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THE PREDICTION OF LAKE-ENHANCED SNOW SQUALLS IN THE CHAMPLAIN VALLEY OF VERMONT

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INTRODUCTION

The Champlain Valley of Vermont (Fig. 1) is the recipient of two or three lake-enhanced snow squalls each winter season. The seemingly capricious nature of these events has made them one of our greatest, local forecast challenges. While the squalls usually last less than an hour, and produce only an inch or so of snow, their impact on the general public and aviation is often greater than that of heavy, synoptic scale snowfalls.

With favorable upper level and surface conditions, Lake Champlain contributes sufficient warmth and moisture to greatly intensify the snow showers that accompany a cold front or trough. Plattsburgh, NY (on the windward side of the lake with northwest surface winds) often receives snow flurries, while Burlington (on the leeward side) has more significant (W0 X 1/4S+) weather.

A preliminary study made of five events uncovered similarities that should make their forecasting easier and more accurate. These similarities were incorporated into a checklist that suggests when lake-enhanced snow squalls should be included in the first or second period forecast. The checklist also includes instructions that assist the forecaster in timing the arrival of the squalls, perhaps allowing the issuance of a nowcast or other statement. While the five events comprise an extremely limited sample, the subjective experience of staff members who have attempted to forecast these events for many years, indicates that the checklist appears to be reasonable. As more cases are archived, it is assumed that the checklist will undergo additional refinement.

APPROACH

WSO Burlington station records were examined to determine if there was a relationship between this type of snow squall, and the absence of ice on the lake, similar to work done by Maximuk (1989). The analysis revealed that the squalls occurred almost exclusively during November, December, and mid-March through April, when Lake Champlain is largely free of ice. A comparison was then made of the upper level and surface weather conditions prior to the squalls. This permitted the composition of a lake-enhanced snow squall climatology for the Champlain Valley, which became the basis for the checklist.

DATA

The 850mb, 500mb and surface maps generated by the National Meteorological Center (NMC) were acquired from the National Climatic Data Center for each of the snow squall events. In addition, data from the Southern Region Upper-Air

Program (Foster, 1988) and the WSFO Albany Mesoscale Climatology Project were available for the two snow squalls of the 1989-90 winter season. Surface weather observations from Burlington, VT (BTV) and Plattsburgh, NY (PBG) were utilized, as were 6-foot depth lake water temperatures from the Lake Champlain Transportation Company in Burlington.

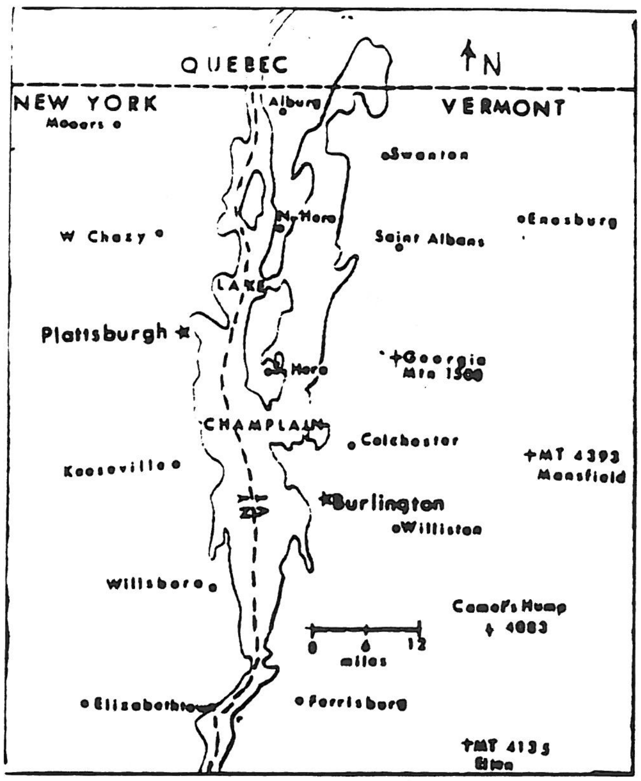

Figure 1. The Champlain Valley of Vermont

PROCESS

Evaluation of the 850mb and 500mb data was conducted in a fashion similar to work done by Niziol (1987) concerning lake effect snow around Lake Erie and Lake Ontario. The 500mb data was inspected to determine the mean longwave pattern and presence of short-wave troughs, while the focus at 850mb was the temperature differential between 850mb and the water surface, as well as the over-water trajectory.

Surface weather maps were analyzed to determine if there were any surface weather conditions common to each of the events. Finally, snowfall amounts were compared for Burlington and Plattsburgh.

RESULTS

Specific values from each of the five cases are presented in Table 1.

The 500mb pattern

In each of the events a long wave trough was established over the northeastern United States, the axis being roughly along a James Bay-Southern Appalachians line. There typically was a short wave passing to the north between the U.S.-Canada border and the Laurentien mountains of Southern Quebec. Figures 2 and 3 show the average 500mb height from the five cases, and a typical vorticity field for the five events.

The 850mb pattern

At 850mb, temperatures ranged from -10°C to -23°C. Winds varied from 280 to 310 degrees, which result in are suitable trajectories to maximize the over-lake fetch.

Surface conditions

Surface weather conditions included an Arctic or Polar high centered over the Northern Plains or Western Great Lakes, with a cold front or trough edging into the Northeast.

For the mesoscale, the following conditions were noted at Burlington several hours before each squall: south winds of 10 to 20 knots and average pressure falls of .01"/hour.

Lake temperatures ranged from 34°F (1°C) to 48°F (9°C). The snow squalls lasted an average of 45 minutes in Burlington, dropping anywhere from 0.2 to 1.9 inches of snow. Plattsburgh received snow showers or flurries of shorter duration, with totals of a trace to 0.4".

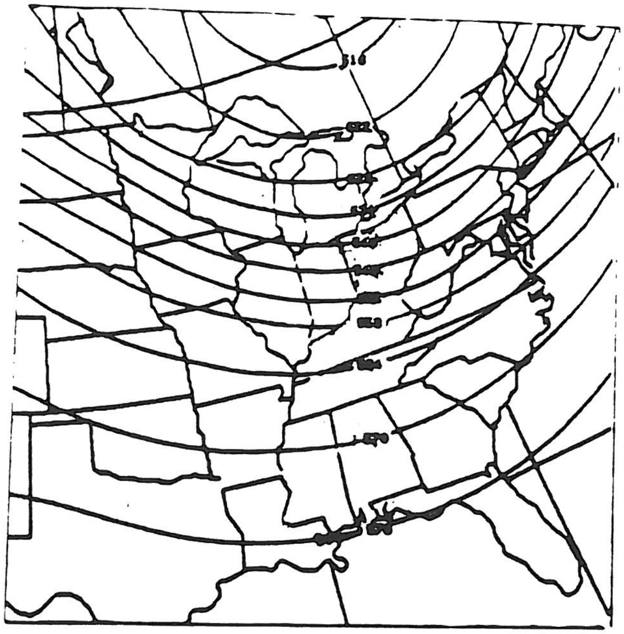

Figure 2. Mean 500mb height field from the five lake-enhanced snow squall events.

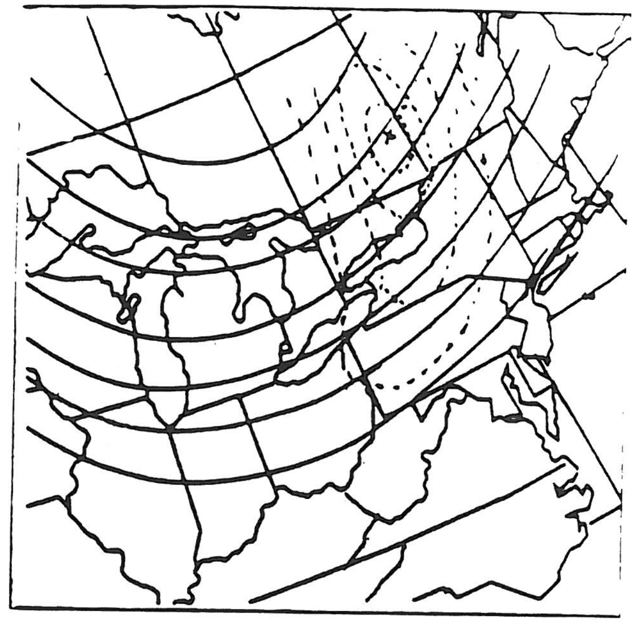

Figure 3. An idealized 500mb vorticity pattern during the five lake-enhanced squall events (isopleths are intentionally not labeled to emphasize the pattern).

DATE	850mb WIND (ddff)	850mb TEMP	LAKE TEMP	ΔT	PBG SNOW	BTV SNOW
Nov. 20, 1987	2925	-10°C	+9°C	19°C	Trace	1.9"
Dec. 9, 1988	2814	-15°C	+6°C	21°C	Trace	1.2"
Mar. 17, 1989	3023	-10°C	+2°C	12°C	.2"	.9"
Dec. 21, 1989	2830	-23°C	+1°C *	24°C	.2"	.2"
Mar. 26, 1990	3126	-13°C	+2°C	15°C	Trace	.4"

* Lake partially frozen (Record cold of December, 1989)

Table 1. Data from the five lake-enhanced snow squall events.

DISCUSSION

The conditions necessary for *lake-enhanced* snow squalls in the Champlain Valley appear to be similar to those needed to generate *lake-effect* snow on lakes Erie and Ontario: a 500mb long wave trough centered over James Bay, a supply of arctic air from a high over the Northern Plains, and an 850mb-lake temperature difference of at least 12°C.

However, since Lake Champlain is smaller than lakes Erie and Ontario, a large 850mb-lake temperature difference and/or a vigorous cold front or trough is required to compensate for the smaller fetch. The fact that the squalls usually last an hour or less suggest a strong dependence on a transient forcing mechanism such as a cold front or trough.

The largest snowfall totals occurred in late November and early December, when the lake was at it's warmest and the 850mb-lake temperature differential was very large. The one exception was the December 21, 1989, case, then the 850mb-lake temperature differential was 24°C. In this case, however, the lake was partially frozen due to a record cold month of December. The frozen lake, in conjunction with the exceptionally cold 850mb temperature, substantially reduced the amount of moisture that might have otherwise been available to produce a heavier snowfall.

CONCLUSIONS

Even though Lake Champlain is smaller than the Great Lakes, it is sufficiently large to produce lake-enhanced snow squalls under the right conditions. Strong shortwaves and large 850mb-lake temperature differences seem to be required to compensate for the relatively short fetch.

Because the snow squalls correlate well with readily forecastable surface and upper air conditions, the prediction of these lake-enhanced snowfalls should be possible through the use of a forecast checklist (Figure 4).

With additional study, it might become possible to further refine the checklist by:

1. Incorporating more cases to improve the numerical thresholds.
2. Consider the orographic effects when the squalls leave the valley and encounter the Green Mountains, ten miles to the east.
3. Predict snowfall locations with a "fetch map", similar to those constructed by Dockus (1985).

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PRELIMINARY FORECASTING CHECKLIST FOR LAKE-ENHANCED SNOW SQUALLS IN THE CHAMPLAIN VALLEY OF VERMONT

1. Is Lake Champlain entirely (or largely) unfrozen?

2. Is a long-wave trough established as illustrated in Figure. 2?

3. Is the 850mb-lake water temperature differential at least 13°C?

4. Is a vorticity maxima of at least 16×10^{-5} sec^{-1} at 500 mb forecast to move across the area during the period in question?

5. Do you expect southerly winds of 10 to 20 knots to develop or prevail prior to trough or frontal passage?

6. Are average pressure falls of .01"/hour expected during the forecast period?

IF ALL OF THE ABOVE CRITERIA ARE SATISFIED, INCLUDE THE CHANCE OF SNOW SQUALLS IN THE FIRST OR SECOND PERIOD OF VERMONT ZONE 1 AND THE BURLINGTON LOCAL FORECAST.

ONCE YOU HAVE INCLUDED THE POSSIBILITY OF SNOW SQUALLS IN THE FORECAST, YOU SHOULD TRY TO DETERMINE THE ARRIVAL TIME OF THE SQUALL AND NOWCAST THE INFORMATION. IF YOU CAN TIME THE ARRIVAL OF THE WIND SHIFT (TO WITHIN AN HOUR OR SO), CONTINUE WITH THE FOLLOWING:

A. Make sure the forecasted winds and pressure falls have materialized.

B. When snow showers or flurries arrive at PBG, issue nowcast for snow squalls arriving in the Champlain Valley of Vermont at the time of the expected wind shift.

Figure 4. Checklist used to forecast Lake Champlain snow squalls.