shows a strong maximum of snowfall hours at 250° with a second maximum at 290°. From Fig. 1b it can be seen that northwest winds at Rochester have a fetch over Lake Ontario. Southwest winds could also result from Rochester's close proximity to the lake. With lake water temperatures much higher than air temperatures, instability, one of the prime conditions for lake-effect, will support upward vertical motion of air over the lake. This, in turn, requires wind convergence via continuity so surface flow from the west or northwest on the north shore of the lake turns to southwest flow on the south shore. As an example, surface data from the lake-effect snow event of 24 January 2000 (Fig. 3a) shows most winds from the west-southwest but Rochester's wind blows toward the lake. A weak radar echo at the east end of Lake Ontario shows part of the snowband. In Fig. 3b, an infrared satellite image shows the complete snowband. In this image, pixels in the relatively low lake-effect clouds have been lightened for emphasis. In this particular example it was not snowing at Rochester. However, during the entire period from 1981-94, the city averaged 246.7 snow hours per season with southwest winds and 208.9 hours with northwest winds so southwest winds were an important component of Rochester's lake-effect weather. It is worth noting that southwest winds at Rochester can result in lake-effect precipitation originating from Lake Erie, especially in late Autumn and early Winter.

Not surprisingly, Syracuse's lake-effect occurred strongly with northwest winds, since the city is located approximately 35 miles to the southeast of Lake Ontario (Fig. 1b). The average season had 180.9 southwest wind snowfall hours versus 285.1 hours of snow with northwest wind. Syracuse also had a more pronounced northeast wind maximum than either Rochester or Buffalo (see Fig. 2). Since Syracuse has the Adirondack mountains to its northeast, snowfall hours with winds from that direction were probably not due to lake-effect. Being the farthest east of the three lake-effect stations, this maximum could have been due to synoptic-scale storms.

Two stations where lake-effect is rare or nonexistent were also selected for comparison. New York City (JFK airport station) and Boston are shown in Figs. 2d and 2e. These stations average much less snowfall than the others (Table 1) with New York City's November-through-April average being only 21.7 inches. Therefore, on these two graphs the ordinate, the number of hours with snowfall, is much less than on the upstate city graphs. Boston and New York, being located on the east coast are affected by synoptic-scale snowstorms, often called coastal snowstorms. These storms are associated with north and northeast winds and the 1981-94 data did show a northeast wind maximum for New York and a north wind maximum for Boston. New York, which rarely experiences measurable snowfall from lake-effect, nevertheless does get snow flurry activity with northwest and even southwest winds on a few occasions during the winter. Fig. 2e for Boston, however, shows a fairly smooth ramp up to a maximum number of snow observations with north winds. The scarcity of west and southwest wind snow events is probably due to Boston's greater distance from the Great Lakes and the existence of mountainous terrain to its west.

Additionally, graphs for two upstate stations not located in close proximity to large lakes, namely Albany and Binghamton (see Fig. 1b for locations), are presented in Figs. 2f and 2g. Binghamton, in particular, received more hours of snowfall than some of the stations near the Great Lakes. Binghamton shows a very large maximum with northwest winds but also shows a minor maximum with winds from southeast to south. The southeast wind snowfalls may occur in wintertime situations with entrenched cold air masses at the surface but warm air advection aloft. In such a scenario, the precipitation can change to freezing rain, sleet, and/or rain, but before that happens, snow is a common precipitation type. However, just to Binghamton's north, Rochester and Syracuse observed very few snowfalls with south-southeast winds.

Albany received less than half the snowfall hours of the others and the ordinate of this graph has been adjusted accordingly. Albany appeared to have three preferred wind directions, south-southeast, northwest, and north. Albany had very few snowfall hours with east winds or with southwest winds. The northwest winds are consistent with lake-effect and snowbands from Lake Ontario do occasionally reach Albany, but as with the other cities, there are many other possible causes. The north-northeast winds may be associated with coastal snowstorms and, as with Binghamton, Albany exhibited a number of southeast wind snowfalls which may again be due to wintertime warm air advection.

b. El Niño and La Niña

Individual seasons in Table 1 varied greatly. In the thirteen seasons, both Buffalo and Rochester had standard deviations around 25 inches while Syracuse's standard deviation was over 35 inches. While there can be many reasons for different seasonal snowfalls, the period being studied, 1981 through 1994, was characterized by several episodes of El Niño and La Niña. These phenomena have been known to greatly affect winter precipitation in the United States (Wang and Fu 2000; Ropelewski and Halpert 1986). By stratifying the data, an attempt was made to assess the effects El Niño and La Niña may have had on the number of snow observations.

Trenberth (1997) has used an objective areal method to characterize weather patterns as El Niño or La Niña. Using his table of events, the six seasons of 1982-83, 1986-87, 1987-88, 1991-92, 1992-93, and 1993-94 were considered to be El Niño seasons for this study. According to Trenberth's classification, La Niña prevailed during the 1984-85 and 1988-89 November to April snow seasons. There were five seasons which did not fall into either category, i.e., neutral: 1981-82, 1983-84, 1985-86, 1989-90 and 1990-91.

The results of separating the hourly snowfall data by El Niño and La Niña are shown in Figs. 4a-g. Since there were six El Niño seasons, five neutral seasons, and only two La Niña seasons, the numbers of observations shown are the single-season averages, calculated simply by dividing the El Niño totals by six, the neutral ones by five, and the La Niña totals by two. With such a small sample, the La Niña results must be considered preliminary but the differences between the El Niño results and the others combined may be more robust.

At Buffalo, Rochester, and Syracuse during 1981-94, La Niña and neutral years averaged more snowfall hours than those of El Niño, although at Syracuse the three were very close. In fact, most of the bars in Figs. 4a-c show little preference for either regime except when west-southwest winds were observed. In all three upstate cities some west-southwest wind bars during La Niña and the neutral winters tower above the corresponding El Niño west-southwest (or west) wind bars. For example, at Buffalo, snowfall with winds of 240°, 250°, 260°, and 270° each averaged 82.1 hours per La Niña season and 63.0 hours during neutral seasons while the same wind directions averaged only 54.5 hours each during El Niño seasons. Similar results occurred at Rochester and Syracuse where the discrepancy was limited to only two wind directions. With winds from 240° and 250°, Syracuse showed an average of 61.5 hours during La Niña and 55.0 hours during neutral seasons but the same winds only averaged 31.3 hours during El Niño. At Rochester, 210° to 250° showed this behavior with averages of 47.7 hours during La Niña and 41.2 hours in neutral seasons but only 32.1 hours during El Niño.

The reduced number of snowfall hours during El Niño does not appear to translate directly into significantly lower accumulations. Considering seasonal snow amounts, for the three upstate New York stations, El Niño seasons averaged 101.7 inches and neutral seasons averaged 107.7 inches but the two La Niña seasons only averaged 89.6 inches (these can be calculated using Table 1). This may indicate that in years without an El Niño (i.e., La Niña and neutral), lake-effect snowfalls with west and southwest wind conditions were more numerous at Buffalo, Rochester, and Syracuse, but the snow did not accumulate as much.

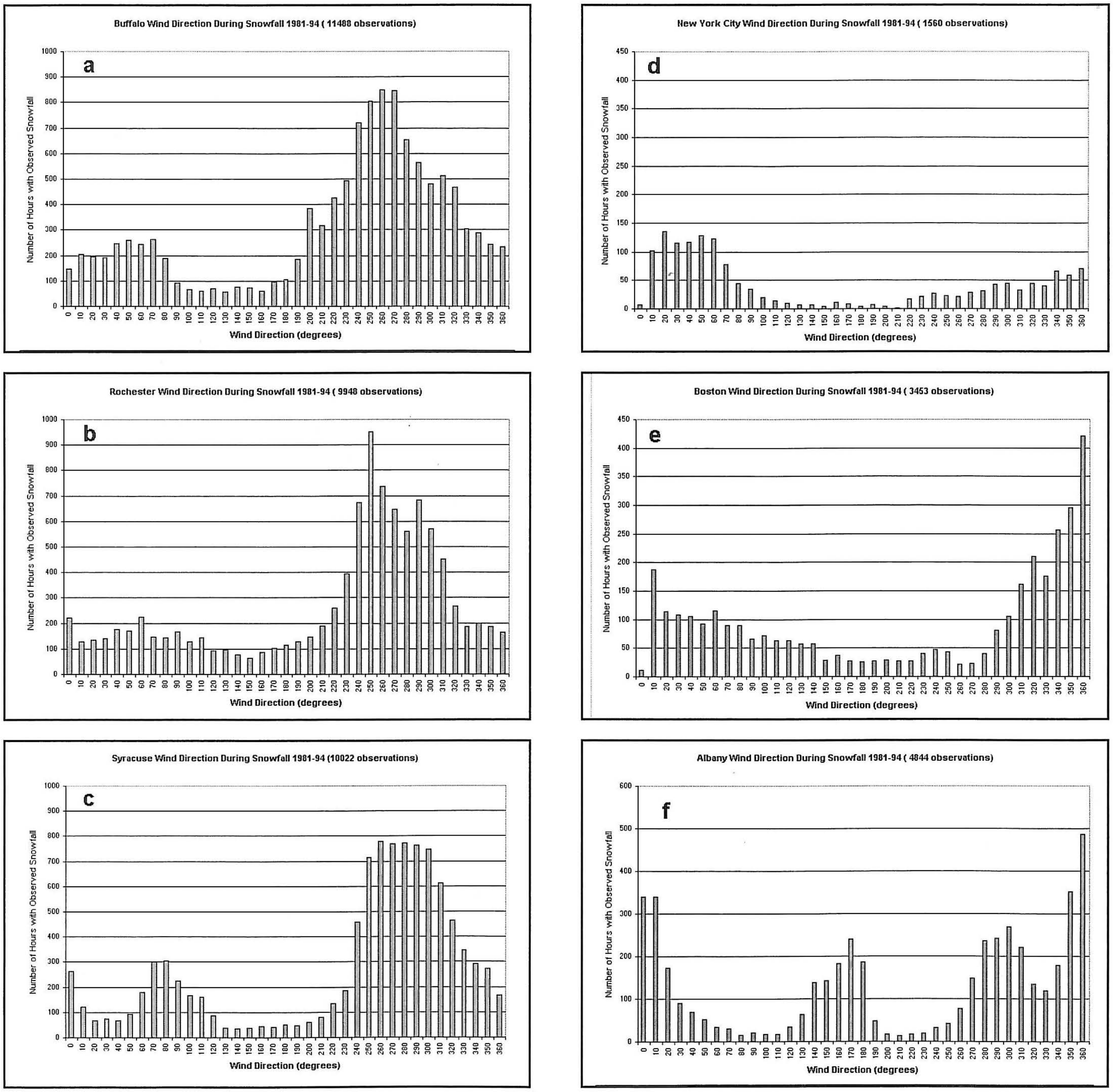
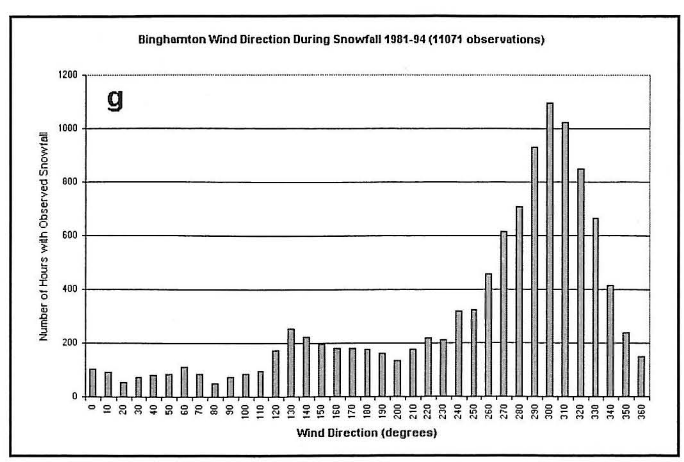


Fig. 2. Distribution of surface wind directions, 0° (calm) through 360° (north), during all hours in which snowfall was observed, November through April, 1981-94. All stations except Boston are in New York State. a) Buffalo, b) Rochester, c) Syracuse, d) New York City (JFK airport station), e) Boston, MA, f) Albany, g) Binghamton



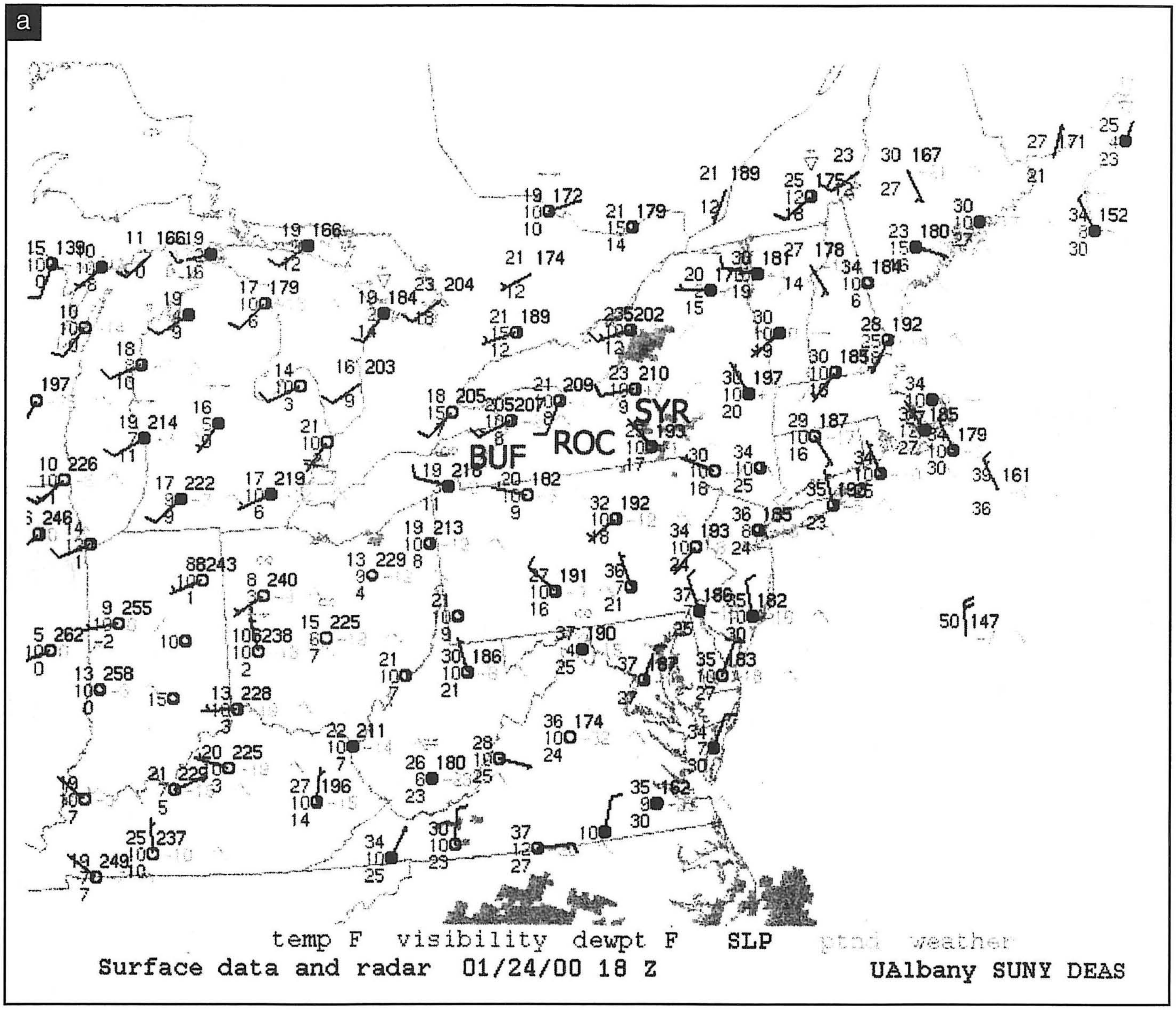
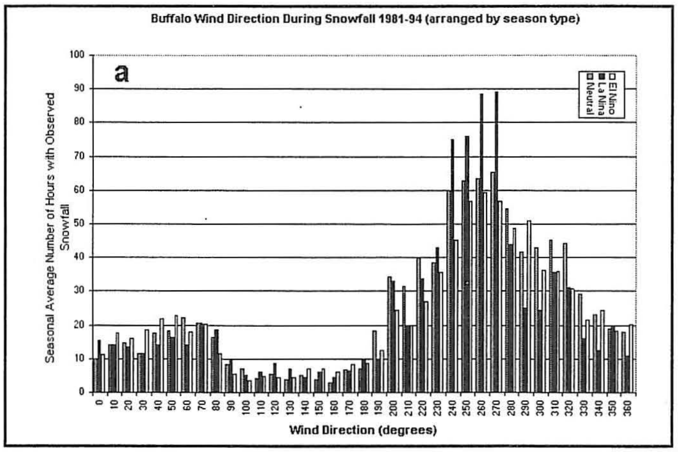
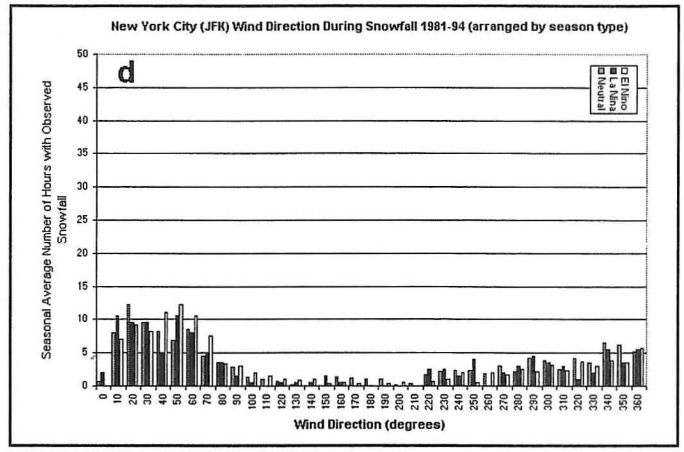


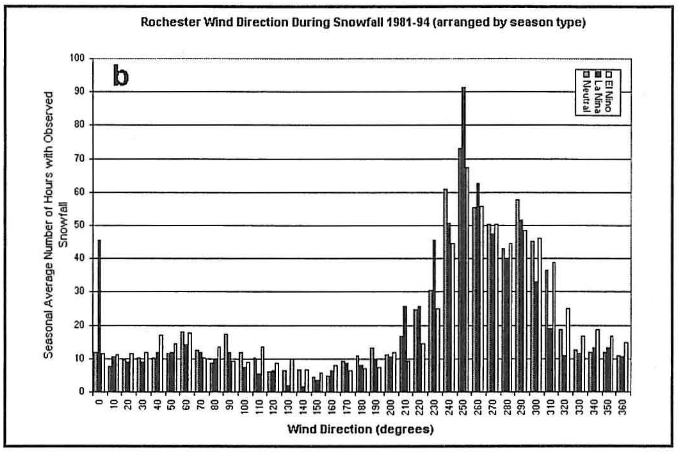
Fig. 3. Example of a lake-effect band with surface wind convergence. (a) 1800 UTC surface conditions plot for 24 January 2000, downloaded from the Web site of SUNY-Albany Department of Earth and Atmospheric Sciences. Syracuse, Rochester, and Buffalo are marked SYR, ROC, and BUF. (b) Portion of an Infrared satellite image for 1815 UTC on 24 January 2000, downloaded from the NRL Monterey Marine Meteorology Division Web site.

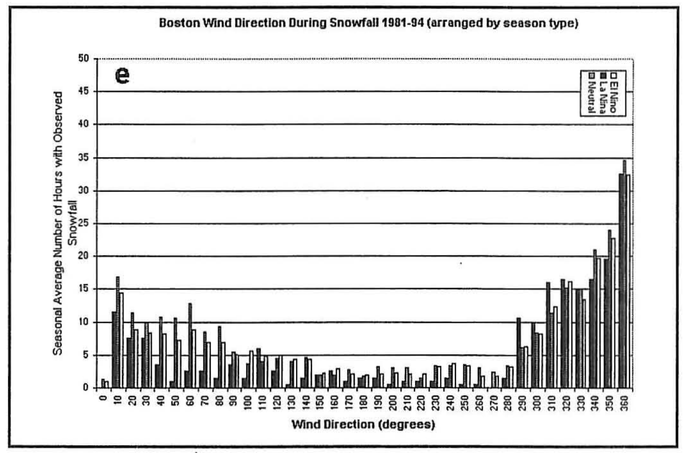
Figures 4d and 4e show the analyses for New York City and Boston. El Niño produced more snowfall observations per season at Boston than either La Niña or neutral winters. Many of these occurred with northeast and east winds. Since it is likely that synoptic-scale snowstorms are associated with northeasterly winds at Boston, it appeared that El Niño may have featured coastal storms. However, during the two La Niñas, snowfall hours with northwest winds at Boston were more numerous (per season) than in either of the other two seasonal types. At New York City the differences were much more subtle as it snowed only 1560 hours in 13 seasons. New York City's west-southwest to northwest wind (250° to 290°) snow events appeared to favor La Niña and neutral seasons as they did upstate. With northeasterly winds in New York City, El Niño had the edge but again very few events were recorded and thus, these results should not be considered definitive.

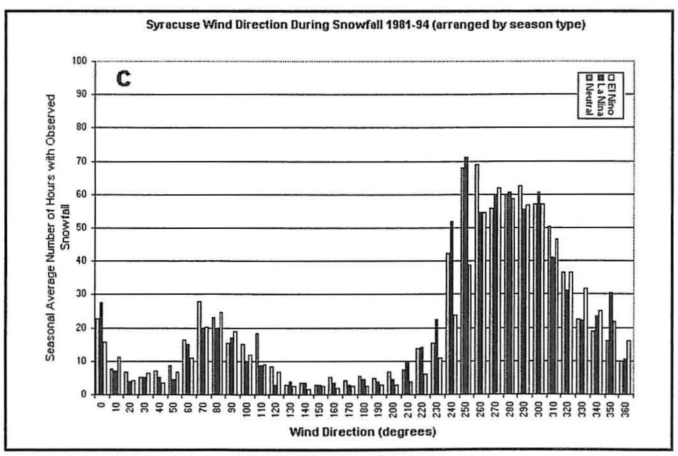
In checking Albany and Binghamton, many of the same characteristics appeared. Albany's graph (Fig. 4f)











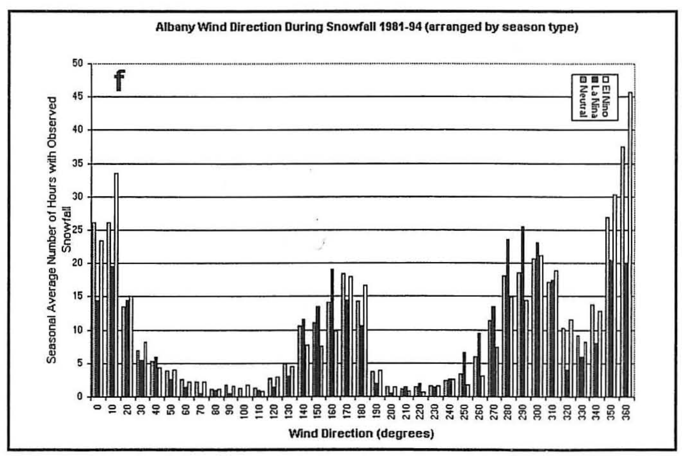
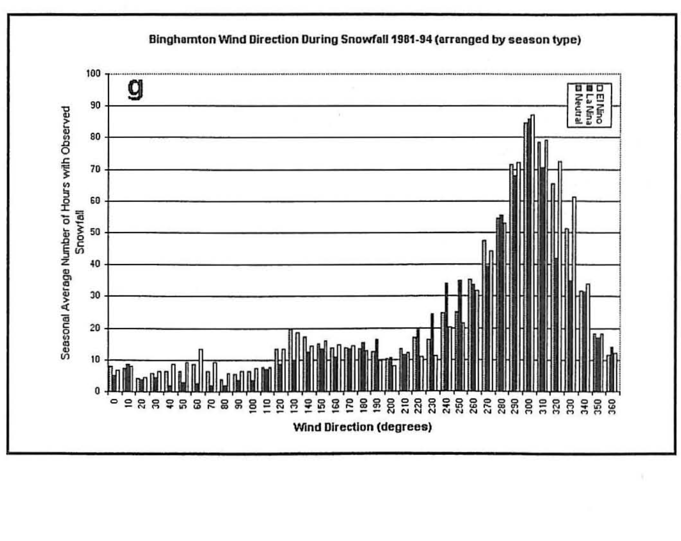


Fig 4. Distribution of surface wind directions as in Fig. 2, but seasonally averaged number of snow events classified for winters identified as neutral, La Niña, or El Niño. Grey bar = neutral, black bar = La Niña, white bar = El Niño. Note Y-axis scales reduced for New York City, Boston, and Albany.



showed that snow tended to occur with northeast, north, northwest, and southeast winds. El Niño conditions were associated with fewer snow observations from westerly directions of 250° through 290°. However, during El Niño, snowfall with north and north-northeast winds dominated the graph. In fact, overall at Albany, El Niño averaged 366.2 hours of snowfall, to 328.0 for La Niña but the neutral seasons had the most at 398.2 hours. Albany, being closer to the coast does experience coastal snowstorms and, being inland, Albany averages more snow and less rain than either Boston or New York City (Table 1). Thus, more coastal storms during El Niño could explain the observations shown in Fig. 4f. Snowfall with southeast and south winds produced the smallest maximum on the graph and the results were mixed.

Binghamton had a modest tendency to favor La Niña from 220° to 260°, 147 hours per season to 133.8 hours during neutral conditions and 95.5 hours for El Niño. However, for the range of directions with the greatest number of snowfall hours, 290° to 310°, the numbers for all types were very similar. El Niño was favored at 320° and 330° with a total of 133.7 hours per season to La Niña's 77.0 hours but during neutral conditions, there were a total of 112.2 hours. Overall, El Niño averaged 856.7 hours per season while La Niña averaged 776.5 hours and neutral seasons averaged 875.6 hours. Interestingly, Binghamton's total snowfall hours (Fig. 2g) indicate very few hours of snowfall with northeast wind (a maximum average of 13.5 hours per season at 60°) but nevertheless, Fig. 4g shows that many of these events occurred during El Niño. La Niña seasons averaged only 2 - 3 hours per season of snow with northeast wind at Binghamton.

5. Summary and Conclusions

During the snow seasons, November through April of 1981-82 through 1993-94, hours in which any type of snowfall was recorded at Syracuse, Rochester, Buffalo, Albany, Binghamton, New York City, and Boston were identified. For each station, the surface wind directions during those snowfall hours were analyzed.

The wind analyses showed preferred directions. At the three stations closest to the Great Lakes, the greatest number of snow observations were associated with "westerlies", i.e., southwest, west, or northwest winds. There are many weather situations, which can result in snow with westerly winds, but near the Great Lakes, lake-effect is a strong possibility for many of these snowfalls. Snow events associated with east and northeast winds, especially at Syracuse, were likely due to coastal snowstorms but the number of snow hours with these kind of winds were much fewer than those associated with the westerly wind regimes. Snowfall rarely occurred with southerly winds at Buffalo, Syracuse, and Rochester, which implies that when southerly winds to the lee of Lakes Ontario and Erie are predicted, say by numerical models, snowfall should not be in the forecast.

Even when winds were westerly, not all directions were equally favored for snow. As was expected, Syracuse, to the southeast of Lake Ontario, received snow with predominantly northwest winds. Rochester had a high number of southwest wind events even though the lake is to its north but it is well known that the warm lake water temperatures can cause surface wind convergence. In addition, snow may fall at any location in upstate New York with southwest winds as a result of a frontal or trough passage. Rochester can also get snow with southwest winds from Lake Erie. Buffalo, being at the northeast end of Lake Erie, was expected to have almost exclusively southwest wind events. However, there were also many west-to-northwest wind events, possibly associated with a fetch over Lake Ontario but also possibly from Lake Huron or from synoptic causes such as a backlash or a frontal passage.

To test the assertions that snow with westerly type (i.e., southwest, west, or northwest) winds at the stations near the lakes was at least partly due to lake-effect, the same analyses were performed on Albany and Binghamton which are farther from the lakes but still inland and also on Boston and New York City, two coastal stations. Boston and New York City exhibited preferences for snow with east and northeast winds with few westerly wind events. Albany displayed characteristics of both coastal and inland regimes in that snow fell with northwest winds, possibly due to lake-effect, with north-northeast winds, possibly from coastal storms, and with southeast winds which may have been due to warm air advection. While these results do not show the cause of the snow events observed with westerly winds to necessarily be lake-effect, they do present a consistent picture of preferred wind directions which match the region's geography.

Stratifying the data into seasons of El Niño patterns, those with La Niña and the rest (neutral) produced complex differences in wind patterns associated with snowfall. The typical U.S. El Niño pattern found by many researchers is characterized by wet conditions in the Gulf coast states, southern Plains, the southern Northwest, and California with dry conditions prevailing over the Ohio valley and east to western New England. From that pattern, one might suppose that El Niño would strongly affect snowfall in New York State by decreasing the number of snow hours.

Instead of decreasing snow hours, El Niño resulted in more snow events with north and northeast winds at the two coastal cities, at Buffalo, and at Albany and Binghamton. El Niño even produced more snowfall at Binghamton with northwest winds. However, the three lake-region cities, Buffalo, Rochester, and Syracuse, showed fewer snow observations with southwest or west winds during El Niño than with either of the other two (La Niña or neutral). Since those wind directions are often associated with lake-effect from Lakes Erie and Ontario, El Niño may have been a time of fewer lake-effect events.

Further analysis could be done using data from after 1994, the ASOS era. While comparing the raw total number of snow events may not be meaningful, the pattern of behavior described above should still occur. This should provide a good test of these conclusions, especially during the strong 1997-98 El Niño and the La Niña of 1995-96.

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References

Blechman, J.B., 1996: A comparison between mean monthly temperature and mean monthly snowfall in New York State. *Natl. Wea. Dig.* 20:4, 41-53.

Chaston, P.R., 1986: 1975-1985 snowiest major cities. *Weatherwise,* 39, 44-45.

Niziol, T.A., W.R. Snyder, and J.S. Waldstreicher, 1995: Winter weather forecasting throughout the eastern United States. Part IV: Lake-effect snow. *Wea. Forecasting*, 10, 61-77.

Reinking, R.F., R. Caiazza, R.A. Kropfli, B.W. Orr, B.E. Martner, T.A. Niziol, G.P. Byrd, R.S. Penc, R.J. Zamora, J.B. Snider, R.J. Ballentine, A.J. Stamm, C.D. Bedford, P. Joe, and A.J. Koscielny, 1993: The Lake Ontario winter storms (LOWS) project. *Bull. Amer. Meteor. Soc.*, 74, 1828-1849

Ropelewski, C.F., and M.S. Halpert, 1986: North American precipitation and temperature patterns associated with the El Niño/Southern Oscillation (ENSO). *Mon. Wea. Rev.*, 114, 2352-2362.

Trenberth, K.E., 1997: The definition of El Niño. *Bull. Amer. Meteor. Soc.*, 78, 2771-2777.

Wang, H., and R. Fu, 2000: Winter monthly mean atmospheric anomalies over the north Pacific and North America associated with El Niño sea surface temperatures. *J. Climate*, 13, 3435-3447.