Linking Spatial Patterns of Tornado Outbreak Intensity with Climatological Variability

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Introduction

Understanding the connection between outbreaks of severe weather, including tornadoes, and patterns of climatological variability proves challenging due to inconsistent methods for quantifying intensity and no formalized definition of a tornado outbreak (TO). This study builds on previous work to address these limitations and offers a new method of quantifying outbreak intensity on regional scales. A resulting TO intensity index will be compared against indices of the El Niño Southern Oscillation (ENSO) to determine spatial patterns.

Hypothesis: Significant regional differences exist in tornado outbreak (TO) intensity and exhibit localized patterns of correlation with climate variability.

Study Area

To examine potential spatial patterns of TO intensity, the CONUS was divided into 7 study regions [Fig. 3] based on climatically consistent regions defined in [2]. States west of the continental divide had no TO clusters and were excluded. The study area was then divided into a grid of 25x25 km^2 squares cut off at coastlines.

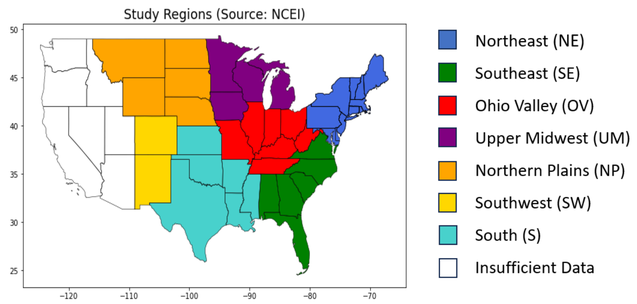


Fig. 3. States were color coded and grouped by similar climatology.

Future Work

Future work will explore underlying atmospheric conditions that make TO's stronger and how these conditions may be altered by ENSO and other patterns of climate variability impacting North America. Additional work will examine the usefulness of this TO intensity area index in forecasting TO events across a region for an upcoming tornado season.

Procedure

Methodology

Following the methodology in [1], tornado reports from the Storm Prediction Center were broken down into 24-hour days spanning 12:00 – 11:59 UTC for the period 1960 through 2022. Kernel Density Estimation (KDE) was used to group clusters of tornado reports into spatially cohesive outbreaks, and outbreaks were defined as KDE regions with more tornado reports than the median report count for a given year. Z-scores were computed for each outbreak by creating a ranked index based on 5 equally weighted variables: the number of total (EF0-5), weak (EF0-1), strong (EF2-3), and violent (EF4-5) tornadoes and total adjusted Fujita miles (product of path length and average F/EF rating).

Intensity Area

Since many tornado outbreaks spanned multiple climate regions, a new variable was defined to quantify the destructive potential of a TO based on spatial coverage in each region. This was computed as:

*Intensity Area = score * area*

Score is the z-score assigned per outbreak based on 5 non-meteorological characteristics of TOs. **Area** is the number of grid boxes with at least 1 tornado report for a given TO cluster [Fig. 1].

TO Intensity Distributions

Bootstrapping was performed on the resulting intensity area index with outbreaks classified based on the ENSO Oceanic Niño Index (ONI) average over November, December, and January (NDJ) of the following year. Data was resampled 1000 times and the 95% confidence intervals were examined.

April 27th, 2011 Outbreak Cluster

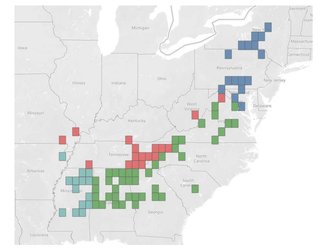


Fig. 1. Example outbreak cluster where each pixel represents a 25x25 km^2 grid box containing at least 1 tornado report

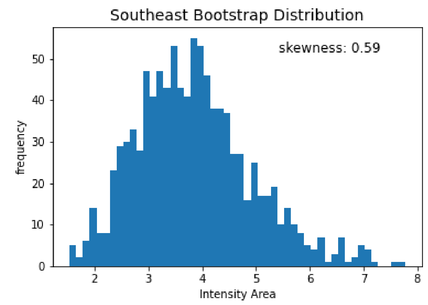


Fig. 2. Example distribution of TO outbreak intensity in the southeast from bootstrapping

Results

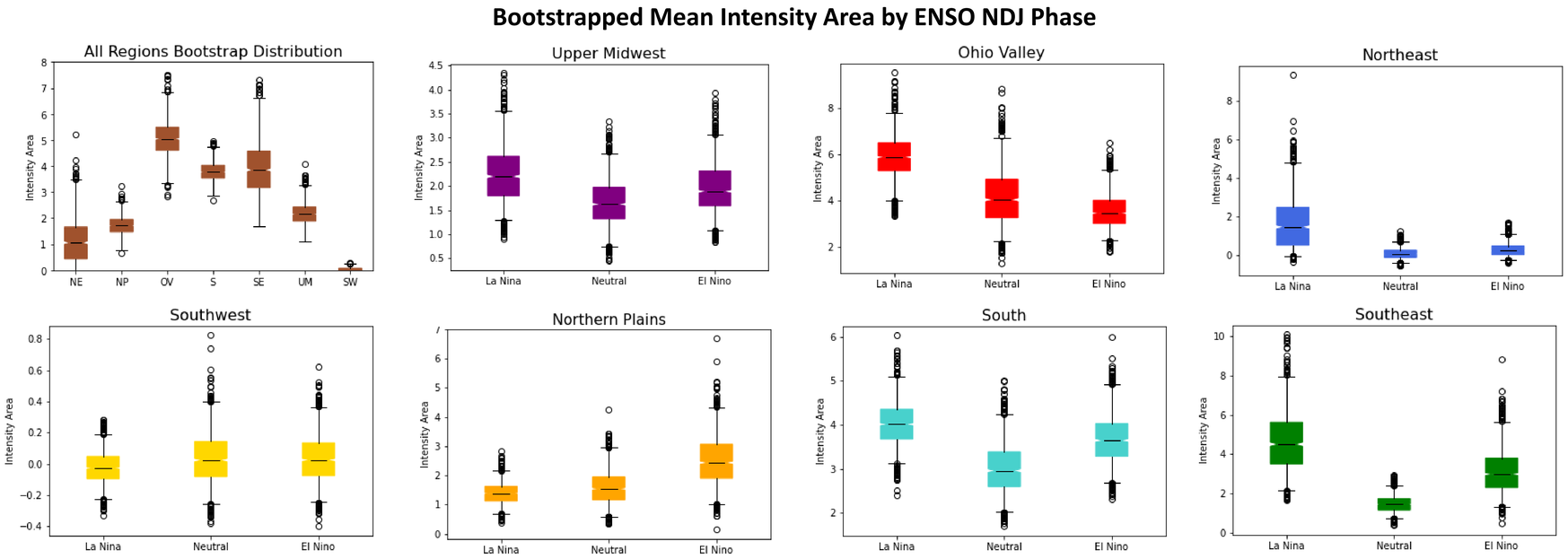


Fig. 4. Box and whisker plots of mean intensity area. Whiskers represent the 2.5% and 97.5% confidence intervals of the mean.

Findings

- Median TO intensity was greatest during La Nina years in 5 out of the 7 study regions (NE, SE, S, UM, and OV)
- Median TO intensity was weakest during neutral years in 4 of the 7 study regions (UM, NE, SE, and S)
- The Northern Plains experienced a reverse of the broad trend, with El Nino years having the most variability and the greatest median intensity
- The southwest, encompassing NM and CO, experienced little variability between ENSO phases
- The southeast had the most significant change in intensity (least overlap) related to ENSO between La Nina and neutral years

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2. Thomas R. Karl and Walter James Koss, 1984: *"Regional and National Monthly, Seasonal, and Annual Temperature Weighted by Area, 1895-1983."* **Historical Climatology Series 4-3**, National Climatic Data Center, Asheville, NC, 38 pp.