Weather Conditions Associated with Rapid Variations in Lake Erie Ice Cover

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Photo taken during Great Lakes Ice Cover – Atmospheric Flux (GLICAF) Experiment, Feb. 2004

Background & Introduction

- Long-term interannual variations in seasonal Lake Erie (Assel 1990) and Great Lakes (Assel 2005) ice cover have been fairly extensively covered

- Less studied, are rapid variations (timescales of days as opposed to weeks, months, and years) in ice cover that can have significant influences on short range weather forecasting (Niziol et al. 1995, Rauber and Ralph 2004), with lake effect snow being a central feature of the regional winter season (Cordeira and Laird 2007)

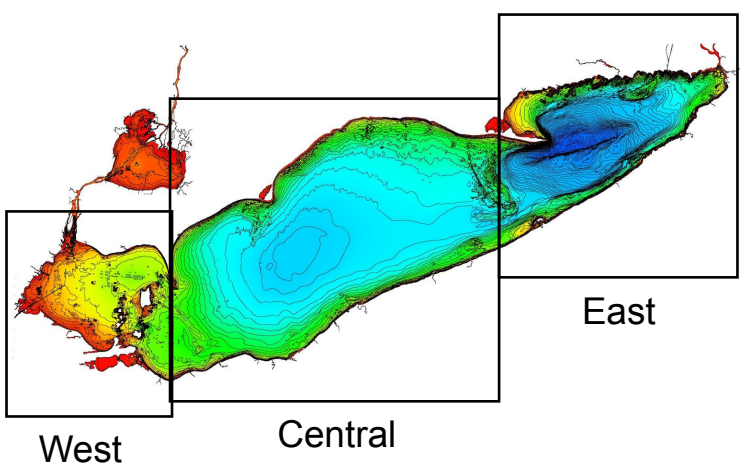
- The purpose of this study is to develop a climatology of periods of rapid changes in ice concentration on Lake Erie, and investigate weather conditions associated with these events.

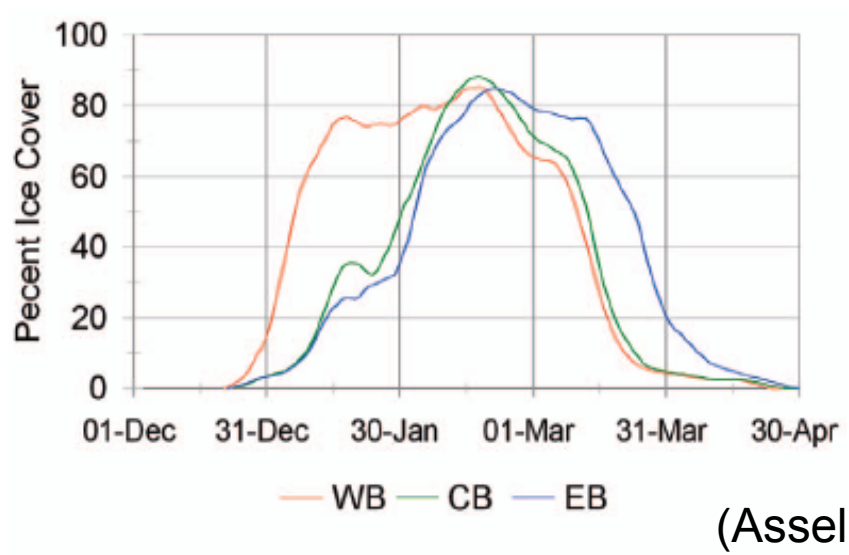
- Since Lake Erie is the shallowest of the Great Lakes, it experiences the most ice cover (typical average maximum ice cover ~ 90%), therefore making it the most suitable for ice studies.

Background & Introduction

- Exact nature of ice cycle is dependant upon individual basins.

	Avg. depth	Avg. period of ice cover	Avg. ice coverage during ice presence
West Basin	8 m	Dec 25 – Mar 15	61.7%
Central Basin	19 m	Jan 7 – Mar 23	39.3%
East Basin	26 m	Jan 6 – Mar 21	36.6%



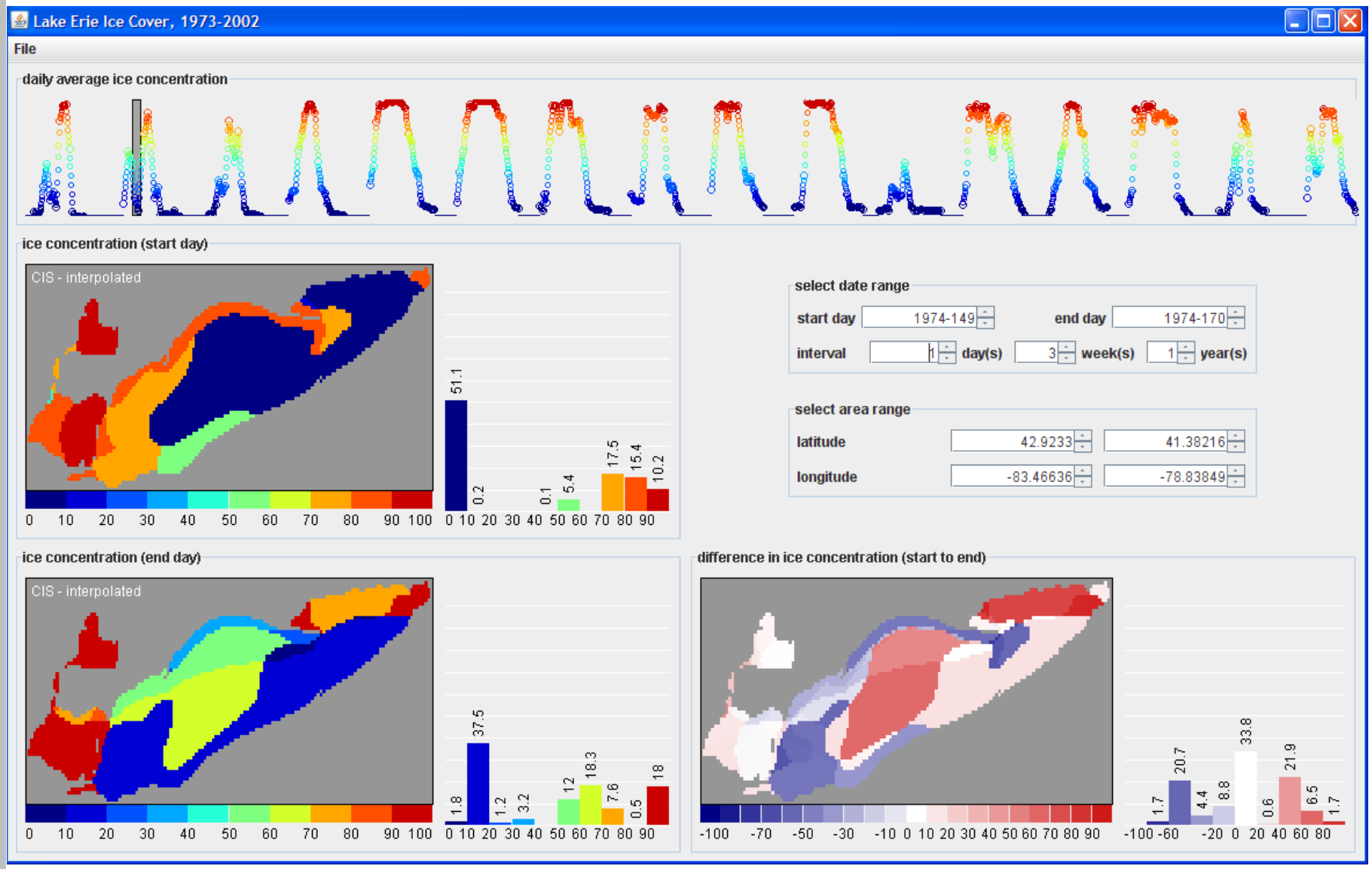


(Assel 2004)

Data & Analysis Methods - Daily Ice Cover Data

- Ice cover data obtained from the NOAA Great Lakes Ice Atlas – a product of the Great Lakes Environmental Research Laboratory (GLERL)
- Includes daily ice cover concentrations for the 30-winter period between 1973 and 2002 primarily obtained through ship, shore, aircraft, and satellite observations.
- Data set is comprised of two sets of observations
  - Prior to 1989, data collected by Canadian Ice Service (CIS) – observations primarily taken at 7 day intervals
  - From 1989 onward, data is primarily collected by National Ice Center (NIC) – observations primarily taken at 2-4 day intervals
- Daily ice cover concentrations at a given grid point on a day without official observation was calculating using a linear interpolation between the two nearest observations before and after.
- Data provided in ASCII text by GLERL – software developed at Hobart and William Smith Colleges was utilized to visually depict the ice cover concentration as well as calculate changes in different concentration levels given a two days during a certain winter of interest

Background & Introduction



Data & Analysis Methods - Identifying Rapid Ice Cover Change Events

Criteria for identifying periods of significant variation in Lake Erie ice concentration distribution. An event must satisfy ALL three criteria.

Rapidity – The event duration is seven days or less.

Spatial Coverage – Event exhibits 80 – 100% change in ice concentration over 10% of lake surface area (2,574 km^2), and/or a 60 – 80% change over 30% of lake (7,724 km^2), and/or a 40 – 60% change over 50% of lake (12,873 km^2)

Timing/Duration (must meet at least one of the following standards)

- Events occur between successive local maxima and minima in time series of daily average ice concentration for Lake Erie. If a strict local maximum or minimum is not observed, these event periods may also be bounded before and/or after by periods of "constant" ice concentration, that is, over the observation periods surrounding the event, ice change is not more than +/- 1% per day over the lake surface.

- Variations during periods where ice cover change is more than +/- 10% per day between successive observations were also classified as events.

Data & Analysis Methods - Identifying Rapid Ice Cover Change Events

- Events were first classified as freezing (ice gain) or thawing (ice loss)

- Further differentiation on a spatial scale was made– events are grouped together according to the primary location of change in ice concentration

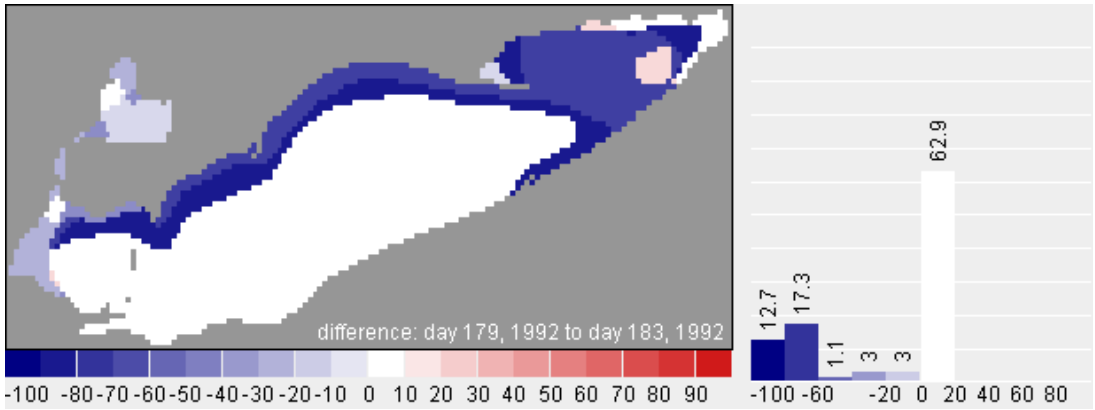
    - North Shore

    - South Shore

    - Basin-wide

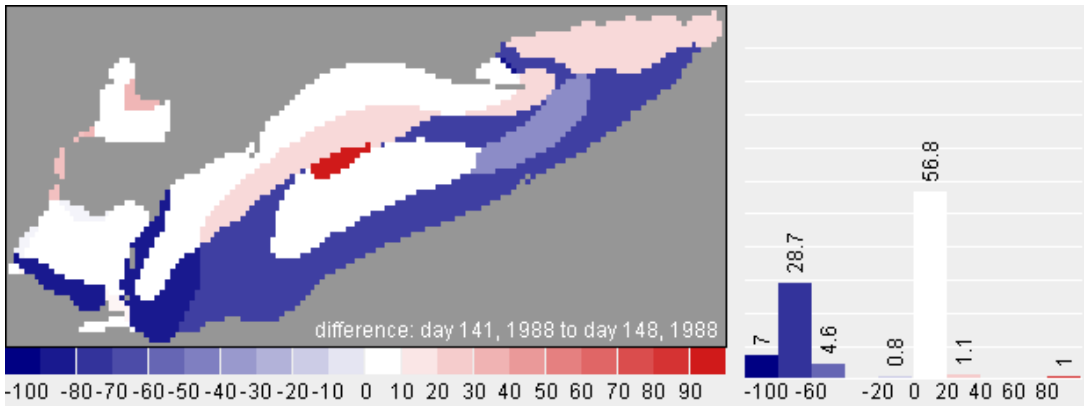
- Data regarding year, start date of event, end date, duration, and magnitude of change in ice concentration difference field were included in the initial database

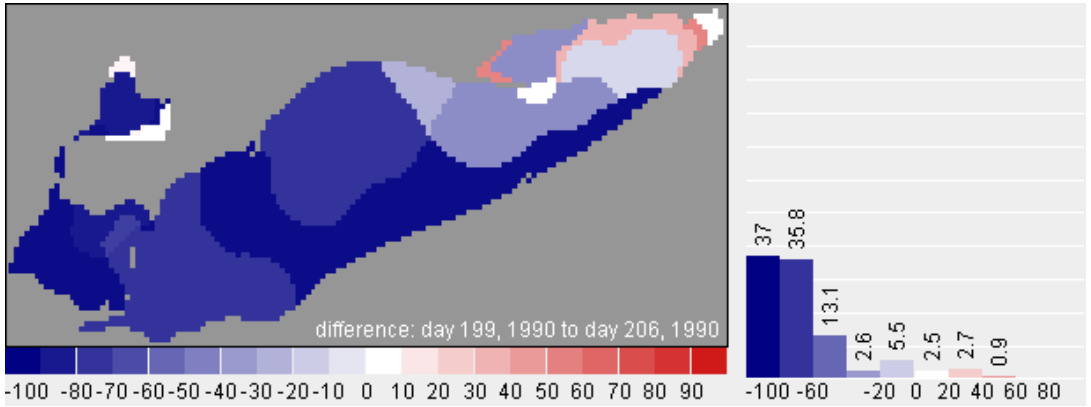
Types of Ice Cover Change Events – Lake Erie



North shore thaw event. This figure shows the ice concentration change over 17 – 21 February, 1992.

South shore thaw event. The figure shows the period of ice loss from 10 – 17 January, 1988.





Lake-wide/basin-wide thaw event. The figure shows ice concentration changes over 9 – 16 March, 1990.

Data & Analysis Methods - Meteorological Data

- Daily surface observations (provided by the National Climatic Data Center) that were used in the analysis were taken at Buffalo-Niagara International Airport (KBUF) and Toledo Express Airport (KTOL) due to their orientation across the long axis of the lake. Observations included in the study are days where ice cover concentration is > 0%.

- Surface observations included, but were not limited to, temperature, dew point, wind speed and direction, sea level pressure, precipitation, snow depth, and cloud cover. Derived variables included relative humidity, and temperature max/mins.

- It is important to note that, to gain a rough estimate of the lake heat cycle, cumulative freezing degree days (FDD) are counted. FDD are added on a daily basis– if the cumulative total for a winter goes below zero (above-freezing temperatures) at any time, the cumulative total is reset to zero. (Assel, 1996).

$$FDD = 0 - T_{AVG} \quad \text{where} \quad T_{AVG} = \frac{T_{\max} + T_{\min}}{2}$$

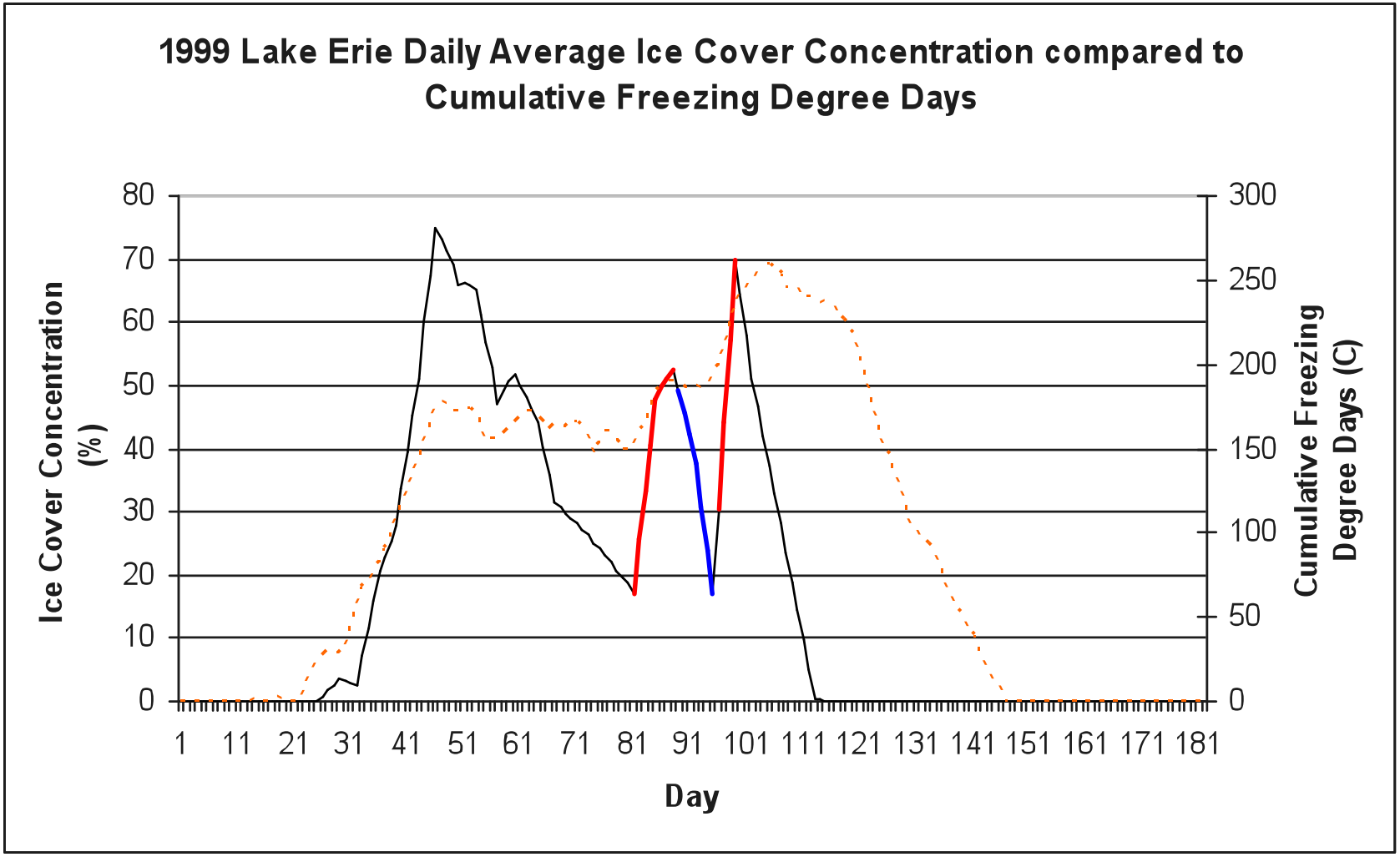
Preliminary Findings – Weather Conditions & Rapid Ice Cover Change

- Weather observations were studied to help discern atmospheric conditions that were present during events with the hope that some form of correlation between certain weather conditions and the occurrence of a rapid ice cover change.

- In this study, events for five years during the observation period were used for data analysis (1990, 1993, 1994, 1996, 1999). These years were chosen because of the frequency of events relative to other seasons, as well as the high-resolution (temporally) nature of the ice concentration data set provided by GLERL.

- Initially, seasonal graphs (observations taken at KBUF) were produced which overlaid the ice cycle (and highlighted events) with daily averages of meteorological variables such as wind speed, sea level pressure, and cumulative FDD.

Preliminary Findings – Weather Conditions & Rapid Ice Cover Change



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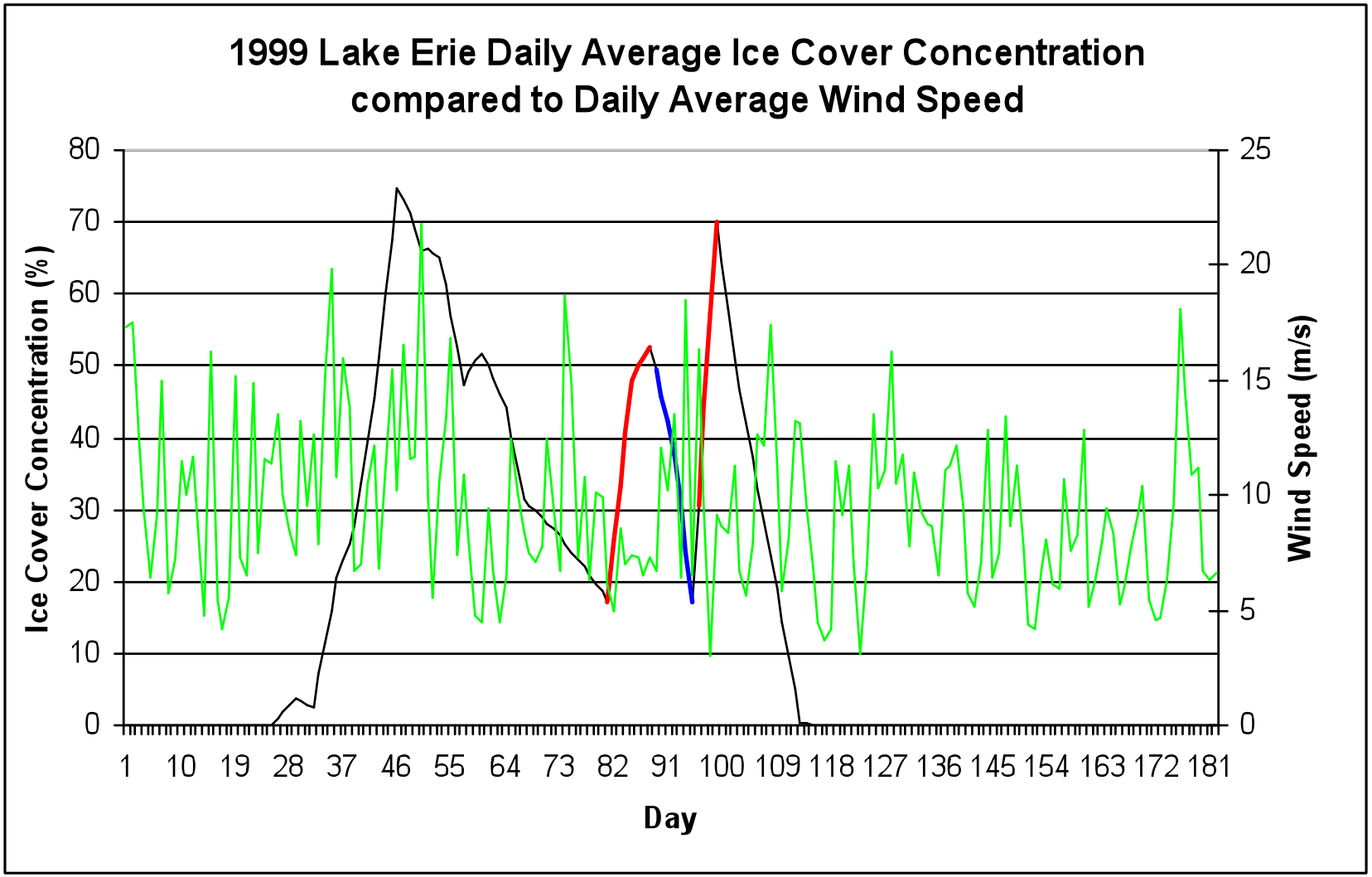

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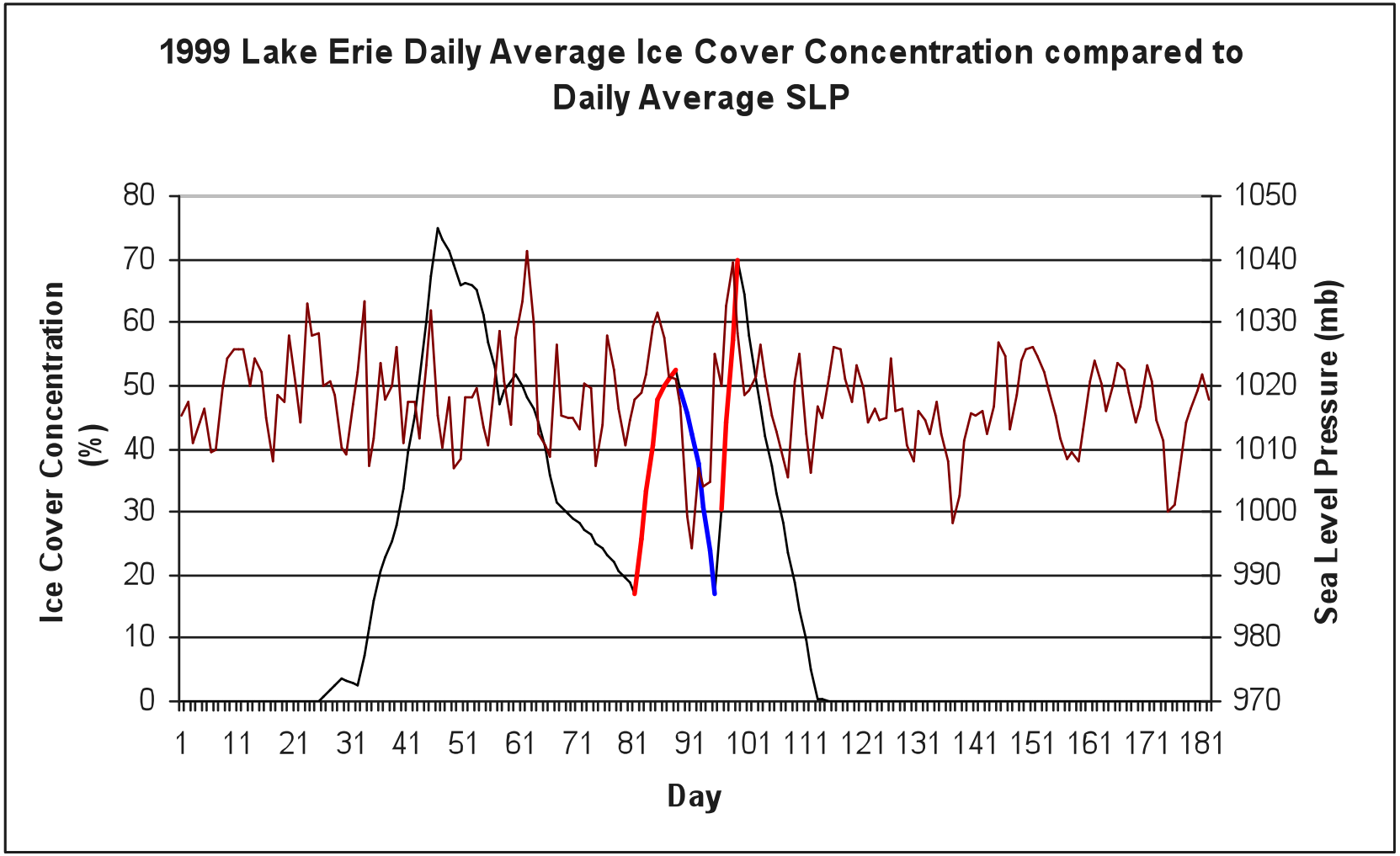
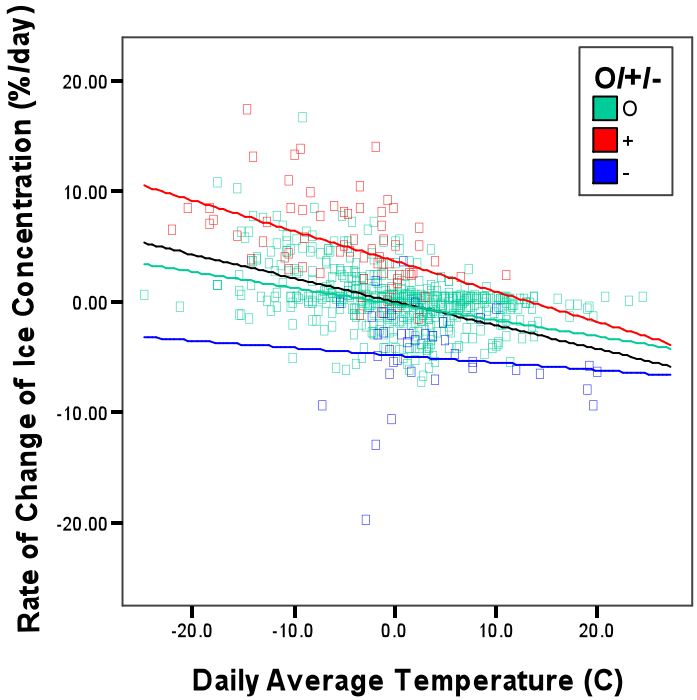
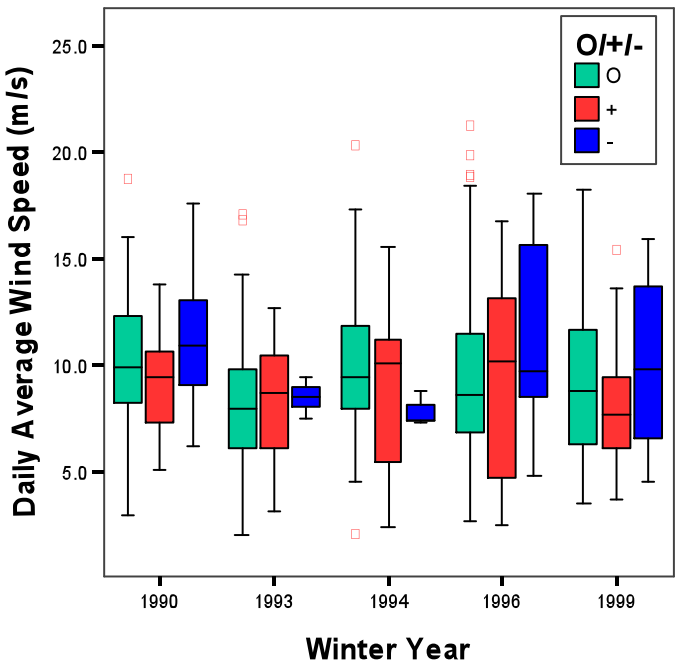


Preliminary Findings – Weather Conditions & Rapid Ice Cover Change

- Also investigated was the summation of “freeze” and “thaw” events over the five years to statistically analyze differences in atmospheric conditions between the two designations, as well as times when ice existed, but events were not identified. (Observations taken at KTOL)





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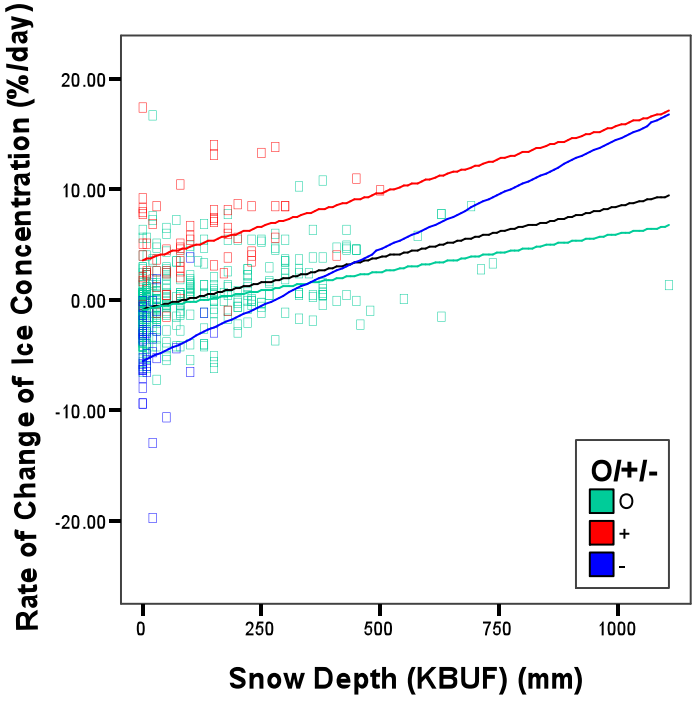

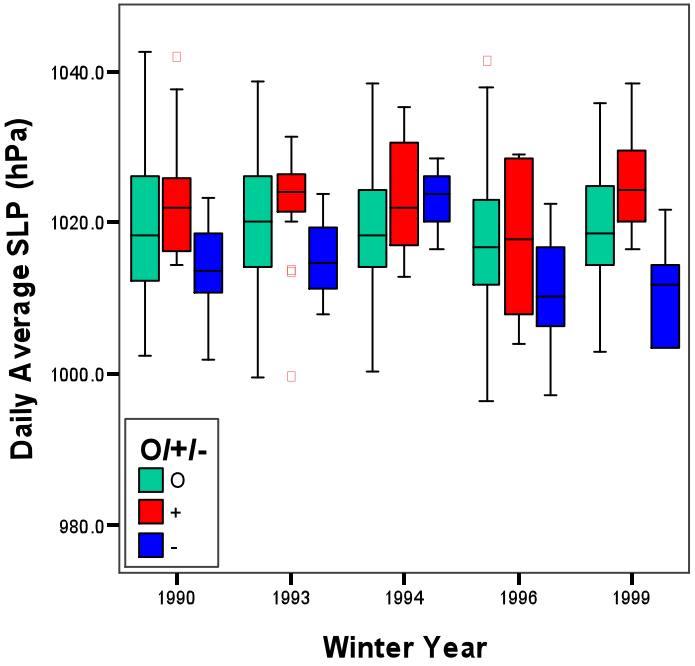

Future Avenues of Investigation

- Where to go from here?
  - Inclusion of additional events into the analysis
  - Analysis of events of different spatial categories (i.e. north shoreline vs. basin-wide events
  - Do different conditions carry different weights? What combinations can force rapid variations in ice cover concentration?
  - What type of relationship exists between the magnitude of a condition and its forcing on lake ice?
  - Further study of the lake heat cycle
    - Are there periods in seasonal cycle where ice cover concentration is more susceptible to certain types of environmental forcing?