A SYNOPTIC CLIMATOLOGY OF SEVERE CONVECTIVE WINDS IN THE NORTHEASTERN UNITED STATES

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INTRODUCTION

There have been several studies investigating the distribution of convective storms throughout the United States. Of the most common thunderstorm hazards (hail, wind, lighting, and flooding), convective winds are the most dangerous to both life and property (Schoen and Ashley 2010). Relatively few studies have focused on severe convective winds in the Northeast U.S. despite the fact that several states in this region are located in the main fatality axis associated with nontornadic convective winds (Black and Ashley 2009; Ashley and Mote 2005). The extremely large population that resides in this area and the overall lack of public hazard perception is cause for concern.

The purpose of this study is to develop a baseline climatology of severe convective winds in the Northeast United States that provides:

- A population correction for the inherent bias associated with wind report data in order to locate areas that receive more/less reports than population alone would predict.
- Interannual, annual, diurnal and spatial distributions.
- Composite synoptic maps representing significant event days.
- An examination of thermodynamic environments and indices associated with significant event days.

DATA & METHODS

Data were obtained from the Storm Prediction Center's (SPC) database containing convective wind damage reports collected by both the National Weather Service (NWS) and the SPC dating back to 1955.

POPULATION CORRECTION

Population count data for the study region were acquired from the Socioeconomic Data and Applications Center (SEDAC) at Columbia University. 0.25 degree grid boxes were created to represent both the 2010 population count and the total number of convective wind reports that occurred within each grid box throughout the 56-year period. This allowed for a simple linear regression equation to be calculated and applied to the population raster in order to create a layer showing the population-predicted wind reports for each grid box. The predicted wind report raster was then subtracted from the actual wind report raster and a hot spot analysis was performed using the difference raster values (Figure 1).

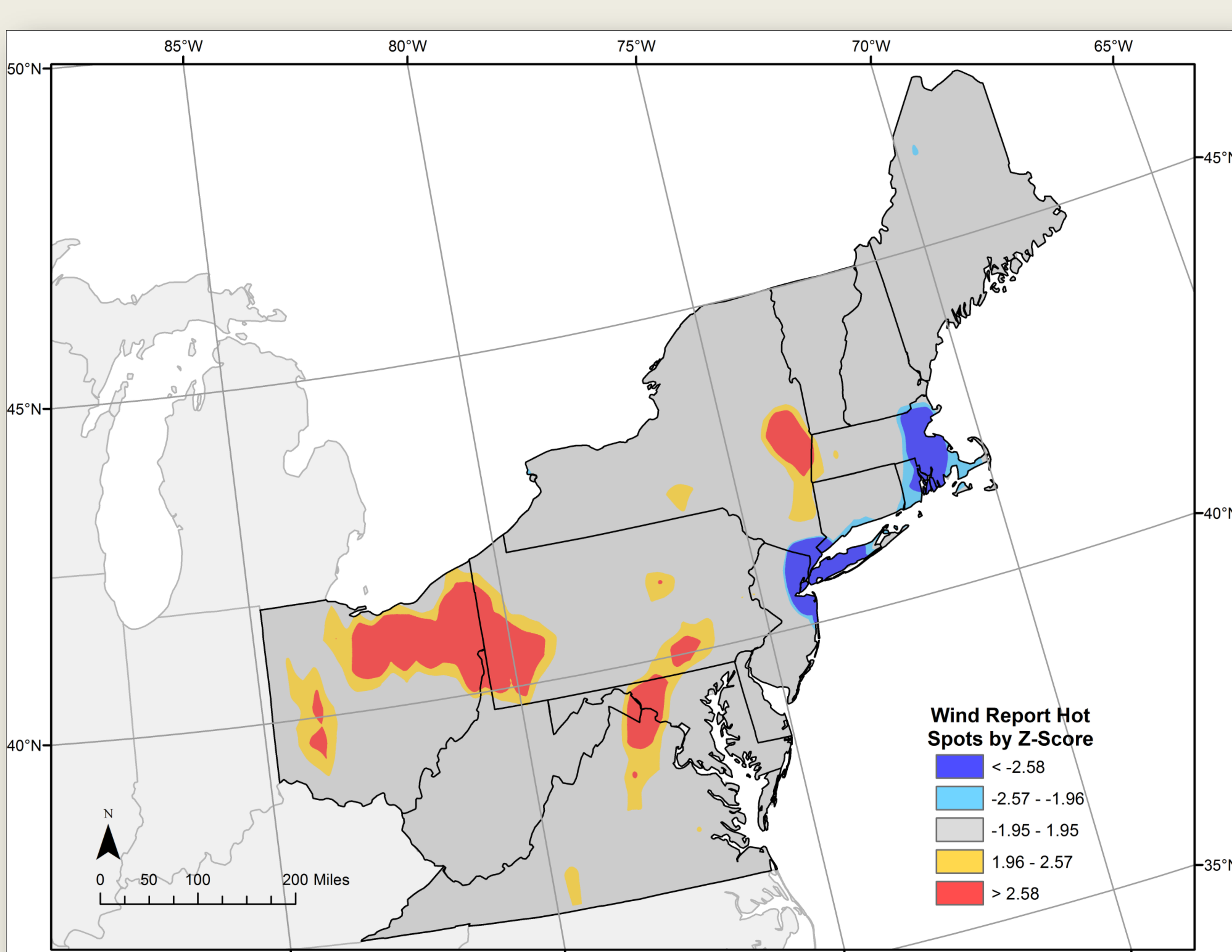


Figure 1: Hot spot analysis showing locations that received more or less convective wind reports than predicted by population alone.

METHODS (cont.)

SIGNIFICANT EVENT DAYS

For this study, days with reports at least three standard deviations above the mean were considered significant. A single day had to have at least 87 wind reports to be used in further analyses. Out of the 4,258 days with severe convective wind reports throughout the 56-year period, 104 days (13,405 reports) are regarded as significant.

SYNOPTIC MAPS

Composite mean and anomaly synoptic maps of the 104 significant event days were constructed using the National Atmospheric and Oceanic Administration's (NOAA) Earth System Research Laboratory (ESRL) webpage which creates composite variable maps from the NCEP/NCAR Reanalysis and other datasets for user-specified dates (Kalnay et al. 1996).

THERMODYNAMIC ENVIRONMENTS

Atmospheric soundings and severe weather indices from the 103 significant event days that fit the following criteria were acquired from the University of Wyoming's Department of Atmospheric Science website. Data were gathered from the 11 upper air stations around the Northeast that covered the largest area and captured the most reports. Similar to the method used by Craven and Brooks (2004), reports had to fall within 180km of the upper air station and occur between 2100 GMT and 0300 GMT (within 3 hours on either side of 00z; Figure 2).

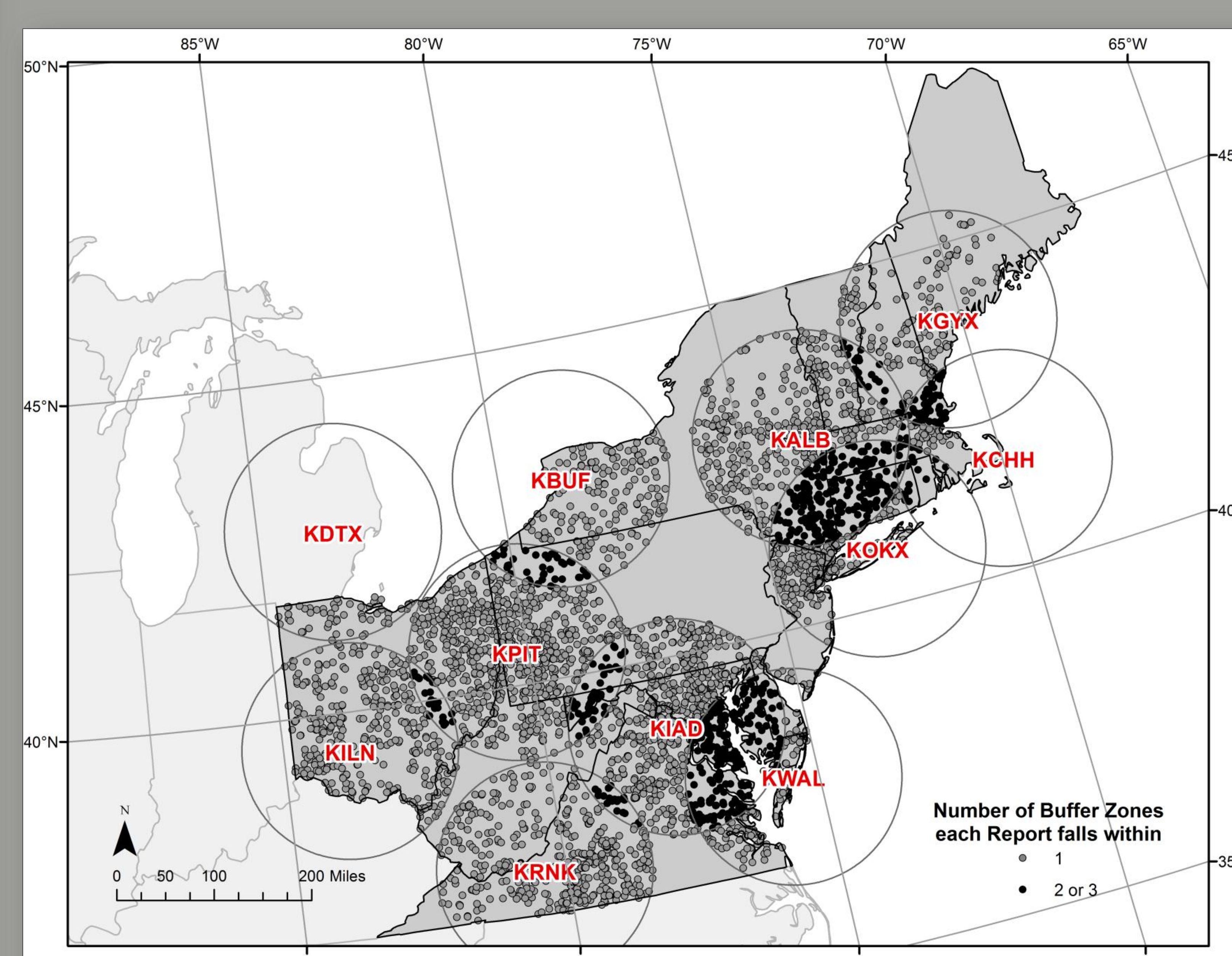


Figure 2: The 11 upper air stations used for analysis of thermodynamic environments shown with 180km buffers.

RESULTS & DISCUSSION

CONVECTIVE WIND CLIMATOLOGY

Reports were aggregated into 1 degree grid boxes to show the total number of wind reports that occurred in that area over the 56-year period. The grid boxes with the largest number of wind reports follow the I-95 corridor from Washington D.C. into the Hudson River Valley. The lowest amount of wind reports occur in Maine and around the periphery of the states due to the fact that those grid boxes encompass the edge of the study region (Figure 3).

Similar to previous studies conducted on convective winds, June and July are the months that experience the highest frequency of wind reports, followed by August and May (Kelly et al. 1985). Together, reports within June and July make up about 52% of those that occurred throughout the study period. Almost 50% of all reports happen in the four hours between 3pm and 7pm eastern standard time (Figures 4a-b).

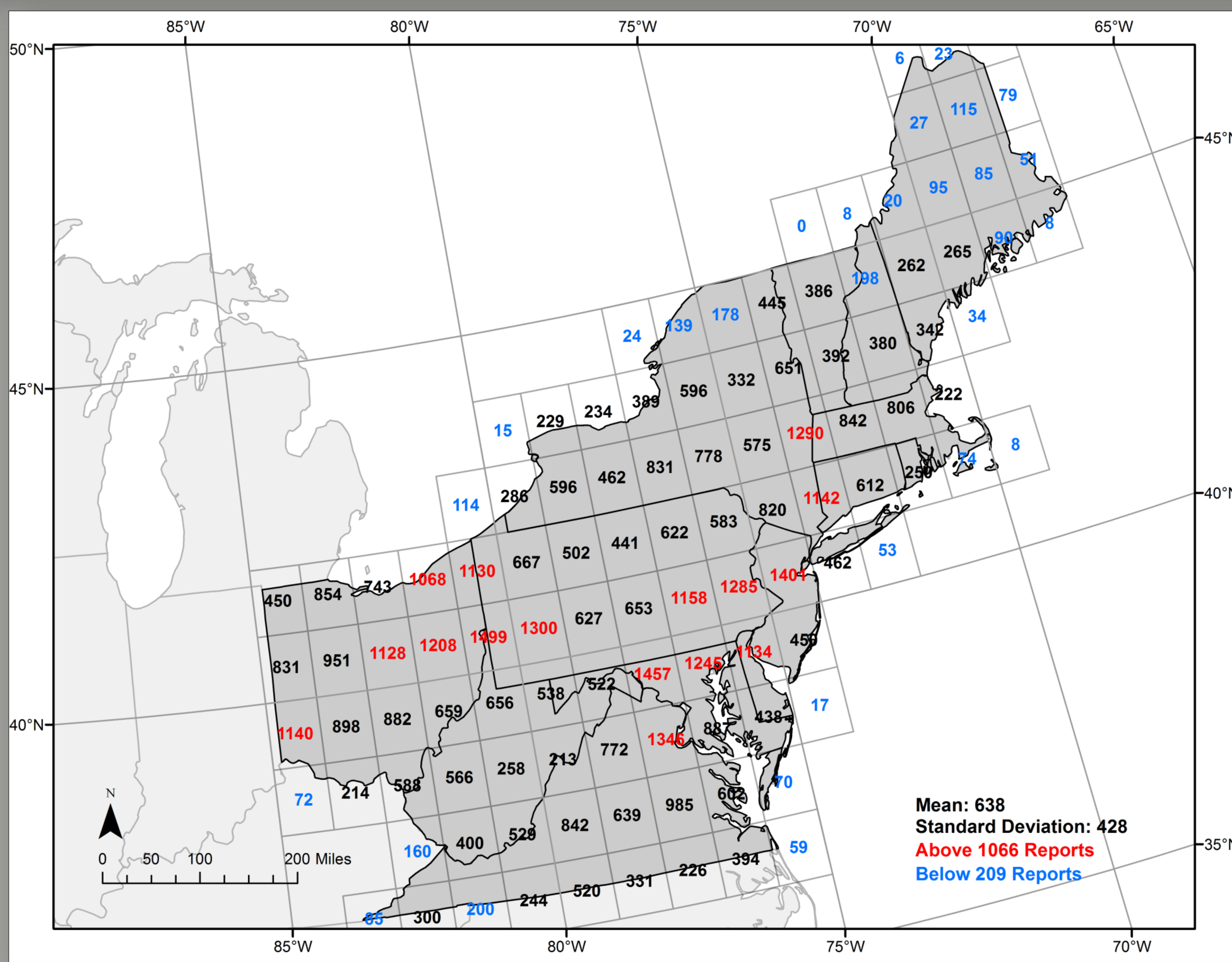
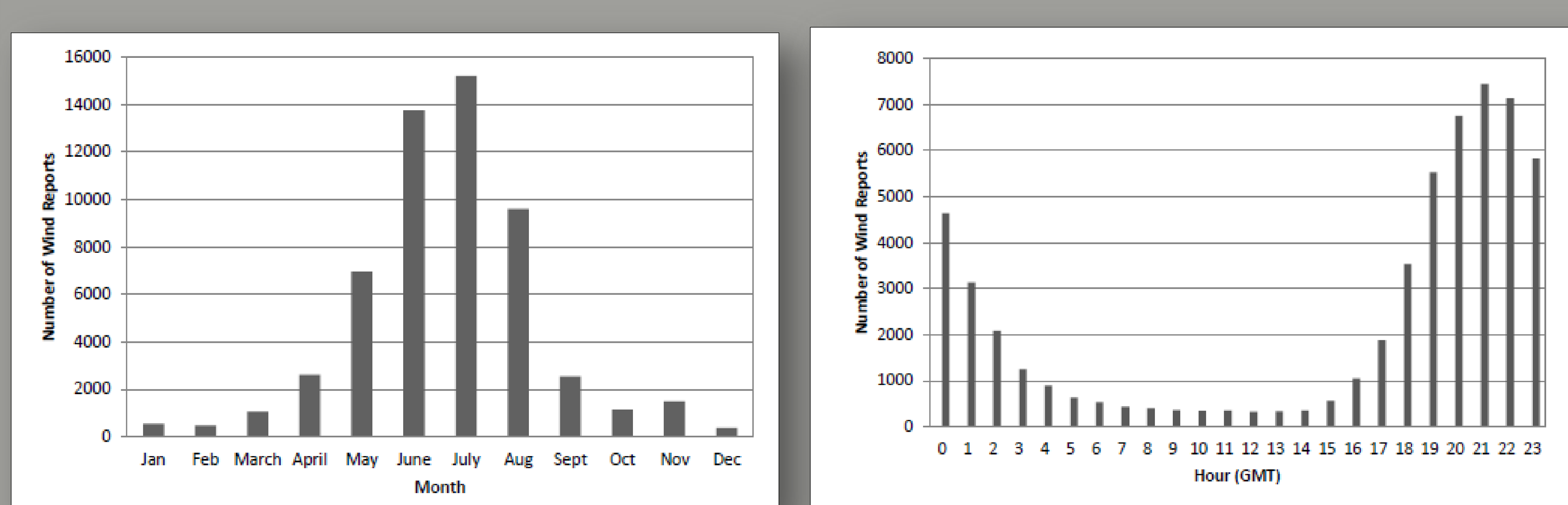


Figure 3: Map showing the number of wind reports that occurred within each 1° grid box throughout the 56-year period. Red numbers denote boxes that received a number of wind reports that is more than one standard deviation above the mean. Blue numbers represent areas with fewer reports than one standard deviation below the mean.



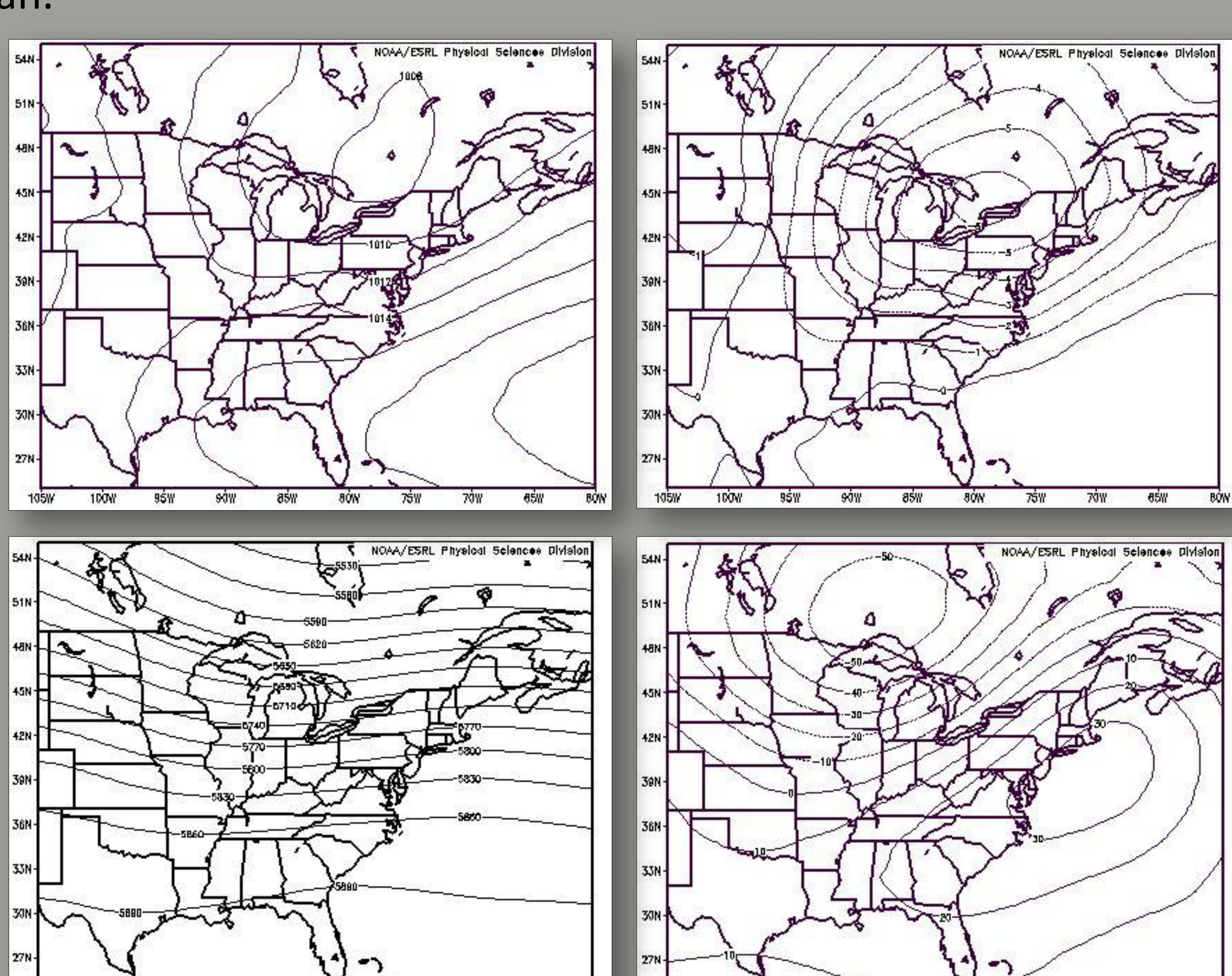
Figures 4a-b:
Annual and diurnal distributions of all convective wind reports from 1955-2010.

RESULTS & DISCUSSION (cont.)

SYNOPTIC PATTERNS

The daily composite mean sea level pressure (MSLP) map shows a weak 1008 hPa closed low north of New York state extending far into Canada (Figure 5a). Lombardo and Colle (2010) found that similar MSLP conditions occur 12 hours before linear convective events begin developing in the Northeast U.S. The composite anomaly map portrays a -6 hPa surface pressure anomaly northwest of New York, north of Lake Ontario (Figure 5b), showing that the lows associated with damaging convective winds are relatively strong for the time of year at which these events take place.

The composite mean 500 hPa geopotential heights are indicative of convective storm development as well (Figure 5c). The study region is located directly under the leading edge of a low-amplitude trough which is associated with upper-level divergence, positive vorticity advection and upward vertical movement of air. The mean composite 500 hPa geopotential height anomaly shows the true strength of the trough over the north-central U.S. (Figure 5d). The longwave trough centered above Lake Superior is 50 geopotential meters (gpm) below the 1981-2010 mean.

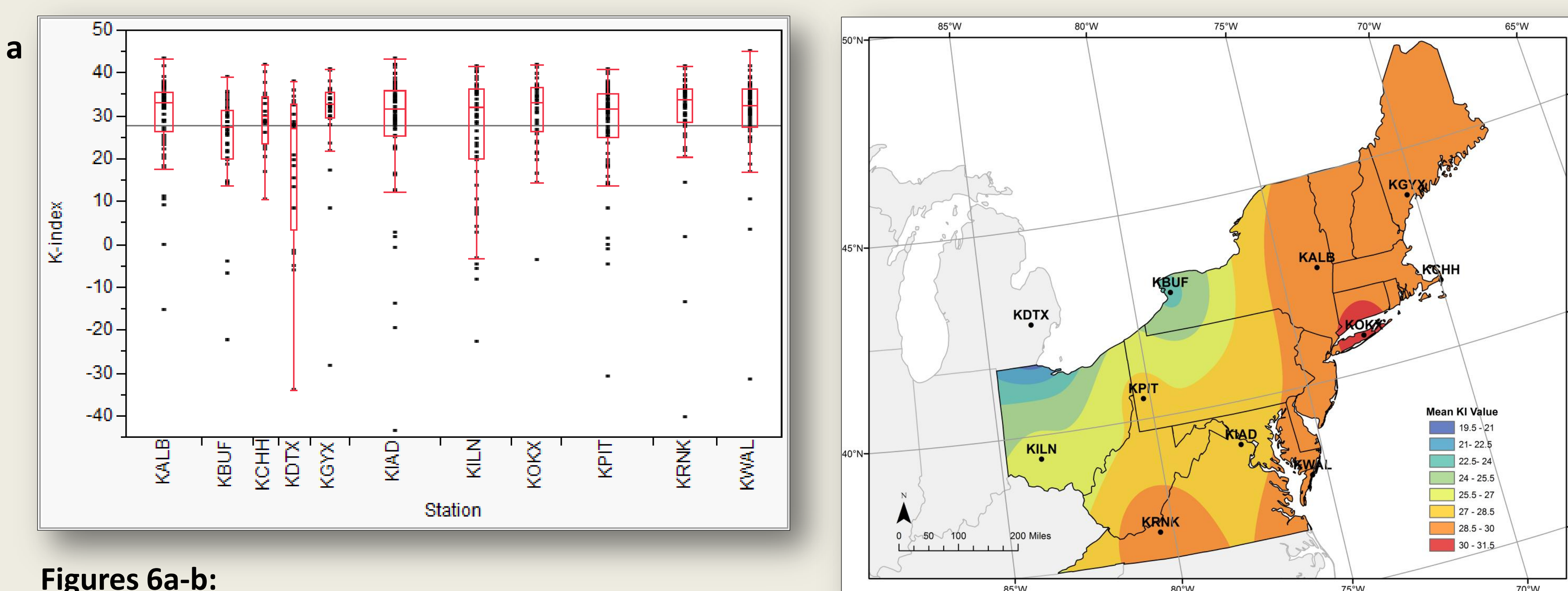


Figures 5a-d: Composite mean maps of (a) sea level pressure (SLP) (hPa), (b) SLP anomalies, (c) 500 hPa geopotential heights (m), and (d) 500 hPa geopotential height anomalies representing the 104 significant event days.

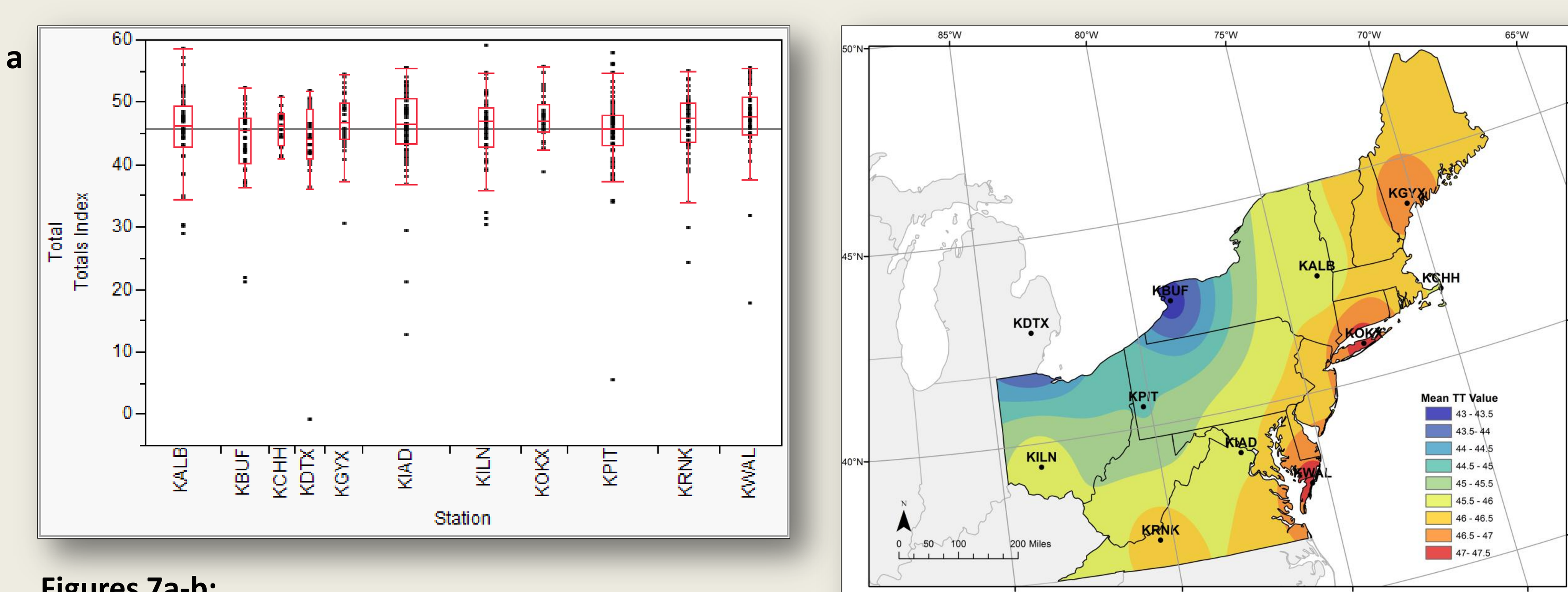
THERMODYNAMIC ENVIRONMENTS

Even though stability indices have been recognized to aid in forecasting severe weather and discriminating between different convective systems in the Great Plains, there is an added degree of complexity for the Northeast simply because of the Atlantic coastal boundary and topographical features (Lombardo and Colle 2010). Despite the obvious geographical dissimilarities, the thermodynamic environments associated with convective wind reports in the study region are investigated in order to identify which of the common stability parameters may aid in convective wind forecasting in the Northeast U.S.

From this analysis, it is concluded that the K-Index (KI) and Total Totals (TT) index are the most applicable of the severe weather indices in predicting severe convective winds for the study area. Well over 50% of the KI values were above 27.4 (the overall station mean) at 9 out of the 11 upper air stations, signifying moderate to high convective potential (Figures 6a-b). 72.5% of the sounding observations had TT values larger than 44, indicative of likely thunderstorm development (Figures 7a-b). CAPE, LI, VT, and SWEAT proved to be less effective predictors.



Figures 6a-b:
Box plots displaying the distribution of KI values and spatial interpolation of mean KI values associated with the 103 significant event days.



Figures 7a-b:
Box plots displaying the distribution of TT values and spatial interpolation of mean TT values associated with the 103 significant event days.

CONCLUSIONS

The Northeastern United States contains some of the largest population centers in the country, but the majority of the populace is unaware that convective surface winds pose such a great threat to life and property. The analysis of population bias, documentation of spatial/temporal occurrence distributions, and construction of composite synoptic patterns provide a better understanding of this phenomenon in the Northeast. The thermodynamic investigation suggests that CAPE may not be a large factor in determining the potential for severe convective winds in the Northeast (Figure 8). Instead, the stability index comparison indicated that the most useful indices for forecasting severe convective winds in the Northeast include the K-Index and the Total Totals Index.

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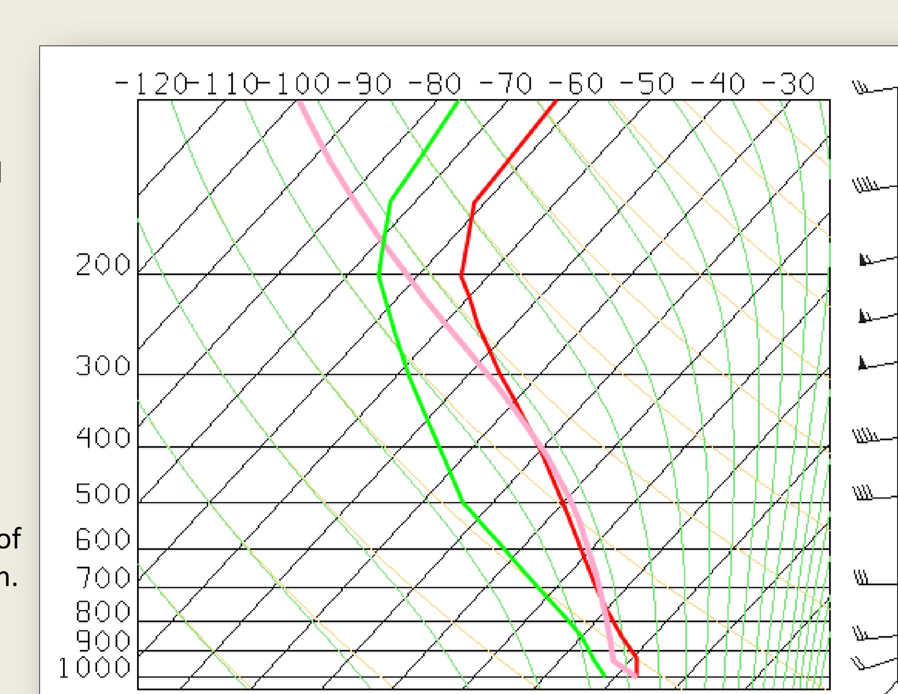

Figures 8: Composite mean skew-t diagram representing the 103 significant event days.