10.1 CLIMATOLOGIC EVALUATION AND MODIFICATION OF THE CLASSIC MESOSCALE PREDICTIVE LAKE-BREEZE INDEX

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1. INTRODUCTION

Great Lakes lake-breeze (LB) circulations, which occur most often during the spring and summer months, can have large economic, societal, and climatic impacts on coastal regions. Although lake breezes are mesoscale weather phenomena, they can significantly modify the summer climatic conditions in the Great Lakes coastal regions by frequently providing cooler temperatures several 10s of kilometers inland from lake shorelines. Lake breezes can provide cool relief to metropolitan areas, such as Chicago, IL and Milwaukee, WI during intense heat waves. These circulations can also influence the dispersion of pollutants and airborne biota in lake coastal regions.

Biggs and Graves (1962) developed a method, the lake-breeze index (LBI), for identifying LB days along the western Lake Erie shoreline. Lyons (1972) later adapted the LBI to provide a simple forecasting tool for lake breezes in the Chicago, IL area. Each study determined a critical value of a LBI that yielded greater than a 90% hindcast accuracy in predicting LB events. However, Biggs and Graves (1962) and Lyons (1972) found 65% and 58% of the error, respectively, was associated with the failure of an expected LB to occur, indicating the LBI tended to overestimate the number of lake breezes. Even when Lyons (1972) refined the index by including cloud cover information 36% of the error still remained due to overprediction of lake breezes.

The current study builds upon the recent results of Laird et al. (2001) and examines the effectiveness of several modified lake-breeze indices in predicting LB events at Milwaukee, WI (MKE), Chicago, IL (ORD), and Muskegon, MI (MKG) during a 15-year period from 1982-1996.

2. CLASSIC LAKE-BREEZE INDEX RESULTS

Biggs and Graves (1962) used the following empirical relationship to forecast LB occurrences on the western shore of Lake Erie:

$$LBI = \frac{V^2}{C_p(\Delta T)_{\max}}$$

where V is the average surface wind speed (m s^{-1}) irrespective of direction at an inland station, $(\Delta T)_{max}$ is the maximum inland-air and lake surface water temperature difference in °K, and C_p is the specific heat of dry air at constant pressure [1.003 J K^{-1} gm^{-1}]. We retain the mixture of CGS and SI units in C_p so that the index can be compared to prior studies. The utility of the LBI for MKE, ORD, and MKG along the shore of Lake Michigan was examined using data from three inland stations (i.e., Madison, WI (MSN), Rockford, IL (RFD), and Flint, MI (FNT)). These sites were chosen to represent environmental conditions uninfluenced by Lake Michigan mesoscale circulations.

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Table 1. 1982-96 LB events predicted using critical values of classic LBI and non-lake-breeze (NLB) days with LB predicted.

	classic lake-breeze index (LBI)				
	2	3	4	5	6
MSN LB (%)	69	80	86	90	91
RFD LB (%)	77	86	91	93	94
FNT LB (%)	75	85	89	92	94
MSN NLB (%)	44	60	67	72	75
RFD NLB (%)	49	65	73	78	80
FNT NLB (%)	48	63	72	76	78

The classic LBI has a considerable tendency to over-estimate the number of LB events. Table 1 shows that at MSN a LBI = 3, the critical value determined by Biggs and Graves (1962), would tend to underestimate the actual number of LB events by about 20% and predict a LB on nearly 60% of non lake-breeze days. The ability of the classic LBI to predict LB events increased slightly for RFD and FNT, however an increase in the percentage of lake-breezes predicted during non-LB events also occurred for these locations. The large false-alarm rate associated with the prediction of lake-breezes during non-LB days suggests that the formulation of the classic LBI may need revision. This would also allow more comprehensive data sets now available for mesoscale research in the Great Lakes region (i.e., buoy-collected offshore air and lake temperatures) to be utilized.

3. MODIFIED LAKE-BREEZE INDEX RESULTS

An examination of alterations to the classic LBI was performed for the eastern, western, and southwestern shorelines of Lake Michigan using data from three inland sites (i.e., MSN, RFD, and FNT). Modifications to the LBI included defining $(\Delta T)_{max}$ as the difference of inland and *over-lake* air temperatures and defining the wind speed as the *shore-perpendicular component*, |U| for both onshore and offshore gradient flow.

Figures 1a-c show results when comparing critical LB indices to data collected at MSN during 1982-96 LB events for LB indices determined using (a) the classic formulation, (b) $(\Delta T)_{max}$ from air temperatures, and (c) the shore-perpendicular component, |U| for wind speed. If the LB indices were accurate in their prediction of LB events, all calculated values of LBI would have been located to the left of the critical LBI values.

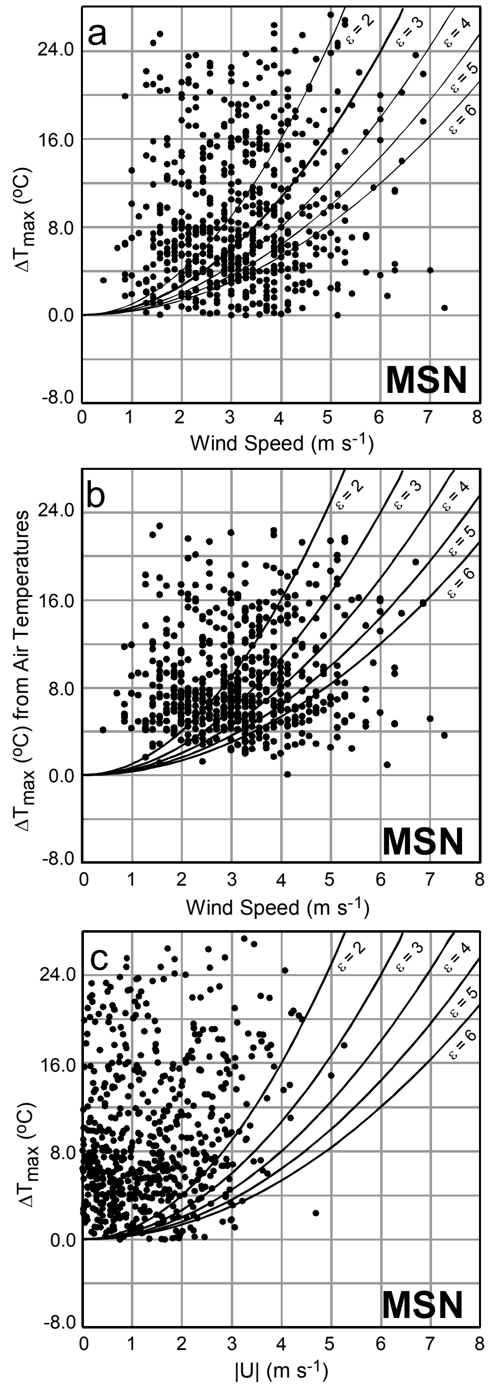

Fig. 1. (a) Classic LBI, (b) modified LBI with use of inland and over-lake air temperatures, (c) modified LBI with shore-perpendicular wind component.

When using |U| to calculate LBI, ≥ 93% of LB events were resolved based on a critical LBI value of 2 (Fig. 1c). However, when wind speed, irrespective of wind direction, was used to calculate the classic LBI the success of the indices noticeably decreased (Fig. 1a). For example, a decrease of 26% was experienced for a critical value of LBI = 2 and a reduction of about 16% resulted for a threshold of LBI = 3. When $(\Delta T)_{max}$ was found using air temperatures (Fig. 1b) in combination with either wind speed or |U|, an improvement of as much as 7% in predicting LB events occurred over the classic definition of $(\Delta T)_{max}$ which uses inland air and lake water temperatures. Considering all locations and critical values of LBI, the average improvement was 3.5%. Although these modifications to the LBI appear to improve the effectiveness of the LBI in predicting LB events, it should be noted that these modifications have only slightly altered the tendency for the LBI to overpredict LB events. When the LBI was found using $(\Delta T)_{max}$ of air temperatures, overprediction was reduced by an average of nearly 4%.

Table 2. 1982-96 LB events predicted using critical values of modified LBI using |U|, $(\Delta T)_{max}$ with air temperatures, or both.

	modified lake-breeze index (LBI)				
	2	3	4	5	6
MSN ΔT (%)	73	85	93	95	97
MSN |U| (%)	95	97	97	98	98
MSN Both (%)	98	100	100	100	100
RFD ΔT (%)	84	94	97	98	99
RFD |U| (%)	96	97	98	99	99
RFD Both (%)	98	99	100	100	100
FNT ΔT (%)	76	89	94	96	98
FNT |U| (%)	93	96	97	98	98
FNT Both (%)	95	99	100	100	100

4. CONCLUSIONS

Several variations of the classic LBI were evaluated using identified LB events along the eastern, western, and southwestern shores of Lake Michigan during a 15-year period (1982-1996). Indices calculated with shore-perpendicular wind speeds at inland sites, |U|, were found to improve the prediction of LB events. The different values of LBI calculated using |U| resolved ≥ 93% of identified LB events based on critical LBI values of 2 through 6. When wind speed, irrespective of wind direction, was used to calculate LBI the success of the critical indices was degraded. The most effective formulation of the LBI was found using a combination of |U| and for $(\Delta T)_{max}$ determined from inland and over-lake air temperatures. The results show that even with the modifications to the LBI described, the LBI retains a significant tendency to overestimate the number of LB events. Future studies of the LBI should be directed at reducing its significant tendency to overestimate LB events.

Acknowledgements: Travel to the 13th Conf. on Applied Meteorology was supported by a travel grant from Hobart & William Smith Colleges.

5. REFERENCES

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