Determining Environmental Parameters Most Important for Significant Cool Season Tornadoes across the Gulf Coastal States

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Abstract

The purpose of this study is to derive a set of parameters for improved forecasting of significant cool season tornado occurrences in the coastal states along the Gulf of Mexico during the period from mid November through mid February. It is important to examine these tornado events because they are characterized by very strong vertical shear and weaker instability than the more typical warm season tornado events. These cool season tornado occurrences are rare, which makes them more difficult to forecast. Forecasting these tornado events are essential since the chance for loss of life is greater with stronger tornadoes. The study examined F2 and stronger tornado events from six cool seasons (1998-2004). Temperatures, dew points and wind data were examined at various levels to see which parameters were better discriminators for these types of events.

1. Introduction

A study by Galway and Pearson (1981) found that 9% of all tornado outbreaks occur during the cool season in the Gulf Coastal states, extending from eastern Texas to the Florida Panhandle. Tornado outbreaks during the cool season are generally characterized by very strong vertical shear and weak instability. These tornadoes can be more difficult to forecast than in the warm season due to their more infrequent occurrence and weak instability. However, when they occur in the cool season, they are often significant (Galway and Pearson 1981). Although forecasting these tornadoes is challenging, they are critical to the mission of the National Weather Service (NWS) for saving lives and property.

A previous study by Galway and Pearson (1981) suggested these winter tornado outbreaks are due to cyclones moving through the Gulf Coastal states, in addition to a strong baroclinic zone. Branick (1981) stated that from the late winter into early spring, this pattern is most often associated with a westerly subtropical jet stream across the Gulf coastal states. The track of surface lows through the Gulf Coastal states helps advect moisture northward and increases the threat of tornadoes. Surface boundaries increase the risk of significant tornadoes due to the enhanced low level shear (e.g., 0-1 km shear), which is an important component for the development of supercells and tornadoes (Thompson et al. 2003). Johns and Doswell (1992) stated that supercell thunderstorms originate with winds that veer strongly with height. Thompson's (1998) study found that the majority of the supercells in his dataset during the cool season were tornadic. Johns and Doswell (1992) stated that the most critical environmental factors affecting supercell development involve the strength and nature of tropospheric winds, particularly in the lower and middle layers. The shear in the mid levels can be important to supercell development because it removes precipitation from updrafts (Johns and Doswell 1992).

The goal of this study is to derive a set of parameters for improved forecasting of significant cool season tornado occurrences in the Gulf Coastal states. The winds at various levels were examined to see if a consistent signal was evident in the wind direction and speed at different levels throughout the troposphere. Temperatures and dewpoints at various levels were also examined to determine the mean thermodynamic conditions associated with significant tornadoes.

2. Methodology

There were several sources used to derive the data set in this study. The tornado events were first extracted from Severe Plot (Hart 1993). This program contains the official NWS StormData reports of tornadoes, hail, and damaging wind. A compilation of tornado events was obtained from November 15 through February 15, during the years 1998 to 2004, in an area from east Texas to the Georgia/Florida Atlantic coast. After the tornado events were plotted, a tabular option was chosen for a printable version of the tornado events. This table was copied and pasted into a Microsoft Word file. The Word file was then reorganized to take out tornado events that were not located within our domain.

After the data reorganization, the tornado date, F-scale rating, and locations were entered into Microsoft Excel. Each cool season was given a separate spreadsheet for the tornado events. When the table was extracted from Severe Plot, the location was provided in a FIPS (Federal Information Processing Standard) county code format, along with the state where the tornado originated. The FIPS codes were then decoded by the county code state maps produced by NOAA's (National Oceanic and Atmospheric Administration) MIRS (Management Information Retrieval System) branch. After the county codes were translated, there were columns added on the spreadsheet for the examined parameters. The hourly surface temperatures, dewpoints, and wind speeds were analyzed. Also, the temperatures, dew points, wind direction and wind speeds at 925 mb, 850 mb, 700 mb, and 500 mb were assessed. The winds at 250 mb were also analyzed. This data was provided through the Plymouth State University Meteorology website. Archived objectively analyzed maps of hourly surface data and upper air data for 00 UTC and 12 UTC were obtained from the website. These maps are derived from hourly observations and sounding data, which are contoured from each site using Weather Processor (WXP) and Man Computer Interactive Data Access System (McIDAS) software. Interpolation of the data was required to determine the most accurate meteorological conditions near the time of the tornadic event. Especially when tornado occurrence was 3 or more hours before or after 12 UTC and 00 UTC, more interpolation was necessary between raob times and/or locations. Tornado events that occurred more than three hours before or after the 00 UTC and 12 UTC raob time, resulted in stronger reliance on 18 UTC soundings when available. In some instances, frontal passages necessitated a further reliance on interpolation between multiple soundings.

After representative data was gathered for each tornado, the significant tornadoes, F2 or greater, were extracted to another Excel file. This new file of significant tornadoes was used to provide statistical information about each of the parameters examined for the cool season tornado occurrences.

3. Results

a. Time and Events

During the six cool seasons, there were 59 significant tornadoes that were examined during this study. These 59 tornadoes occurred on 17 separate days. Out of the six cool seasons, the time of day appeared to have a strong signal for when these tornadoes were most likely to occur. Of the 59 significant tornado events, 32% occurred between the hours of 18 UTC and 21 UTC (Fig. 1). Twenty percent occurred during the mid to late evening. However, 17% of the significant tornadoes occurred during the overnight and early morning hours (Fig. 2). This also corresponds with previous studies on tornado climatology in the Gulf Coastal states (Fike 1993)

b. *Temperature and Dewpoint*

The vertical profiles from the surface to 700 mb were nearly saturated (Fig. 3). At the surface, temperatures were above normal. The average temperature for significant tornado events was 68F degrees while the normal high temperatures during the cool season across this region are in the mid 50's F. The average dewpoint was in the mid 60's F (Fig. 3). Above normal temperatures and very high moisture content in the lower levels of the atmosphere appears to be an essential ingredient for the formation of significant tornadoes in the Gulf Coastal States.

c. Wind Parameters

This study also found that, strong winds at all levels appear to be another important environmental factor for significant tornadoes in the Gulf Coastal states. Winds were typically from the south or southwest (Fig. 4). Generally, the winds veer from the south at the surface to southwesterly at 500 mb. These strong and veering winds profiles provided a favorable environment for supercells and tornadoes (Fig. 5-Johns and Doswell 1993). The strong southerly wind also aids in rapidly advecting richer boundary layer moisture northward from the Gulf of Mexico.

Another important factor is the wind speeds. The wind speeds increased with height, but were strong at all levels except the boundary layer (Fig. 6). The surface wind speeds averaged 12 kts, with 38 kts at 925 mb, 43 kts at 850 mb, 48 kts at 700 mb, and 62 kts at 500 mb. Even though winds veered gradually with height, the strengthening winds resulted in shear. However, the dramatic increase in wind speed between the surface and 925 mb resulted in very strong 1 km shear. Thompson et al. (2003) found strong 1 km shear along with LCL heights were favorable for tornadoes. The findings in this study are consistent with Thompson's et al. (2003) findings.

d. Other Parameters

The 500 mb thicknesses ranged from 5600 meters to 5700 meters (Fig. 7) and the 500 mb Geopotential heights ranged from 5675 meters to 5760 meters for all of the significant tornado events.

4. Conclusions

There are many environmental parameters that operational meteorologists can observe when forecasting significant tornadoes during the cool season for the Gulf Coastal States. This includes surface temperatures averaging at 68F, 16C at 925 mb, 13C at 850 mb, and 3C at 700 mb. The dewpoints averaged 64F at the surface, 15C at 925 mb, 10C at 850 mb, and -3C at 700 mb. The winds veered from south to southwest, averaging 12 kts at the surface, 38 kts at 925 mb, 43 kts at 850 mb, 48 kts at 700 mb, and 62 kts at 500 mb. Because over half of these tornado events occur during the early to mid afternoon and overnight, increased situational awareness by operational forecasters during these times of the day is necessary, although significant tornadoes can occur at any hour of the day. If these conditions are present, significant tornadoes in the Gulf Coastal states are more probable. Additional research is needed regarding these significant cool season tornado events. Future research will include an additional number of cases, incorporation of additional data (such as derived shear and instability values), as well as null cases.

5. Acknowledgements

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6. References

Branick, M. L., 1981: Meteorological analysis of a severe supercell thunderstorm over southern Mississippi, 31 March 1981. Southern Topics, July 1981, Southern Region Headquarters NWS, Ft. Worth, Texas, 7pp.

Fike, P. C., 1993: A climatology of nocturnal severe local storms outbreaks. Preprints, 17th Conf. on Severe Local Storms, St. Louis, Amer. Meteor. Soc., 10-14.

Galway, J.G., and A. Pearson, 1981: Winter tornado outbreaks. Mon. Wea. Rev., **109**, 1072-1080.

Hart, J. A., 1993: SVRPLOT: A new method of accessing and manipulating the NSSFC Severe Weather Database. Preprints, 17th Conf. on Severe Local Storms, St. Louis, MO, Amer. Meteor. Soc., 40-41.

Johns, R.H., and C. A. Doswell III, 1992: Severe local storms forecasting. Wea. And Forecasting, **7**, 588-612.

Plymouth State University Meteorology Program, http://vortex.plymouth.edu

Thompson, R.L., 1998: Eta model storm-relative winds associated with tornadic and nontornadic thunderstorms. Wea. And Forecasting, **13**, 125-137.

Thompson, R.L., R. Edwards, J. A. Hart, K. L. Elmore, and P. Markowski, 2003: Close proximity soundings within supercell environments obtained from the rapid update cycle. Wea. And Forecasting, **18**, 1243–1261.

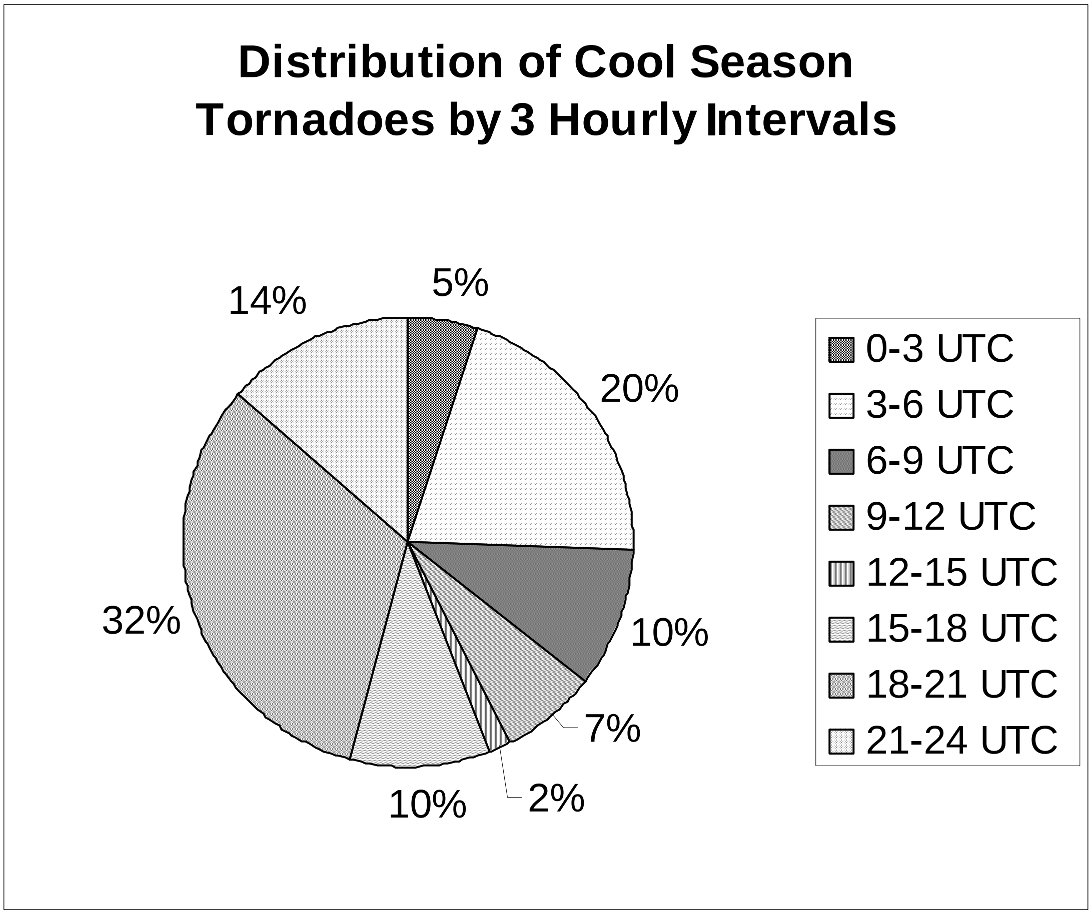

Figure. 1: The distribution of cool season tornadoes by 3 hourly intervals in percentages.

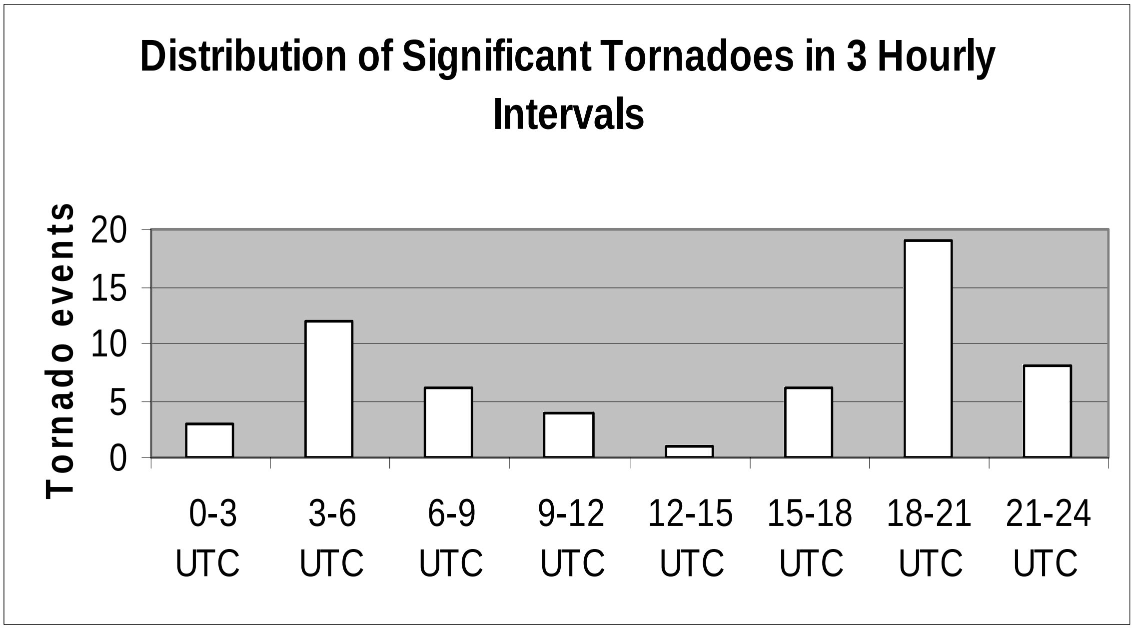

Figure. 2: Bar graph of the distribution of significant tornadoes in 3 hourly intervals by tornado events.

Temperatures and Dewpoints from the Surface to 700 mb

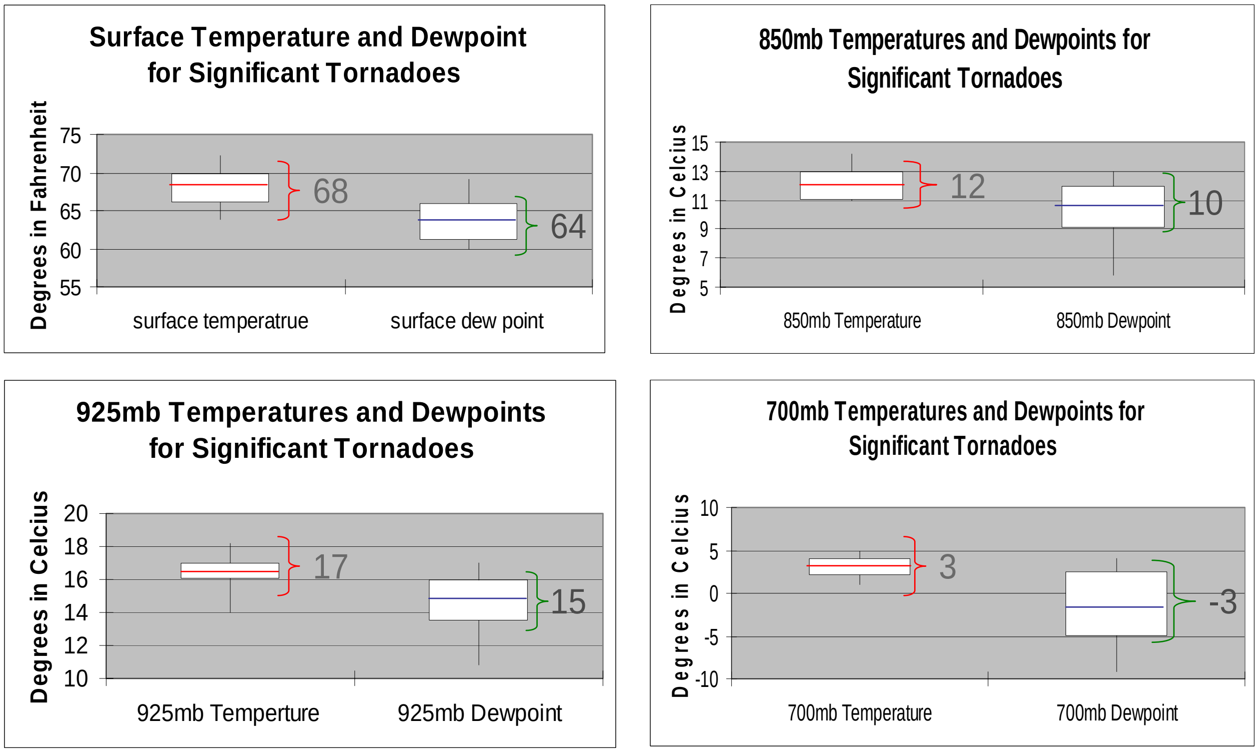

Figure. 3: Box and whiskers comparison of temperatures to dewpoints from the surface to 700 mb of the significant tornadoes.

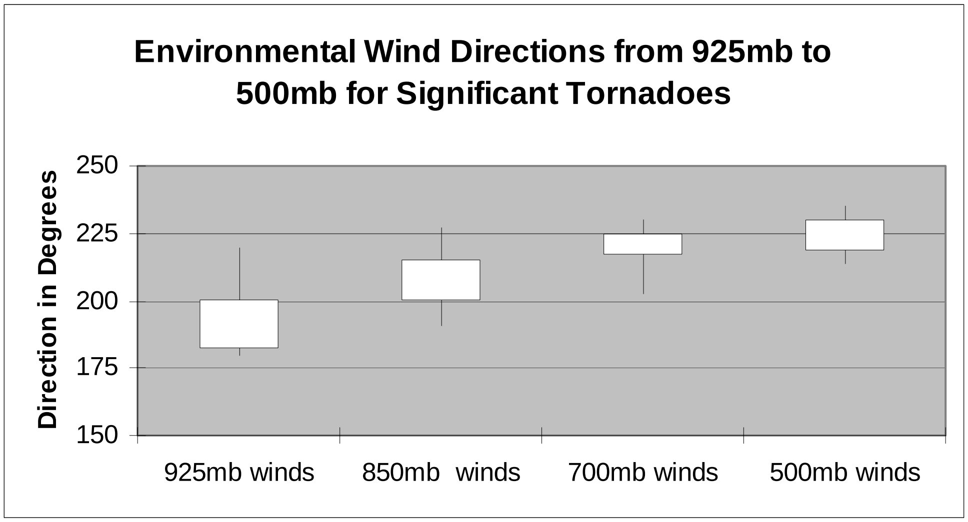

Figure. 4: Box and whisker comparison of wind directions from 925 mb to 500 mb of the significant tornadoes.

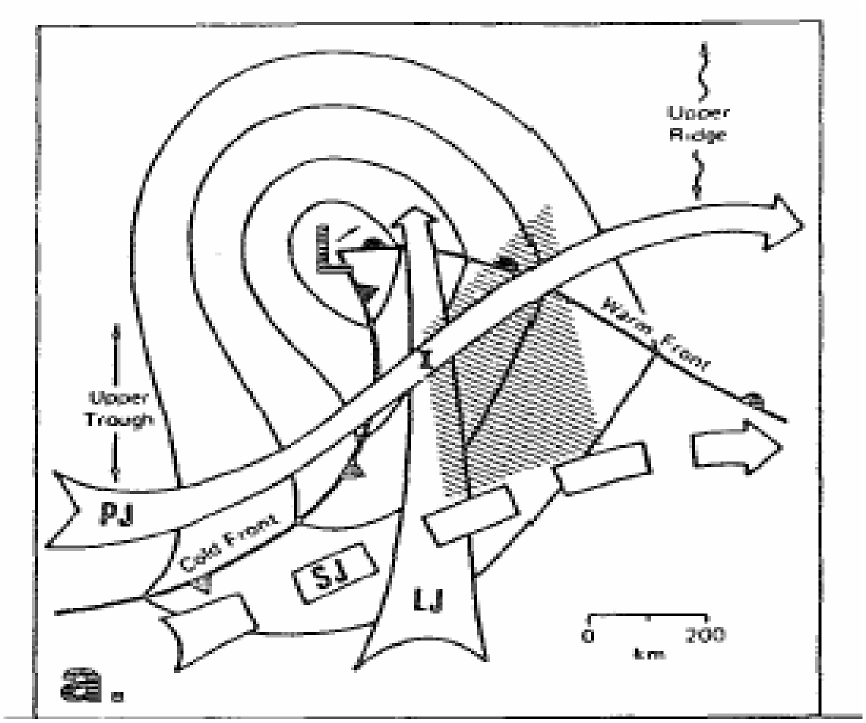

Figure. 5: Diagram of winds veering with height. From Johns and Doswell (1992).

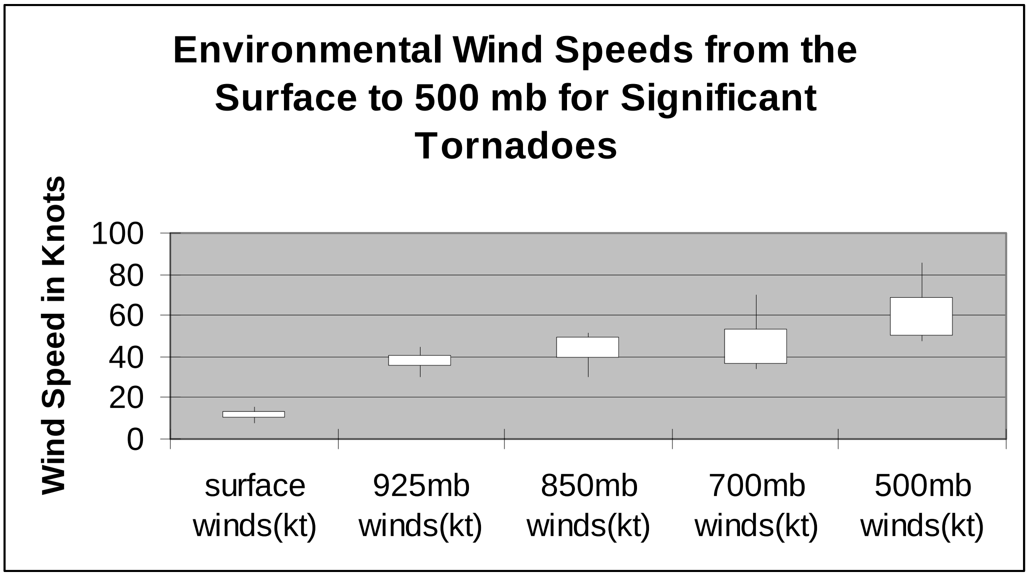

Figure. 6: Box and whisker wind speeds comparison from the surface to 500 mb of the significant tornadoes.

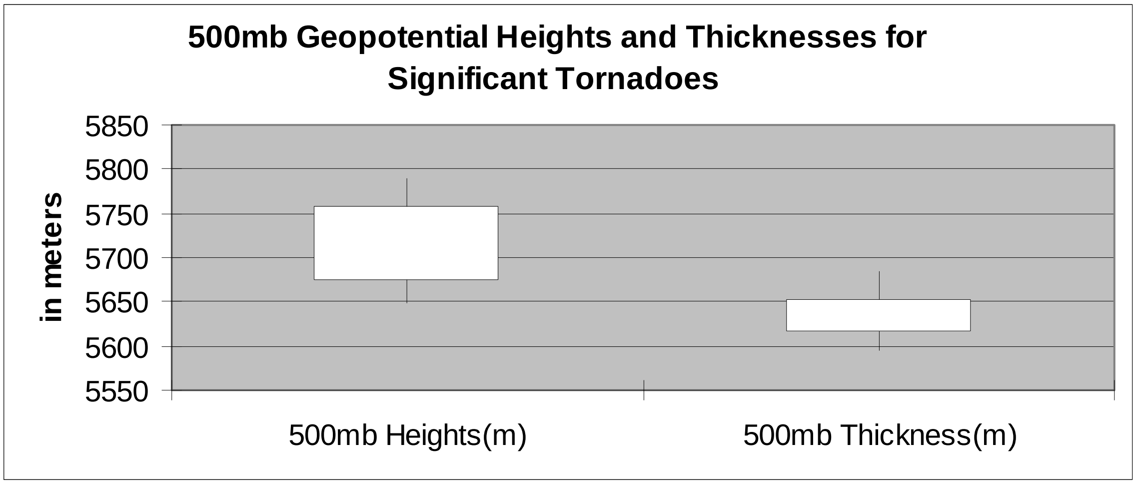

Figure. 7: Box and whisker comparison of 500 mb geopotential heights and thickness in meters of the significant tornadoes.