An Evaluation of the Impact of the Niagara River Ice Boom on the Air Temperature Regime at Buffalo, New York[1]

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ABSTRACT

The objective of this study was to determine if the Niagara River ice boom has prolonged the Lake Erie ice cover at Buffalo, New York, resulting in significant changes in the spring warm-up of Lake Erie and longer, colder winters in the area. Statistical analysis of Buffalo air temperatures compared with those for Lockport, NY does not reveal statistically significant cooling in the climate at Buffalo related to the operation of the ice boom. However, because of the distance of the airport (where the temperature gage is located) from the shore zone, the possibility of a localized effect of small magnitude within the vicinity of the ice boom cannot be ruled out. A comparison of the water temperature at the Buffalo intake as recorded in pre- and post-boom years also indicates that the ice boom has not had an impact on the timing of the spring rise in Lake Erie water temperature at Buffalo. Analysis of winter temperature trends since 1898 shows that the winter severity at Buffalo follows a general pattern characteristic not only of the region around the eastern end of Lake Erie but also of the Great Lakes Region as a whole. Winters have become colder since the installation of the ice boom, but these colder winters are part of a general climatic trend toward more severe winters beginning in 1958. Thus, there is no evidence to suggest that the ice boom has increased winter severity or duration at Buffalo relative to other areas around the Great Lakes.

1. Introduction

This study on the impact of the Niagara River ice boom on the local air and water temperature regime at Buffalo was to determine whether the installation of the ice boom, beginning in the winter of 1964–65, prolonged the Lake Erie ice cover at Buffalo, resulting in significant changes in the spring warm-up of Lake Erie and longer, colder winters. In 1964 the International Joint Commission granted authority to install an ice boom in eastern Lake Erie just above the head of the Niagara river. The boom was installed near the location where a natural ice arch formed each winter. The purpose of the boom was to aid in establishing and retaining the natural ice arch by accelerating the formation of natural ice cover, reducing movement of the ice cover during ice formation, and by stabilizing the downstream edge of the ice cover so that erosion and breakoff of ice is reduced. By stabilizing the ice cover the boom reduces property damage due to massive ice runs in the Niagara River and aids substantially in hydroelectric power generation. The criteria for boom removal is that the boom is removed after the ice dissipation process begins and before the remaining ice on the lake is equal to the normal seasonal ice discharge through the river, ~200 mi^2 during an average spring. Thus, ~98% of the ice formed in the lake melts in the lake and 2% is removed by transport down the Niagara River.

In recent years many residents of the Buffalo area have believed that the boom retains the ice in the lake longer than under no boom conditions leading to more severe winters. This study was undertaken to investigate, using available data, if the installation of the ice boom did delay the onset of spring warming at Buffalo and lead to longer, colder winters.

2. Station homogeneity analysis

The Buffalo weather station was moved in 1913, resulting in a small change in station location in downtown Buffalo (53 m) but a major change in the height of the thermometer (from 54 to 75 m above the ground). Then, in July 1943 the station was relocated from the waterfront to the Buffalo Airport administration building, a distance of ~14 km (see Fig. 1). Finally, in August 1960 it was moved ~0.6 km to its present National Weather Service site. At this time the temperature sensor was moved from a roof exposure 10 m above the ground and mean sea level (MSL) of 211 m to an exposure 1.5 m above the ground and 215 m MSL. The impact of these changes on the Buffalo temperature time series can be assessed by comparing the series with a homogeneous time series from Lockport. The station located in Lockport is the only nearby station with a

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homogeneous record. The parameter used to examine the Buffalo station changes is the difference of the monthly mean temperature between Buffalo and Lockport (Buffalo minus Lockport).

A comparison was first made for the homogeneous period 1914–42. The "lake effect" at Buffalo (shown in Fig. 2) is very pronounced on the average, with Buffalo colder than Lockport during spring and early summer and warmer than Lockport during fall and winter. To determine if this relationship remained constant, we divided the base period into two equal periods, 1914–28 and 1929–42. The lake effect was found to be continuous throughout the base period but more pronounced during the 1929–42 period.

Following the weather station move to the airport in 1943 the spring lake effect was essentially eliminated (Fig. 2). The statistical significance of the move as determined by using the one-sided t-test to compare the temperature differences for the 1944–59 period with those for the 1914–42 period indicated that, despite the high variability of the data, the station change was significant at the 10% confidence level for March, April, May, June, July, September, October and December. Thus, the greater Buffalo area is seen to include two temperature zones: one, a zone in close proximity to the lake which exhibits the typical lake-effect temperature pattern, and the second, further inland, which does not exhibit a well-defined lake effect. A similar analysis of the shift from a roof exposure to a ground level exposure in August 1960, which compared the pre-boom years of 1961–64 and the post-boom period of 1965–79, indicated that the instrument shift was significant for each month of the year.

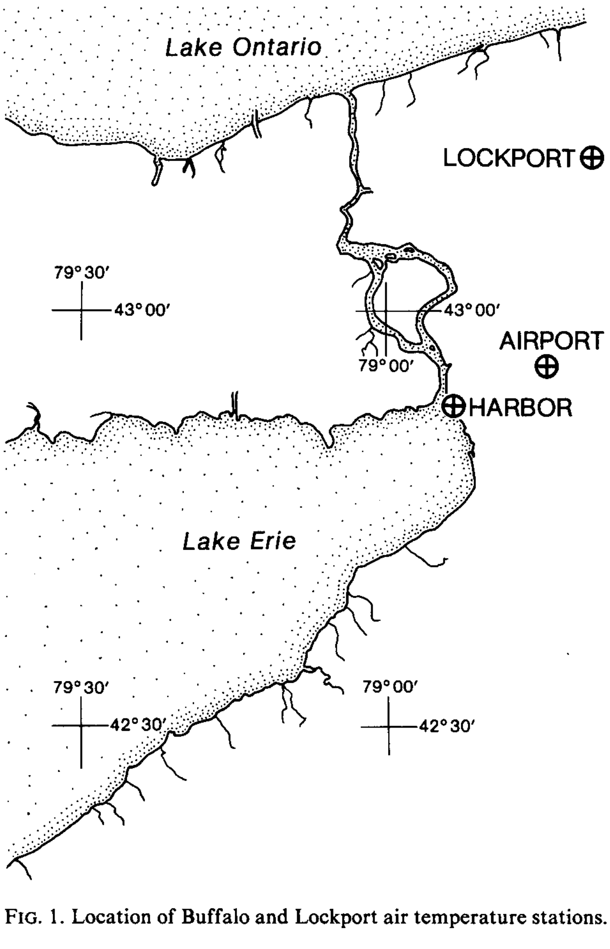

FIG. 1. Location of Buffalo and Lockport air temperature stations.

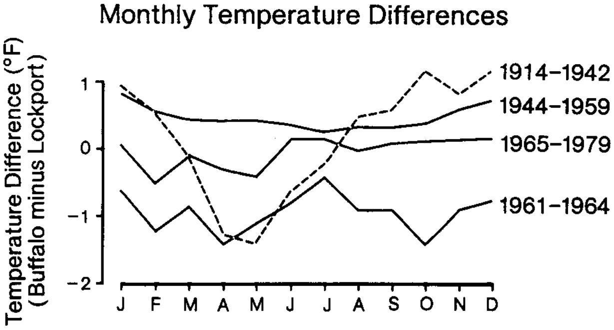

FIG. 2. Difference of mean monthly temperature between Buffalo and Lockport, 1914–42, 1944–64, 1965–79.

These station changes are extremely important as they limit the value of the Buffalo temperature time series for determining the possible impact of the boom to the period 1961–79 at the airport location, which has been shown to be outside the lake-effect temperature zone.

3. Impact on Buffalo air temperatures

In the preceding analysis, the relocation of the weather station from the waterfront to the airport was found to eliminate the lake effect in the monthly time series. This is further verified by comparative data for the years 1941 and 1942, when both the waterfront and airport stations were maintained simultaneously. Table 1 shows the average lake effect as determined from the two years of simultaneous measurements and from homogeneity analysis. The two years of measurements agree very well with the homogeneity study, with the maximum lake effect reaching ~1.1°C during May. Thus, the airport temperatures are not representative of the waterfront temperatures during spring and cannot be used to determine the impact of the boom at the waterfront.

It has been shown that the relocation of the air temperature sensor to the Buffalo airport in July 1960 has resulted in statistically significant differences in mean monthly air temperatures. Thus, the pre-boom period available for comparison with the post-boom period is necessarily limited to the four years from 1961 through 1964 since the operation of the Niagara ice boom began in the 1964–65 winter.

TABLE 1. Lake effect on Buffalo air temperature as indicated by differences in waterfront and airport locations, waterfront minus airport in degrees Celcius.

Month	Difference in average max. temp.*	Difference in average min. temp.*	Difference in average mean temp.*	Difference**
Jan	−0.08	0.44	+0.12	+0.06
Feb	0.25	0.94	+0.44	0.00
Mar	0.56	0.50	−0.28	−0.33
Apr	−2.5	0.72	−0.83	−0.89
May	−2.7	0.44	−1.1	−1.0
Jun	−3.2	1.5	−0.61	−0.56
Jul	−2.7	1.8	−0.50	−0.28
Aug	−1.8	2.3	+0.17	+0.11
Sept	−1.5	2.1	+0.28	+0.11
Oct	−0.83	1.4	+0.28	+0.44
Nov	−0.28	0.72	+0.22	+0.11
Dec	−0.39	0.67	+0.11	+0.17

* From 1941, 1942 simultaneous measurements.
** From homogeneity analysis.

The hypothesis to be tested is that the ice boom has prolonged the winters in the Buffalo area and made them more severe than would otherwise be expected. A statistical test of this hypothesis can be made by comparing the differences in the monthly mean air temperatures at Buffalo and Lockport during the pre-boom period with those during the post-boom period. If, in fact, the Niagara ice boom has extended winter-like conditions at Buffalo and made them more severe, one would expect a change in the difference series (Buffalo minus Lockport mean monthly temperatures) that would reflect the increased severity and duration of Buffalo's winters. The ice boom, of course, would not be expected to have any impact on the difference series for the late summer, fall and early winter of the year.

The post-boom period from 1965 to 1979 was divided into two periods of equal length: 1965–72 and 1972–79. (The second period overlaps the first period in 1972.) One-tailed *t*-tests, conducted to compare these periods to the 1961–64 period to determine if the monthly air temperatures at Buffalo had cooled relative to Lockport in any month, indicated no statistically significant cooling in any month.

Thus, there is no evidence in the difference series of Buffalo minus Lockport mean monthly temperatures that would suggest any significant cooling in the local climate at Buffalo airport relative to Lockport resulting from operation of the ice boom. Therefore, the supposition that a dramatic cooling had taken place in the local climatic regime represented by the Buffalo airport during late winter–early spring as a result of operation of the ice boom is rejected. Since the airport is several miles from the vicinity of the ice boom, these results do not rule out the possibility of an impact of small magnitude occurring in the immediate vicinity of the boom.

It should be pointed out that 4-year samples are insufficient in length for the purpose of obtaining reliable estimates of the mean and standard deviation of a population. However, even though the statistical estimates may not be highly accurate, they should indicate any local climatic changes of a dramatic nature. Therefore, the mean temperature differences between Buffalo and Lockport for the 1961–64 period were also compared with the 4-year mean differences following the installation, as shown in Table 2. The comparisons show that, for every period following installation of the boom, the Buffalo monthly temperatures were higher relative to Lockport than for the period prior to the installation. Thus, based on the Buffalo air temperature data, there is no indication of significant lowering of the air temperature at the airport location attributable to the installation of the ice boom.

4. Impact using water temperatures

A second climatic indicator used to analyze the impact of the boom on the Buffalo climate is the seasonal rise in the Lake Erie water temperature as measured at the Colonel Ward Filtration Plant, Department of Public Works, City of Buffalo. The temperature sensor is located at a depth of 5.5 m and ~305 m downstream of the ice boom and 305 m toward the United States side of the United States-Canadian border in Lake Erie. It is hypothesized that any significant additional ice retained by the boom would slow the spring warm-up of the underlying water by using the energy, which would originally be available to warm the lake, to melt the ice cover. A delayed or late rise in the water temperature would tend to retard spring warming in the adjacent land areas. This is one aspect of the lake effect. The pa-

TABLE 2. Four-year mean temperature differences for the 1961–79 period, Buffalo minus Lockport in degrees, Celsius.

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1961–64*	−0.3	−0.7	−0.5	−0.8	−0.6	−0.4	−0.2	−0.5	−0.5	−0.8	−0.5	−0.4
1965–68	0.1	−0.2	−0.2	0.1	0.1	0.2	0.3	0.2	0.1	−0.1	0.1	0.2
1969–72	0.4	0.2	0.1	0.1	−0.1	0.3	0.3	0.2	0.2	0.3	−0.1	0.1
1973–76	0.1	−0.1	−0.1	−0.4	−0.5	0.2	−0.1	−0.2	−0.1	0.0	−0.1	−0.1
1976–79**	−0.3	−0.7	−0.2	−0.3	−0.6	−0.3	0.3	−0.1	0.1	−0.1	0.2	0.1

* Pre-boom.
** Note: 1-year overlap with previous group.

TABLE 3. Calculation of the water temperature parameter (WT) 1927–79*. WT = number of days past 15 March before the water temperature measured at Buffalo intake is 1.7°C (3°F) greater than the coldest water temperature experienced from 1 January through 15 March.

Year	Date	WT	Year	Date	WT	Year	Date	WT	Year	Date	WT
1927	14 Apr	30	1941	14 Apr	30	1955	2 Apr	18	1969	28 Apr	44
1928	16 May	62	1942	27 Apr	43	1956	18 Apr	24	1970	30 Apr	46
1929	25 Apr	41	1943	17 May	63	1957	11 Apr	27	1971	25 May	71
1930	5 May	51	1944	24 Apr	40	1958	7 Apr	23	1972	4 May	50
1931	6 Apr	22	1945	29 Mar	14	1959	11 May	57	1973	16 Mar	1
1932	18 Apr	34	1946	5 Apr	21	1960	4 May	50	1974	6 Apr	22
1933	25 Apr	41	1947	16 May	62	1961	15 Apr	31	1975	15 Apr	31
1934	9 Apr	25	1948	2 Apr	18	1962	30 Apr	46	1976	19 Apr	35
1935	15 Apr	31	1949	28 Mar	13	1963	9 May	55	1977	30 Apr	46
1936	20 May	66	1950	2 May	48	1964	22 Apr	38	1978	14 May	60
1937	13 Apr	29	1951	16 Apr	32	1965	13 May	59	1979	22 Apr	38
1938	12 Apr	28	1952	28 Mar	13	1966	25 Apr	41	1980	22 Apr	38
1939	9 May	55	1953	20 Mar	5	1967	15 Apr	31			
1940	29 Apr	45	1954	8 Apr	24	1968	29 Apr	45			

* After International Niagara Working Committee (1979).

rameter often used to define the onset of the spring temperature rise is the water temperature parameter, defined as the number of days past 15 March that it takes the water temperature measured at the Buffalo intake to reach a value 1.7°C greater than the coldest water temperature experienced from 1 January–15 March. For example, if the water temperature measured at the intake reached 1.7°C on 30 March and the coldest water temperature was 0°C, then the water temperature parameter for that year would be 15 days. The data are given in Table 3.

Analyses of variance statistically tested were used to determine if the post-boom period differs significantly from the pre-boom period by dividing the water temperature parameter time series into three approximately equal periods. Testing the hypothesis (at the 90 and 95% confidence levels) that the boom has no effect on the water temperature parameter would call for the hypothesis to be rejected only if the probabilities (given in Table 4) are 10 and 5%, respectively, or less. As none are, the boom is considered to have no significant impact on the water temperature parameter and therefore on the spring rise in the Lake Erie water temperature at Buffalo.

The periods were also analyzed to determine by how many days the water temperature parameter in the post-boom period would have to be increased before the boom could be said to have a statistically significant impact. It was found that the parameter would have to be increased by an additional 4 days to be significant at the 95% confidence level and by an additional 2 days to be significant at the 90% confidence level. However, even with these increased values, the mean of the post-boom period was found to be nonsignificantly different, at the 95% confidence level, from the 1927–45 pre-boom period.

An example of the use of mean values to determine the impact on the water temperature parameter of the ice boom is shown in Table 5. The time series was broken into eight periods of similar length and the mean water temperature parameter determined for each period. The periods are arranged in increasing order of the mean water temperature parameter. Of particular interest is the fact that period eight, comprising the last 8 years after the boom was installed, has the third lowest value of the mean water temperature parameter of the series and is lower than three of the five pre-boom periods. This indicates an earlier spring warming during this particular 8-year period than during three of the five pre-boom periods.

A second method of analysis would be to test the pre- and post-periods using the student's *t*-test to consider both type I and type II errors. A type I error is the rejection of the null hypothesis when it is true

TABLE 4. Analysis of variance test of water temperature parameters, three periods. *F* probability = 18.2%. Kruskal-Wallis rank test, *F* probability = 15.7%. Tests for homogeneity of variances: Cochrans test, probability = 66.0%; Bartlett-box text, probability = 84.6%.

Period	Years included	Number (years)	Mean (days)	Standard deviation (days)	Coefficient of variation (%)	95% confidence interval for means
1	1927–45	19	39.5	14.7	37	32.4–46.5
2	1946–64	19	31.8	16.8	53	23.8–39.9
3*	1965–80	16	41.1	16.2	39	32.5–49.8

* Post-boom period.

TABLE 5. Mean water temperature parameters by periods in ascending order.

Period	Years included	Number of years	Mean (days)
4	1948–53	6	21.5
5	1954–59	6	28.8
8*	1973–80	8	33.9
3	1941–47	7	39.0
2	1934–40	7	39.9
1	1927–33	7	40.1
6	1960–64	5	44.0
7*	1965–72	8	48.4

* Post-boom periods.

or the acceptance of the alternative hypothesis when it is false. A type 2 error is the acceptance of the null hypothesis when it is false or the rejection of the alternative hypothesis when it is true. Performing the student's *t*-test for the 1927–64 and the 1965–80 periods with sample means of 35.66 and 41.13 days, respectively, and with a pooled standard error of the mean of 4.79 days yields a *t* value of −1.14. This translates into an achieved significance level of $\sim$13%. Thus, the two distributions would be considered significantly different for significance limits (α) 13% or greater. The probability of a type 2 error (β) was determined as per Thom and Thom (1972) from

$$U_{1-\beta} = \frac{f(|d| - U_{1-\alpha}) - 1.21U_{1-\alpha}(U_{1-\alpha} - 1.06)}{f + 1.21(U_{1-\alpha} - 1.06)},$$

where $U_{1-\beta}$ is a normal unit quantile, f the number of degrees of freedom, and d the difference between distribution means given in terms of the standard error.

Thus, in the current example d would be the t value of 1.14, while f would be 52 degrees of freedom. Fig. 3 shows the relationship between α and β for the present example. The figure shows that for the achieved significance level of 13% the probability of rejecting the alternative hypothesis (that the ice boom changed the water temperature parameter) when it is true would be $\sim$49%. With Fig. 3 a decision on the relative importance that one might wish to attach to α and β can be factored into the decision-making process. For example, if equal importance is placed on α and β, it would call for an α of 28%. At this significance level, the hypothesis that the ice boom had no effect on the water temperature parameter would be rejected (28% is greater than the achieved significance level of 13%).

5. Impact on winter temperature severity

Freezing degree days (FDD's) are defined as the departure of the mean daily air temperature below 0°C (32°F). FDD accumulations for a given winter season are a measure of the cumulative departure of the average daily air temperature below 0°C and the maximum seasonal value is an index of the severity of a particular winter season.

Winter severity in the Buffalo area was compared to a three-station average in the Buffalo region (Toronto, Ont.; Rochester, NY; and Erie, PA) and to the Great Lakes shore zone as a whole (Fig. 4). Port Dover, Ont., was not used in the regional analysis because of a discontinuity in the station temperature records occurring in 1924. In general, the extremes in winter severity usually occurred simultaneously in Buffalo, the three-stations region, and the Great Lakes. The four coldest and the four warmest winters at Buffalo, in the region, and in the Great Lakes shore zone are shown in Table 6. With the exception of the 1977 winter, which was one of the four coldest for the region, the extreme winters all occurred prior to the installation of the ice boom; two of the four coldest winters and three of the four warmest winters occurred simultaneously for Buffalo, the region, and the Great Lakes. Thus, winters during the post-ice boom years have not been as extreme as those during the pre-boom years.

As a further illustration of trends in winter severity at Buffalo relative to regional and Great Lakes trends, analysis of the cumulative standardized FDD values indicated that 1) winter severity increased from 1898–1918; 2) winter severity decreased from 1920–58; and 3) winter severity increased from 1958 to the present.

Buffalo winters were relatively less severe than either the regional or the Great Lakes averages from

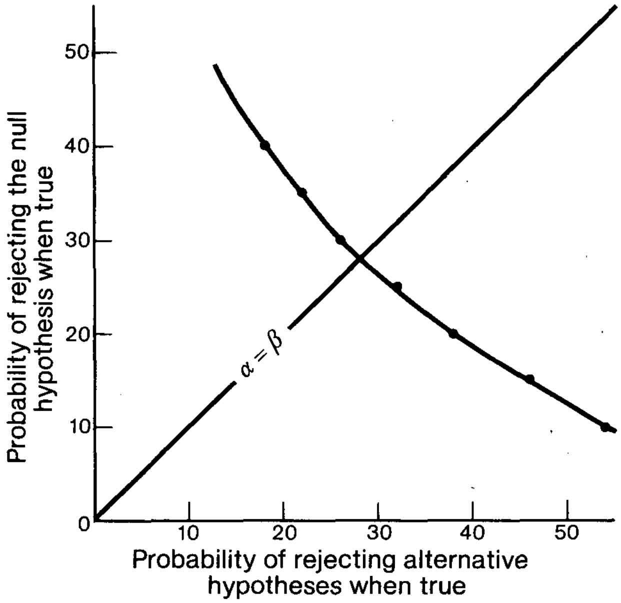

FIG. 3. Probability of rejecting the null hypothesis when true versus probability of rejecting the alternative hypothesis when true.

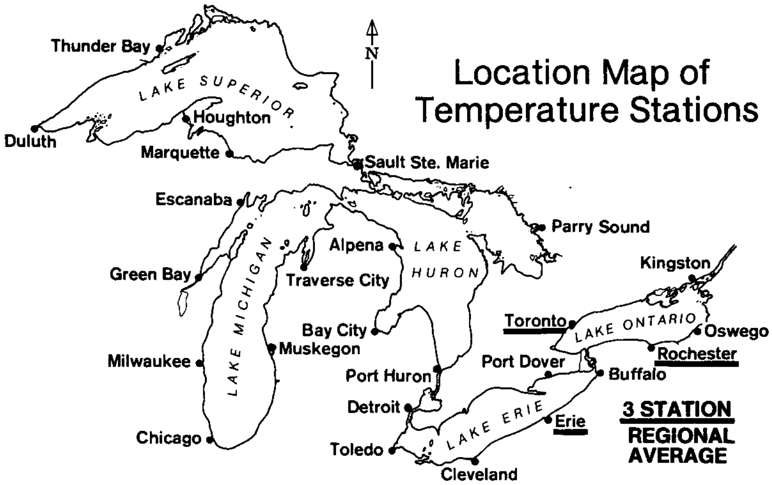

FIG. 4. Location map of temperature stations.

1898 to 1938 and relatively more severe than those for the rest of the Great Lakes from 1938 to 1952. The Buffalo winters were relatively cold compared to the regional average and the rest of the Great Lakes from 1958 to 1974 and milder than the Great Lakes average from 1975 to 1979. The relatively cold winters at Buffalo as compared to the regional average were due, at least in part, to the air temperature sensor move in 1960, which resulted in lower air temperatures in winter. Thus, yearly FDD accumulations at Buffalo since the installation of the ice boom have tended to be higher than the mean for 1897–1960, but this trend toward cooler winters coincides with a general climatic trend toward more severe winters in the Great Lakes shore zone as a whole starting in 1958.

Since fluctuations in standardized maximum FDD accumulations at Buffalo and the region show similar trends, a regression of Buffalo maximum FDD accumulations on the regional average was used to predict maximum FDD accumulations at Buffalo. The regression was based on the 45-year pre-boom period 1920–64. Deviations of actual FDD accumulation at Buffalo from the predicted values based on the regression are shown in Fig. 5 (Y − Buffalo). Positive deviations indicate that Buffalo has been warmer than expected, and negative deviations indicate that Buffalo has been colder than expected. If the impact of the ice boom has been to make Buffalo's winters colder, the regression equation should consistently underestimate maximum FDD accumulation at Buffalo. Fig. 5 shows that eight of the predictions for the post-boom period are too high and seven are too low, with no consistent temporal pattern to these errors. This implies that the installation of the boom has had no impact on the expected value of FDD accumulations at Buffalo and therefore has not affected the severity of Buffalo winters.

In addition to investigating the intensity of winter severity, indicated by the maximum FDD accumulation each winter, the duration of Buffalo winters was also investigated through the use of TDD's. TDD's are the deviation of average daily air temperature above 0°C. Cumulative values of TDD's for March and April represent an index of the duration of the winter season air temperatures: for winter-like weather in spring, smaller TDD values would be accumulated. If the ice boom has had the effect of extending the duration of the winter season at Buffalo, this should be reflected in a marked decrease in TDD accumulations for post-ice-boom winters as compared to pre-ice-boom winters. A time series of TDD's at Buffalo and the three-station regional average used in the FDD analysis was calculated for TDD accumulations for March and April. Analysis of these data showed that the extreme winters, i.e., the longest and the shortest, occurred prior to the ice boom installation and also that the trend at Buffalo is the same as the regional average for almost the entire period of record. Analysis of the cumulative

TABLE 6. Winter severity.

	Four coldest winters				Four warmest winters			
Buffalo	1904	1905	1918	1920	1919	1932	1933	1953
Region	1904	1905	1918	1977	1919	1932	1933	1953
Great Lakes	1904	1912	1918	1920	1919	1921	1932	1953

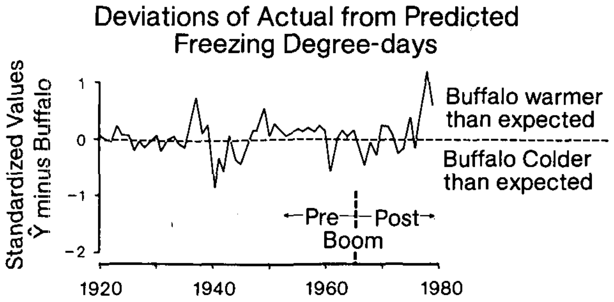

FIG. 5. Deviations of actual from predicted FDD accumulations at Buffalo, 1920–79.

TDD values at Buffalo and the region indicated that the trend has been toward longer winters from 1898 to 1943 and then toward shorter winters to 1958. From 1958 to the present, winter duration has also tended to decrease for Buffalo, but has tended to increase for the region. Warmer temperatures recorded at Buffalo in March and especially in April after 1943 (and thus including post-ice-boom years) can be attributed to the 1943 station move from downtown to the airport location; these warmer recorded temperatures are responsible for the apparent trend toward shorter winters at Buffalo from 1958 to the present. Additional detail on the relative winter severity can be found in Quinn *et al.* (1980).

In order to examine the variability of winter duration during this post-ice-boom period in greater detail, we ranked the years of the post-ice-boom periods from shortest winter to longest at Buffalo and in the region. We found that four of the five shortest and four of the five longest winters were the same at Buffalo and the region, indicating that, regardless of when the ice boom was removed each winter, it is the general weather patterns prevailing in the region that determines the length of the winter season at Buffalo, as reflected by the comparison of winter length at Buffalo to the regional average.

A second method used to examine the relationship between pre- and post-ice-boom winter duration relative to the regional trend is regression analysis. Since the standardized TDD series for Buffalo and the region show similar trends, a regression equation of Buffalo TDD's on the regional average was used to predict TDD's at Buffalo. As was the case in the FDD analysis, the regression was based on 45 preboom years (1920–64). Deviations of actual TDD's at Buffalo from the predicted values based on the regression are shown in Fig. 6 (Y − Buffalo). Positive deviations indicate that Buffalo had longer winters than expected and negative deviations indicate that Buffalo had shorter winters than expected. The regression overestimates the length of winter during the post-ice boom period, but this appears to be related to the station move in 1943 rather than to the ice-boom installation resulting in shorter winters.

6. Conclusions

Based on this analysis, there is no evidence to suggest that the ice boom has enhanced winter temperature severity at Buffalo relative to other areas around the Great Lakes. Winter temperature severity during the post-boom period is within the range of natural climatic variability identified during the pre-ice-boom winters: the ice boom has not had an identifiable impact on the winter temperature regime at Buffalo.

The analysis showed that there was a statistically significant change in monthly average temperature in March, April and May, as well as other months, because of the relocation of the instruments from downtown Buffalo to the airport. In addition, the relocation of the instrument from a roof top to a ground exposure in 1960 also caused a difference in the average monthly air temperature record so that the Buffalo air temperature record for determining the possible impact of the boom on a monthly time scale is limited to the period 1961–79 for the temperature zone represented by the airport location. Since the analysis did not show a statistically significant cooling for the late winter-early spring months, we conclude a dramatic cooling resulting from the ice boom did not take place at the airport location. These results, however, do not rule out the possibility of an impact of a smaller magnitude occurring in the immediate vicinity of the boom.

The effect of the Lake Erie ice cover and heat storage on extending winter-like weather at Buffalo can be seen by comparing air temperatures at downtown Buffalo and Lockport. The downtown Buffalo temperatures are cooler in spring because of ice cover and because of cooling of the air as it moves over the ice or water after the ice melts. Away from the shore, the magnitude of the cooling decreases as indicated by our comparison of temperature records at the airport and downtown Buffalo for the years 1941 and 1942; the maximum average monthly temperature difference was 1.1°C for May.

The severity of winters at Buffalo was examined in terms of FDD's and TDD's as indexes of the severity (coldness) and duration (length), respectively,

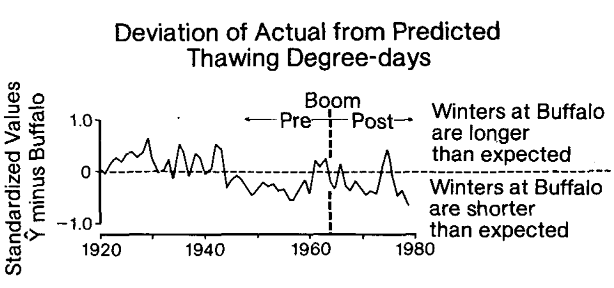

FIG. 6. Deviation of actual from predicted TDD at Buffalo, 1920–79.

of the winters at Buffalo. Compared to a 62-winter mean (1897–1960) of FDD accumulation, winters at Buffalo during post-boom years have higher FDD accumulations (are cooler) than the mean, but these cooler winters began in 1958 and are part of a climatic trend toward cooler winters that began that year. This same trend is seen in a three-station regional average of FDD's and a 25-station Great Lakes average FDD time series. Thus, winter severity trends at Buffalo are very similar to those of the region and of the Great Lakes. A regression equation of regional and of Buffalo FDD's based on the period 1920–64 was used to predict winter severity for the post-boom period. Because the residuals for the post-boom period did not show a marked difference from the residuals of the pre-boom period, it is concluded that post-boom winter severity has not been affected by the ice boom. Winter duration was examined through the use of TDD accumulations in March and April. Comparison of TDD values for the regional average and for Buffalo for 83 years shows that trends in winter TDD's, and thus winter duration, are the same for Buffalo as for the region for pre-boom years. In addition, the trend in winter duration in post-boom years does not suggest that Buffalo has had longer winters during that period compared to the region or compared to Buffalo in pre-boom years. Thus, the ice boom has not increased winter duration.

The analysis of the water temperature parameter, which would indicate possible temperature effects in the nearshore zone, is consistent with the results of the TDD analysis at the airport location. The analysis has shown that the ice boom has not resulted in a statistically significant delay in the timing of the spring rise of Lake Erie water temperature which would have lead to delayed spring warming in the Buffalo nearshore zone.

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