S85 SYNOPTIC-SCALE PRECURSORS AND CHARACTERISTICS OF HIGH-END TORNADO OUTBREAKS IN THE SOUTHEASTERN REGION OF THE UNITED STATES.

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1. INTRODUCTION

Atmospheric conditions and patterns preceding high-end tornado outbreaks (HETO) are important to understand, as such events often lead to loss of life and property. Examining synoptic-scale features leading up to tornado outbreaks is important to forecasting such events. However, the severity of these tornado outbreaks is difficult to predict (Mercer et al. 2009).

In the southeastern region of the United States, the spring is the primary tornado outbreak season with most events occurring between January and June (Fuhrmann et al. 2014). These temporal and spatial domains were used in attempt to identify the differences between differing severities of tornado outbreaks. Objective categorization of tornado outbreaks resulted in two types: HETO and Moderate-end Tornado Outbreaks (METO). The focus of this study was to identify synoptic-scale features corresponding to HETO by comparing HETO and METO. After qualitatively comparing HETO and METO, weighted anomalies were calculated with respect to a 30-year climatology and statistical significance was assessed.

2. DATA AND METHODOLOGY

The main task for this study involved comparing composite plots of HETO and METO. In order to create the composite plots, a domain was first defined. The southeastern region of the United States included Mississippi, Alabama, Georgia, North Carolina, South Carolina, Tennessee, and Kentucky. Data from the NOAA NCEI Storm Events Database was used from 1 January – 31 May, 2001 -2014, inclusive, to produce a list of events that took place in any part of the defined domain (NOAA NCEI 2016). Each day in the domain was considered an event and all of the events were sorted from most tornado reports in a day to the least amount of reports in a day. Ranked first was 27 April 2011 with around 300 tornado reports, and all of the days in the domain with zero reports were ranked last. From this sorted list, objective categories of tornado outbreaks were produced using percentile ranges: HETO, METO, and Low-End Tornado Outbreak (LETO) (Fig. 1).

90th Percentile (≥20 Tornadoes)	High–End Tornado Outbreak
85th – 75th Percentile (9-14 Tornadoes)	Moderate-End Tornado Outbreak
70th Percentile (≤5 Tornadoes)	Low-End Tornado Outbreak

Figure 1: The three categories of tornado outbreaks based on percentile ranges. Percentiles were determined based on the number of tornado reports in a given day.

The separation between the different outbreak categories helped to eliminate borderline cases and make the categories more distinct. Additionally, only the top 19 events in each category were used for compositing. After comparing individual events of all three categories, LETO events were no longer considered for the study because of the large variability in synoptic setups. HETO and METO events proved to have more consistency with regards to synoptic characteristics.

For the events in the HETO and METO groups, daily-averaged NCEP Reanalysis-2 data was collected for each event (Kanamitsu et al. 2002). This data included 250 hPa height and wind speed, 500 hPa height and absolute vorticity, 850 hPa height, wind speed, and equivalent potential temperature, sea level pressure (SLP), and 1000-500 hPa thickness. For each group (HETO and METO), the corresponding reanalysis data was composited each day from three days prior (d = -3) to one day (d = +1) after each tornado outbreak. The same

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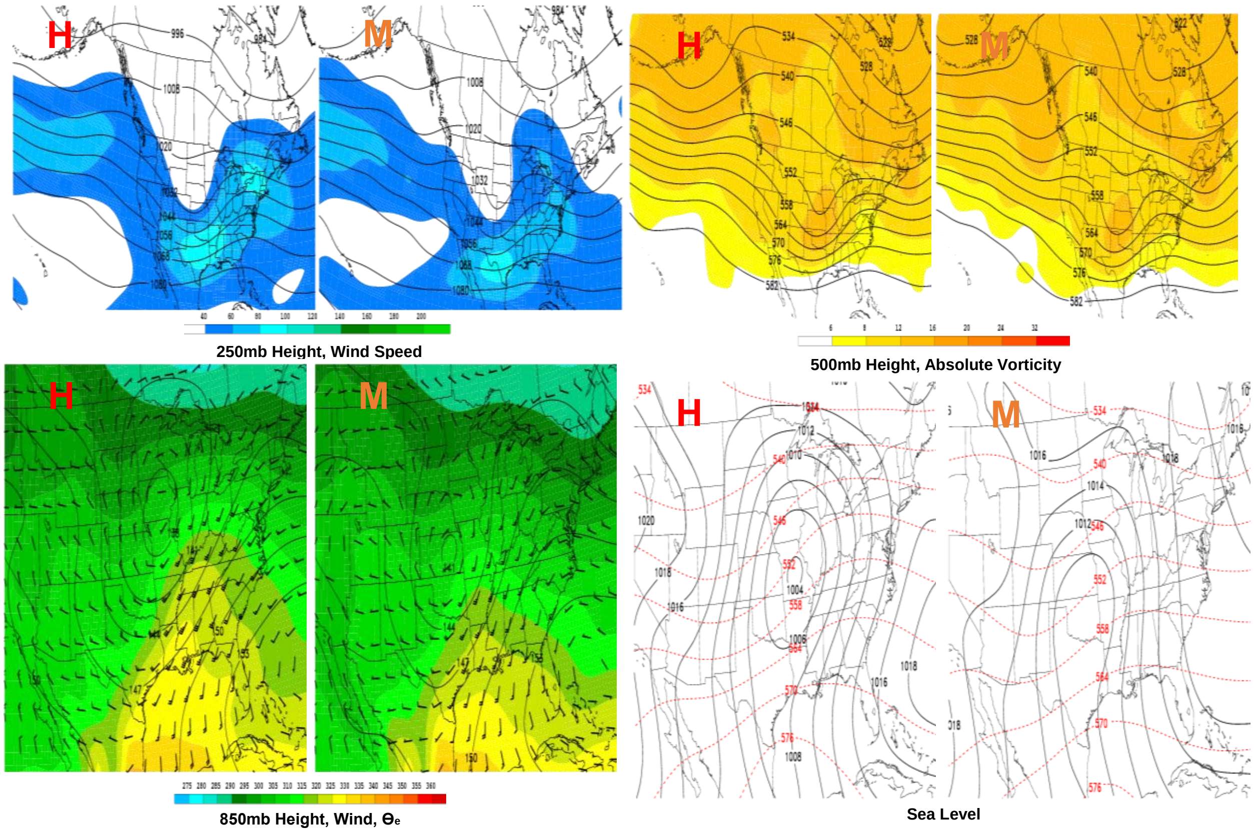

Figure 2: Comparison of the HETO composites, marked with a red "H," to the METO composites, marked with an orange "M" the day the actual composited outbreaks occurred. Looking at the synoptic settings for both composites during the time of the outbreaks shows key synoptic differences between high-end and moderate tornado outbreaks. In the top left, composited 250 hPa winds (ms^{-1}, shaded) and, composite 250 hPa heights (dam, black solid contours). In the top right, composited 500 hPa absolute vorticity (s^{-1}, shaded) and, composite 500 hPa heights (dam, black solid contours). In the bottom left, composited 850 hPa equivalent potential temperatures (K, shaded) and, composited 850 hPa heights (dam, black solid contours) and, 850 hPa wind barbs. In the bottom right, composited sea-level pressure (hPa, black solid contours), and composited 1000-500hPa thickness (m, red dotted contour).

compositing technique was used to produce composite soundings for various locations throughout the Southeast.

For the quantitative assessment, the HETO and METO composite plots were compared to the 1981-2010 30-year climatology by calculating weighted anomalies of both HETO and METO events. In order to represent this, the mean values from the HETO and METO events were contoured on a plot, then the respective weighted anomaly was shaded against the contours to highlight extreme values. Using a two-tailed, 99th confidence interval t-test resulted in a true quantitative comparison of the HETO versus the METO and also both types of outbreaks versus climatology. 99th and 95th confidence interval t-test contours were added to the plots to show regions of statistical significance in the variables that were used.

3. RESULTS AND CONCLUSIONS

Comparing composite plots proved to show synoptic-scale differences between the HETO and METO events. After comparing the differences between each, the HETO events showed stronger, more pronounced features in every case compared to the METO events. At the 250 hPa level there was a stronger upstream jet streak in the two days before the outbreak along with dual jet divergence over the Southeast on was deeper before the day of the outbreak and was more negatively tilted by the day of the outbreak with a closer proximity to the Southeast. The 850 hPa level showed a more prevalent low-outbreak. At 500 hPa, the trough level jet with higher equivalent potential the day of the temperatures. At the surface, the low pressure system was much deeper (Fig. 2). Comparing

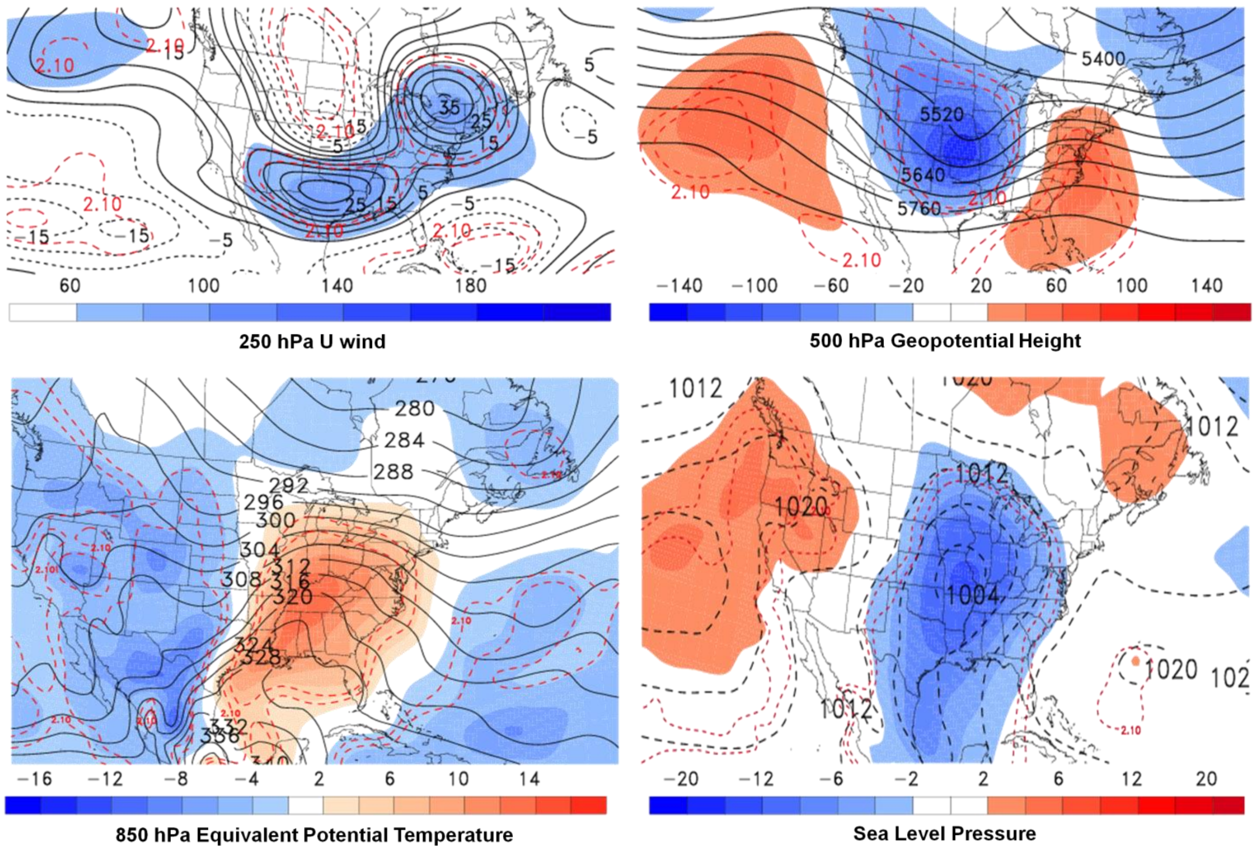

Figure 3: In the top left, 250 hPa zonal winds weighted anomalies (ms^{-1}, shaded), composite 250 hPa mean wind (ms^{-1}, black contours) and, statistical significance from the two-tailed student's t-test at the 95th and 99th confidence intervals (red dashed contours.) In the top right, 500 hPa geopotential heights weighted anomalies (m, shaded), composite 500 hPa mean heights (m, black solid contours) and, statistical significance from the two-tailed student's t-test at the 95th and 99th confidence intervals (red dashed contours). In the bottom left, 850 hPa equivalent potential temperature weighted anomalies (K, shaded), composite 850 hPa mean equivalent potential temperature (K, black contours) and, statistical significance from the two-tailed student's t-test at the 95th and 99th confidence intervals (red dashed contours.) In the bottom right, sea-level pressure weighted anomalies (hPa, shaded), composite mean sea-level pressure (hPa, black dashed contours) and, statistical significance from the two-tailed student's t-test at the 95th and 99th confidence intervals (red dashed contours.)

sounding composites of the HETO and METO cases showed additional differences, including higher dew point temperatures, steeper low and mid-level lapse rates and, stronger veering wind profiles from the surface to 500 hPa.

Furthermore, results from the anomaly and t-test analysis showed significant anomalies in the jet stream, mid tropospheric heights, low level moisture and, mean SLP compared to the 30-year climatologies. Similar to the HETO and METO composites comparison, the HETO anomalies and statistical significance were more pronounced in every way.

For the 250 hPa anomalies and statistical significance, only the zonal component of the wind was used. Referring to Figure 3, the HETO cases showed a strong positive anomaly of the zonal wind centered over central Texas. The t-test showed a statistical significance overlaying the same area. Similar features are present in the two days before the outbreak as well. The HETO 500 hPa height anomaly plot showed strong negative anomalies centered over Kansas with mild positive height anomalies on either side of the trough for the day of the outbreak. Specifically, the downstream ridge showed a strong anomalous signature. This ridge structure plays a role in the high equivalent potential temperatures in the Southeast. The t-test showed statistical significance between the HETO cases and the 30-year climatology from the Canadian Rockies to the Mississippi Valley. Similar, yet milder anomalies existed in the two days before the outbreak. The equivalent potential temperature HETO anomaly plot was consistent the 250 and 500 hPa plots. The equivalent potential temperature showed a definite positive anomaly over the entirety of the Southeast with the t-test again showing statistical significance over most of the eastern United States all for the day of the outbreak. The two days before the outbreak showed moderate anomalies but shifted farther towards the West. The SLP anomalies patterned very closely with the equivalent potential anomalies for the day of the outbreak and the two days before. SLP, like the other variables, showed statistical significance with an area from the Great Lakes through the Gulf of Mexico. The only difference was the SLP statistical significance stayed in the same area for the most part in the two days before the outbreak. The METO case anomalies were much more subtle compared to the HETO cases. In the HETO cases, atmospheric patterns and synoptic features were easily identified by looking at the anomalies to the 30-year means where this was not the case for METO.

Overall, the HETO cases proved to have stronger synoptic forcing in the different parameters examined in this study compared to the METO cases for the day of the outbreak. The days preceding an outbreak also showed more defined synoptic features for the HETO cases. Looking at the anomalies gave a quantitative description of the differences between a HETO and METO to the 30-year climatology. Examining the same material for the two days before an outbreak also showed notable differences between HETO and METO. The results of the obvious differences between HETO and METO for the day of the outbreak and the days before the outbreak are useful in helping to identify key signatures associated with deadly tornado outbreaks.

4. FUTURE WORK

The data sets used for the HETO and METO composites were just one particular set of data. In the future, comparing different percentiles of number of storms, and examining 6-hourly NCEP Reanalysis-2 data to create the composites would result in additional data for HETO to METO comparison. Moreover, looking at more severe weather-related variables, such as CAPE and helicity, would better describe the difference between HETO and METO.

5. REFERENCES

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