Atmospheric Efficiencies for Severe Weather

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Introduction

According to the Storm Prediction Center of NOAA's National Weather Service severe weather is defined as an occurrence of one or more of the events associated with a severe thunderstorm. These criteria are: a tornado of any intensity level, wind gusts that are equal to or in excess of 50 knots (58 mph), or hail that has a diameter of an inch or greater.

The damages associated with severe weather occurrences are not insignificant. Studies have found that the damages due to hail storms alone exceeds $1.7 billion dollars (**Changnon 1997** in 2015 dollars), and, according to the National Oceanic and Atmospheric Association (NOAA) an average of 76 people are killed by tornadoes in the United States every year. Understanding how and why severe wind, hail, and tornadoes occur is important because it will help one to better understand where and when a severe weather event is going to occur, so that those who it will impact can be properly prepared.

Previous studies have shown the relationship between environmental parameters, especially how high values of CAPE, 0-1km SRH, 0-3 km SRH, and vertical wind shear are associated with tornadoes and severe hail. (**Barrett and Gensini 2013** and **Barrett and Henley 2015**). The ingredients for severe weather are known, but what remains unknown is how efficient different environments are at producing severe weather. For example, if an area in Texas has lots of CAPE a lot of the time, but there are only a few tornadoes a year, it is not as efficient as somewhere in North Dakota that only has high CAPE twice a year, and every time there is high CAPE, a tornado occurs.

Purpose

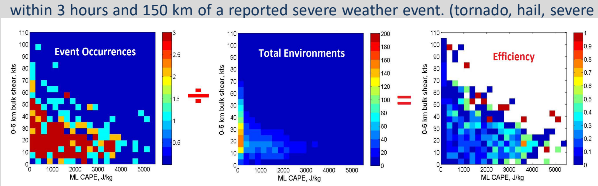
The main purpose of this research is to understand the spatial distributions of environmental efficiencies as they pertain to severe weather occurrences.

Data

- Environmental parameter data came from the Integrated Global Radiosonde Archive (IGRA), which is maintained by NOAA's National Climate Data Center
- Analysis was done for 69 different stations across the United States from 1994-2013.
- Severe wind, severe hail, and tornado occurrences came from a database maintained by the Storm Prediction Center

Methods

- CAPE, 0-1 km storm relative helicity (SRH), 0-3 km SRH, and 0-6 km bulk wind shear were taken from all of the 0000Z soundings by station
- Every recorded environment was assigned to one of the blocks within the grid on each plot based on its environmental parameters, and a count was kept of how many times an environment was assigned to each box.
- The number of "hits" was put on a color scale, and then plotted with on each of the "CAPE vs." plots. These were the "total number of environments" plots.
- Next the radiosonde data was grabbed for all the atmospheric soundings that were within 3 hours and 150 km of a reported severe weather event. (tornado, hail, severe



- However, to get rid of noise within the data, the "smoothn" function was applied to both the "total number of environments" and the "number of times as event occurs" plots at every station, and a new "smoothed" efficiency was calculated and plotted for each parameter combination.
- The following three equations were applied to both the weighted average and the 50% average parameter data to get six values:
  - $\sqrt{CAPE\ x\ 0-1\ SRH}\ \sqrt{CAPE\ x\ 0-3\ SRH}\ \sqrt{CAPE\ x\ 0-6\ wind\ shear}$
- Each value was assigned a square and a color (higher values had bigger squares and warmer colors).
- The colored squares were then plotted, by "value combination" (i.e. weighted average of CAPE x 0-1 km SRH) by station location on a map of the United States.

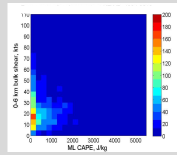


Fig. 1: Total number of environments for CAPE vs. 0-6 km bulk wind shear at FWD

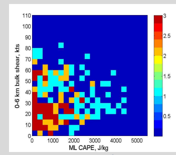


Fig. 2: Raw plot of severe wind events for CAPE vs. 0-6 km bulk wind shear at FWD

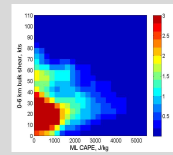


Fig. 3: Smoothed plot of severe wind events for CAPE vs. 0-6 km bulk wind shear at FWD

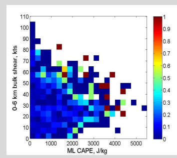
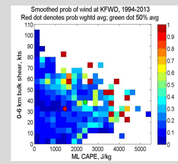


Fig. 4: (left) Raw plot of severe wind efficiency for CAPE vs. 0-6 km bulk wind shear at FWD

Fig. 5: (right) Smoothed plot of severe wind events for CAPE vs. 0-6 km bulk wind shear at FWD red dot is the weighted average, green dot is the 50% average



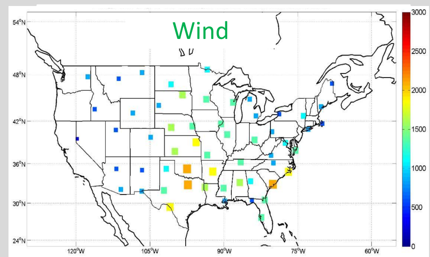


Fig. 6: 50% average of CAPE x 0-6 km bulk wind shear for severe wind

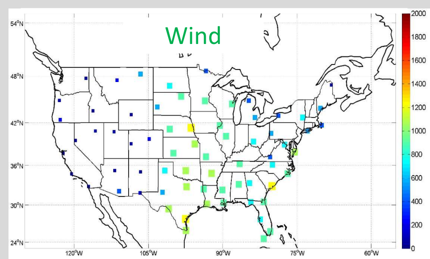


Fig.7 : Weighted average of CAPE x 0-6 km bulk wind shear for severe wind

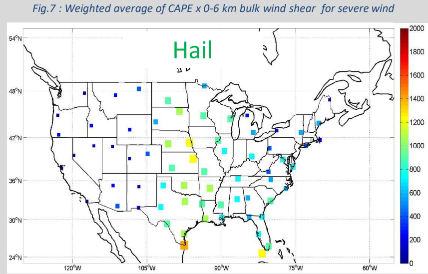


Fig.8 : Weighted average of CAPE x 0-6 km bulk wind shear for hail

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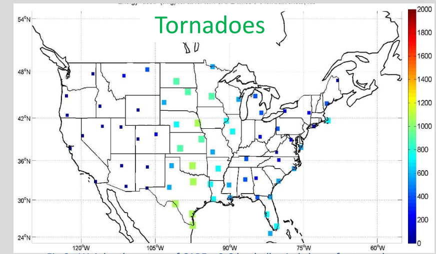

Fig.9 : Weighted average of CAPE x 0-6 km bulk wind shear for tornadoes

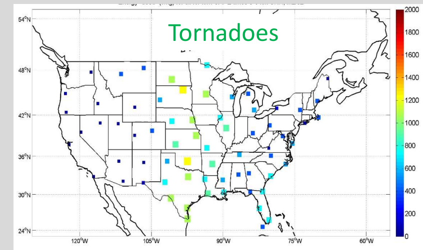

Fig.10 : Weighted average of CAPE x 0-3 km SRH for tornadoes

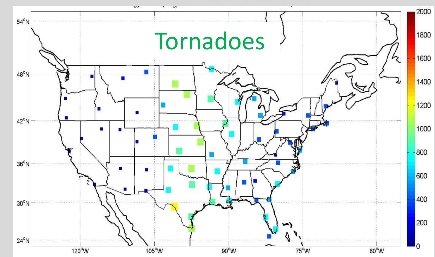

Fig.11 : Weighted average of CAPE x 0-1 km SRH for tornadoes

Results

- The Midwest has higher average CAPE, 0-6 km wind shear, 0-1 km SRH, and 03- km SRH for all severe weather events for severe wind, hail, and tornadoes.
- The Southeast also has higher average CAPE, shear, and SRH for both hail and severe wind occurrences.

Conclusions

- There is a spatial distribution of environmental efficiencies in the United States.
- Severe wind events and hail storms are, on average, more severe in the Midwest and the Southeast.
- Tornadoes are, on average, more severe in the Midwest than anywhere else in the country.

Future Work

- Look at how time affects efficiency- season, year
- Explore how other meteorological phenomena affect efficiency- MJO, El Nino/ La Nina
- Use a smaller grid-size to look at how more minute differences in CAPE, shear, and SRH combinations affect efficiency.
- Compare the efficiencies for the same parameter combinations at different stations