PROBING LAKE-EFFECT SNOWBANDS USING A PORTABLE RADIOSONDE UNIT

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ABSTRACT

Measurements of the thermodynamic environment in the vicinity of lake-effect snowbands over Western New York were obtained during the winter of 1987-88, using portable radiosonde equipment. During the experimental period, a total of 17 soundings were launched during 10 field days. Credible results were obtained for a variety of conditions, including snowfall rates of nearly 13 cm per hour. On 6-7 February 1988, soundings were launched within and adjacent to an intense snowband. Parcel buoyancy of 2.5 C was noted inside the band at 2 km AGL, and the cloud top inversion was some 0.6 km above the environmental stable layer. Sensible heating of the northwesterly flow of air at low levels is postulated to be the primary source of this temperature surplus. Strong surface convergence and the parcel buoyancy within the band were sufficient to produce the overshooting cloud top and the observed heavy snowfall rate.

1. Introduction

The understanding of the nature of intense lake effect snowbands has been limited by the lack of detailed observations on small enough scales to resolve these features. Our current knowledge of the thermodynamic environments associated with lake-effect in Upstate New York is primarily based upon measurements from the conventional sounding locations shown in Figure 1. The fixed conventional sounding observations are often far removed from the lake-effect activity and are constrained to the 0000 and 1200 UTC observing times. During the winter of 1987-88, we attempted to gain further insight into the nature of these snowbands by making measurements on much smaller time and space scales. This was accomplished by use of portable sounding equipment which could be quickly dispatched to make measurements precisely at the time and location of interest.

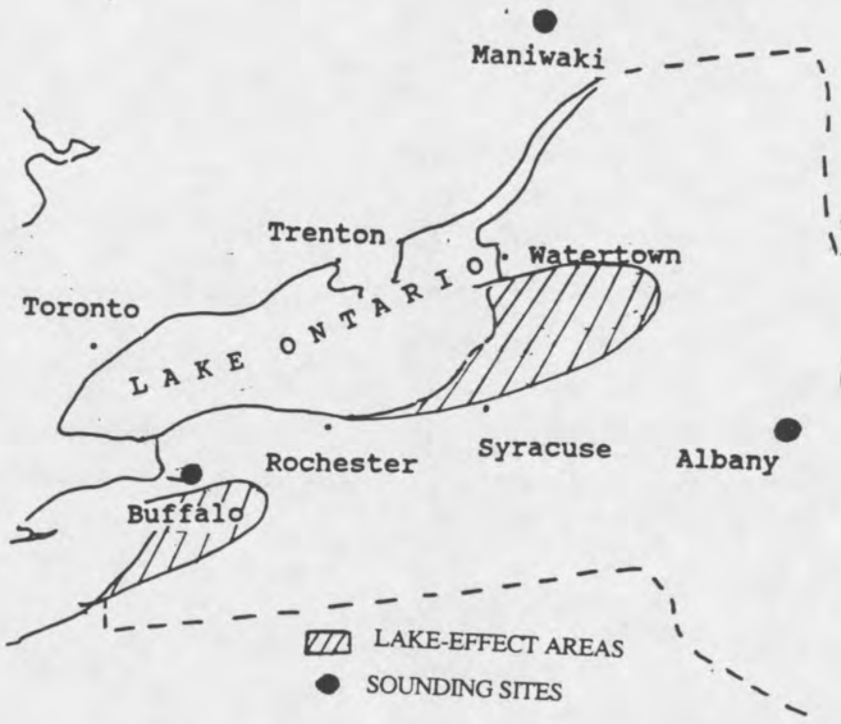

Figure 1: Map of Western New York showing preferred lake-effect areas and conventional sounding locations.

2. Methodology

Portable sounding techology has been successfully employed to measure the thermodynamic and kinematic environments of a variety of mesoscale disturbances, including dry line and severe thunderstorm features in the Southern Plains documented by Bluestein, et. al. (1988). Similar methodology was employed when observing lake-effect snowbands. The portable radiosondes we used were AIRSONDES from Ambient Analysis Inc. of Boulder, Colorado (Call and Morris, 1980,1981). The shoe-box sized ADAS (Automated Data Acquisiton System) was used to receive and decode the radiosonde data. The data was then printed out using a modified HP-97 calculator system which was connected to the ADAS unit. In the field, the ADAS ran on rechargeable batteries which usually lasted 2-3 hours, and soundings could be launched at time intervals of as little as 1 hour.

A 4-wheel drive Subaru was used to transport the portable radiosonde equipment and accessories. The typical field crew consisted of the team leader/driver and 1-2 assistants for radiosonde deployment. We used 100 g balloons which were filled to a level corresponding to a pressure drop of about 200 psi on the helium tank regulator guage. This enabled us to achieve balloon ascent rates of 2-3 ms^{-1}. The AIRSONDE was then attached to the balloon with a 10 m length of cord. Meanwhile, the ADAS was readied and a paper radiosonde calibration tape was fed through the receiver unit. Data was output at intervals of 25 seconds, and reliable measurements were obtained to altitudes as high as 10 km AGL. We had no electronic tracking capability and the adverse conditions prevented optical theodolite tracking; therefore, we were unable to obtain any wind data.

A field day was usually identified 24-48 hours in advance. On the field day, we identified a favorable region for lake-effect development through analysis of meteorological data received at the State University College at Brockport and through consultation with forecasters at the National Weather Service. Once a target area was identified, we drove to the region for a sounding release. We attempted to get measurements both within and adjacent to the snowbands, for the purpose of comparison.

3. Field Study Results

Table 1 summaries the 1987-88 field season in which a total 17 soundings were launched on 10 different days on which lake-effect snow was observed in the Lake Erie and Lake Ontario region. Figure 2 shows the locations of various sounding launches. On several days, soundings were taken within as well as adjacent to intense lake-effect bands. Seven of the seventeen soundings were launched from the campus at Brockport, with the remainder of the launch sites scattered over Western New York, from west of Brockport northeastward to near Watertown. In the following section, we present preliminary results from one particular field day.

TABLE ONE

SUMMARY OF FIELD EVENTS

DATE	NO. OF SOUNDINGS	DESCRIPTION
11/20/87	1	One sounding approximately 6 hours prior to the onset of lake-effect snow in eastern Monroe County.
1/5/88	1	Squalls off Lake Erie in southern Wyoming County.
1/6/88	2	Squalls off Lake Ontario in Eastern Monroe County
1/10/88	1	Squalls off Lake Ontario near Oswego.
1/13/88	3	Frontal passage and onset of lake-effect at Brockport.
2/6/88	3	Squalls off Lake Erie in Genesee County; Squalls off Lake Ontario between Watertown and Oswego.
2/8/88	2	Lake-effect squalls at Brockport.
2/13/88	1	Lake-effect squalls at Brockport.
2/20/88	1	Pre-frontal convective snow squall at Brockport.
2/21/88	2	Squalls off Lake Ontario in eastern Monroe and Wayne Counties.

Total of 17 sounding launches on 10 different field days.

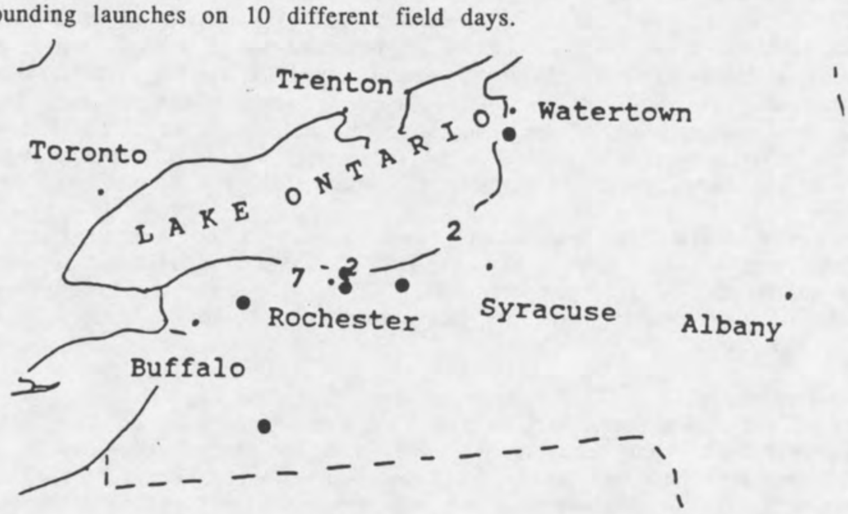

Figure 2: Sounding launch locations for the field study.

a. Case Study Result

On 6-7 February 1988, an intense east-west oriented lake-effect snowband was observed over and to the east of Lake Ontario. During the afternoon, the snowband drifted slowly southward past Watertown, to a point just north of Oswego by 0100 UTC on 7 February. This movement coincided with the passage of a vigorous 500mb short wave trough. Figure 3 shows a time series plot of surface winds and temperatures during band passage at Nine Mile Point power plant, located about 10 km northeast of Oswego. Surface winds shifted from 215 to 303 and increased to 12.5 ms^{-1} between 2330 and 0000 UTC, and this was accompanied by an 3 C increase in surface temperature.

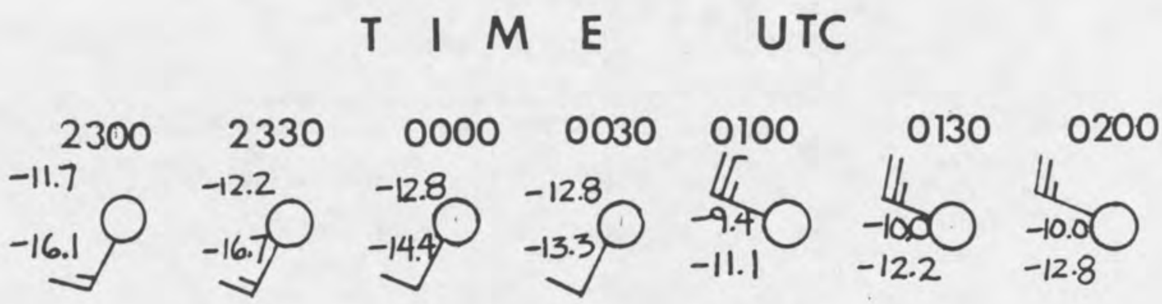

Figure 3: Surface wind speed and direction, temperature and dew-point observations for 9 Mile Point on 6-7 February 1988. Long barbs represent 5 ms^{-1} and short barbs are 2.5 ms^{-1}.

The solid lines of Figure 4 show the 2126 UTC sounding which was launched within the snowband at Wescott Beach State Park about 25 km southwest of Watertown. Heavy snow was occurring at launch time, with surface winds from the southwest at 10 ms^{-1} and horizontal visibility reduced to 50m. The sounding shows that cloud base is at about 1 km AGL, above a moist boundary layer. Above cloud base, moist adiabatic conditions are observed up to a cloud top inversion located at 3.6 km AGL. This is 1 km above the maximum tops observed by Buffalo Weather Service radar. However, the Buffalo radar was not able to detect the precipitation within the sounding region, which was over 200 km east-northeast of the radar site. In addition, even if the sounding region precipitation had been detectable, it is likely that the radar tops would have been lower than the cloud top inversion height, since radar measures precipitation tops, not cloud tops.

The subsaturation evident in the middle and upper regions of the Wescott Beach sounding is probably explained by the fact that the carbon hygristor is measuring relative humidity with respect to liquid water. At the observed temperatures of -25 C to -30 C, the cloud environment is saturated with respect to ice crystals, which are likely to dominate the cloud particle distribution in the upper regions of the cloud.

When compared to the 0108 UTC 7 February sounding (dashed line in Figure 4) taken south of the band at Oswego, we see a temperature surplus within the band, peaking at 2.5 C at 2 km AGL. The parcel buoyancy, coupled with strong convergence evident in the surface data would imply that vertical velocities of several meters per second were possible within the core of the band updraft. These factors appear sufficient to produce a cloud top which overshoots the surrounding environmental inversion (at 3km AGL in the Oswego sounding) by some 0.6 km. This would appear to be consistent with the observed heavy snowfall rate of 12.5 cm in 57 minutes at the Wescott Beach site.

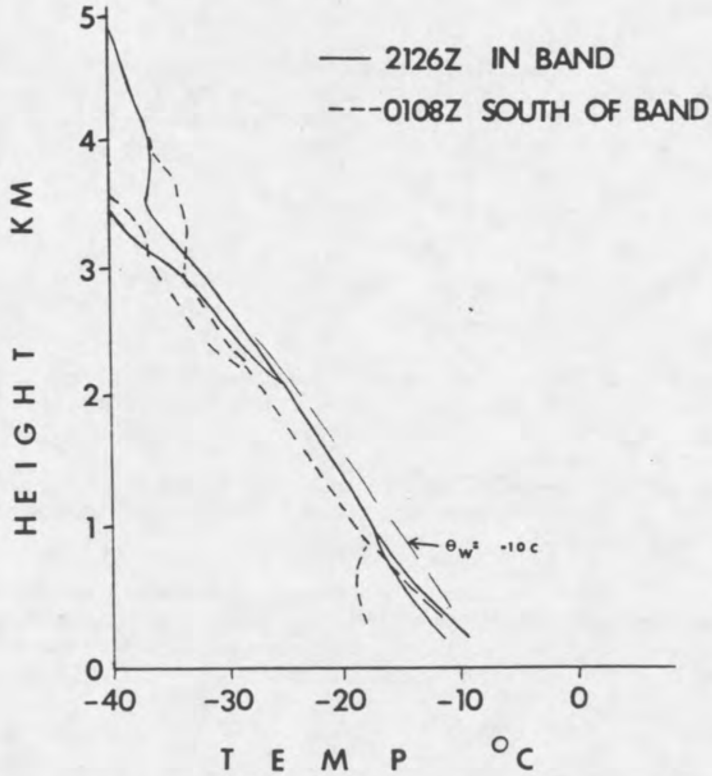

Figure 4: Soundings for 6-7 February 1988. Solid lines are the 2126 UTC sounding within the band at Wescott Beach State Park. Dashed lines are from the Oswego sounding taken south of the band at 0108 UTC.

An obvious question arises as to the role of sensible and latent heating in modulating the buoyancy within the cloud. We suggest that with observed temperatures of -15C to -35C in the cloud region, latent heating is a relatively unimportant factor. Sensible heating of air which has experienced a significant fetch over the warm (2 C) surface waters of Lake Ontario is likely to be the dominant mechanism explaining the parcel buoyancy in the cloud. Recall that the surface wind shift (Figure 3) associated with band passage is accompanied by a 3 C temperature increase, which correlates well with the observed parcel temperature excesses observed at mid-band level. Although the temperature near the surface is nearly the same in both soundings, the surface winds at Wescott Beach sounding time were from the southwest, or to the cold air side of the surface wind shift line. During ascent, the balloon was apparently drawn into the warm air plume which originated in the lake-warmed northwesterly boundary layer flow to the north of the surface wind shift line. Admittedly, these results are preliminary, and much more detailed analyses are needed before any definitive conclusions may be drawn.

4. Concluding Remarks

We have demonstrated that portable radiosonde equipment may be used to obtain credible thermodynamic measurements in the vicinity of intense lake-effect snowbands. Synoptic and radar analyses are currently being combined with the sounding data to shed further light on the nature of the lake-effect snowbands observed during the 1987-88 season.

In the future, we plan to make simultaneous sounding launches from multiple vehicles. We plan to use portable radiosonde units with wind-finding capability, since the vertical wind profile is a crucial component which has not been addressed in the present study. These data will be combined with radar/synoptic analyses and numerical model simulations in order to gain further insight into the formation, development, and dissipation of lake-effect snowbands.

5. Acknowledgements

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