P12.7 A SYNOPTIC CLIMATOLOGY OF HIGH IMPACT EVENTS IN THE COUNTY WARNING AREA OF THE NATIONAL WEATHER SERVICE FORECAST OFFICE IN CHARLESTON, SC

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1. BACKGROUND

While the National Weather Service (NWS) forecast offices across the country are responsible for forecasts that effect the entire population in one form or another, perhaps the most important role of the NWS is providing forecasts of high impact weather events as far in advance as possible. For the purpose of this paper, high impact events are defined as meteorologically adverse conditions that can cause a threat to life and property as well as a significant disruption to commerce, transportation, and local economies. Situations that are likely to cause such problems include landfalling hurricanes, extreme heat and cold, large hail, tornadoes, excessive rainfall, and significant winter weather. This manuscript and associated poster will concentrate on extreme heat and cold, strong tornadoes, and summer season large hail events.

Over the past few decades, increases in both computer power and our understanding of the atmosphere have led to the development of robust atmospheric models and distribution of their solutions, greatly improving a forecaster's ability to indentify impending high impact weather situations. However, despite these advances, important details between different model solutions can vary significantly. Model ensembles try to remedy the inherent and unavoidable errors in deterministic solutions, but these ensembles can have their own issues, such as oversmoothing critical details or providing a solution set that is underdispersive.

A tool that has aided forecasters for a long time, and will continue to be a necessary element in the forecast process, is the understanding of a region's climatology. This will help define both the frequency of high impact events and the likelihood that they would occur in a given atmospheric environment. This tool is especially useful for forecasters who are new to a region and need to quickly spin up on the significant threats.

The goal of this study is to examine historical synoptic scale patterns from 3 days prior to the high impact event up to the day of the event. Important signals to the potential for upcoming events are expected to be discovered that will help a forecaster determine if the details of a model solution, or a given set of solutions, is a likely outcome based on the synoptic situation.

2. DATA AND METHODOLOGY

The first step in the project was to define events that would be considered high impact in the county warning area (CWA) of the NWS office in Charleston, SC (CHS). The area of responsibility for CHS stretches from the central South Carolina coast through the northern Georgia coast, including the larger population centers of Charleston, South Carolina, and Savannah, Georgia (SAV).

The authors decided that significant events included strong tornadoes (F2 or greater), large hail (1 ¾ inch or greater), extreme cold (max temperature 32°F (0°C) or less), extreme heat (max temperature 101°F (38°C) or greater), excessive rainfall (5 in (127mm) or greater in a calendar day), significant winter weather (accumulating snow of 1 in (25.4 mm) or greater), and landfalling hurricanes. The thresholds were chosen based on both the frequency of occurrence of the event (less than 20 times since 1950) and the potential impact on the area. For example, F0 tornadoes are not uncommon in the summer months in the region when waterspouts move briefly ashore before dissipating, but they cause very little impact, so they were not included.

The data used in the study was searched back to 1950. The dates for the tornadoes and large hail were determined by searching the National Climate Data Center's (NCDC) Storm Event database http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms. This database is made up of severe weather reports relayed to the local NWS offices. The dates for the extreme heat, extreme cold, excessive rainfall, and snow accumulation were obtained from the XMacis database hosted by the Northeast Regional Climate Center at Cornell University. The stations used in the search were Charleston, South Carolina and Savannah, Georgia as these locations represent to 2 largest metropolitan population centers in the region. The hurricane landfalls for the region were obtained through the NOAA Coastal Service Center's (CSC) interactive hurricane mapping database taking from the best track data from the National Hurricane Center.

Once the dates were established and duplicates were eliminated, the data listing was entered into the Climate Diagnostic Center's (CDC) website page that acts as a portal to the NCEP/NCAR reanalysis daily data set (Kalnay et al. 1996). Meteorological data was then composited for the day of the events as well as the previous 3 days.

Mean and anomaly composites of temperature (T), geopotential height (GH), and vector wind (VW) were created for the 250, 300, 500, 700, 850, and 925 hPa levels. All the resulting maps have been posted to the NWS Charleston intranet for use by the forecasters in the office. Review of the maps has been made part of all new forecaster's development or orientation plan. The volume of maps is quite high, so only a subset of the results are highlighted and discussed in this manuscript.

3. RESULTS

Extreme Cold

Since 1950, there have been 18 days at CHS where the maximum temperature was 32°F (0°C) or lower. A histogram shows the monthly frequency (fig. 1). As expected, the peak occurs in January, which on average is the coldest month of the year at CHS.

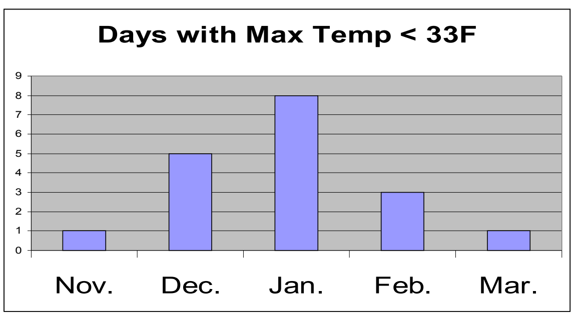

Figure 1. The monthly distribution of days with maximum temperatures 32°F (0°C) or below at CHS since 1950.

The primary surface synoptic scale signal for extreme cold events across southern South Carolina and southeast Georgia was found in the mean of the MSLP field. A large and anomalously strong area of high pressure was in place over Western Canada three days prior (D-3) to the extreme cold event (Fig. 2a). The high then builds south-southeastward through the Plains States over the next couple of days and into the Lower Mississippi Valley and northeastern Gulf Coast by the day of the event (Figs. 2b-2d).

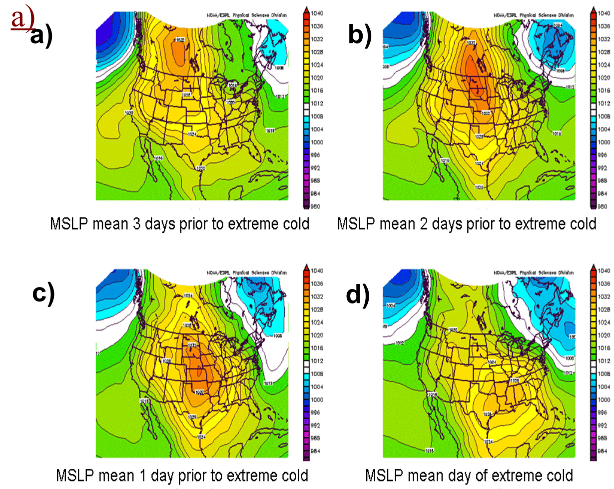

Figure 2. The composite MSLP field ranging from three days prior to an extreme cold day (upper left) to the day of the event (lower right).

At 500 hPa, a long wave trough is already in at D-3 (Fig. 3a). During the next three days, a significant amplification of the long wave trough over eastern third of the United States takes place, shown by increasingly negative GH anomalies (Figs. 3b-3d) Similar results were observed in the temperature fields (not shown).

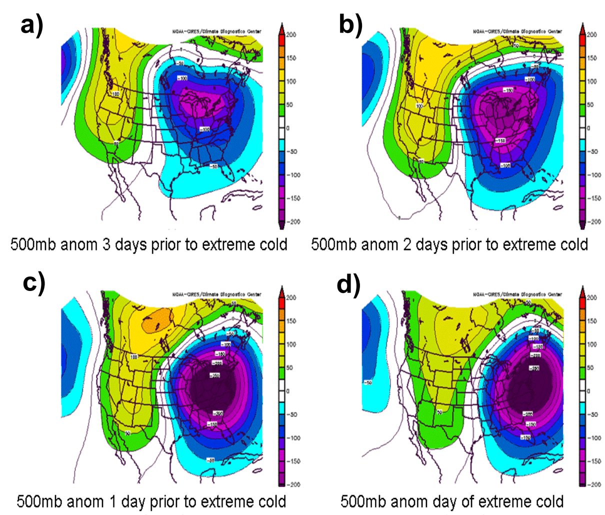

Figure 3. As in Figure 2, except for 500 hPa GH anomalies.

Another important observation was the existence of colder than normal air already in place several days before the extreme event. This indicates the extreme cold days did not come "out of nowhere" but were preceded by at least one other cold air outbreak. Figure 4 shows 850 hPa T anomalies leading up to the cold event. At D-3 (Fig. 4a), below normal T were already in place over almost the entire CONUS, with the strongest negative anomalies near and just south of the surface high in southern Canada and the northern Plains. The anomalies intensified and expanded south and east with time, eventually covering the entire east with negative anomalies colder than 15°C at its core (Figs. 4b-4d).

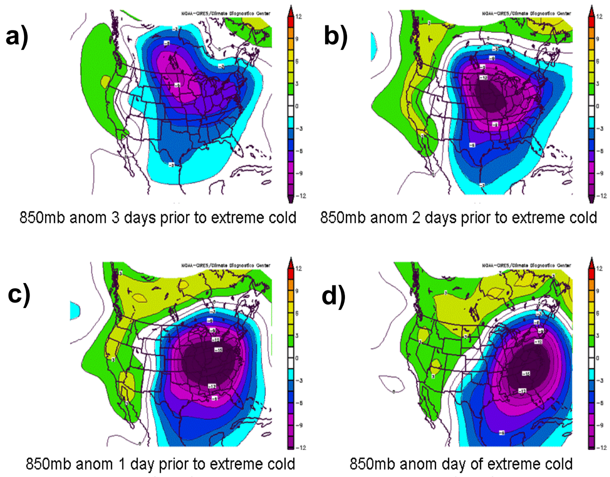

Figure 4. As in figure 2, except for 850 hPa T anomalies.

Extreme Heat

Since 1950, there were 16 days with the maximum temperature > 100°F (36°C) at CHS (Fig. 5). They occurred entirely in the months of June, July and August.

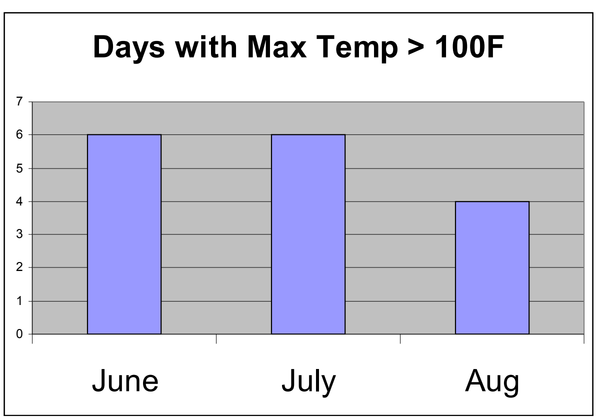

Figure 5. The monthly distribution of days with maximum temperatures higher than 100°F (36°C) at CHS since 1950.

The strongest signal can be seen in the 850 hPa T anomalies. Two and three days prior to the event, significant warm anomalies are in place across the western Great Lakes and northern Plains, with the largest values warmer than 5°C (Figs. 6a-6b). The area of maximum anomalies begins to slide southeastward, eventually winding up along the eastern seaboard with the maximum centered over the mid-Atlantic (Figs. 6c-6d).

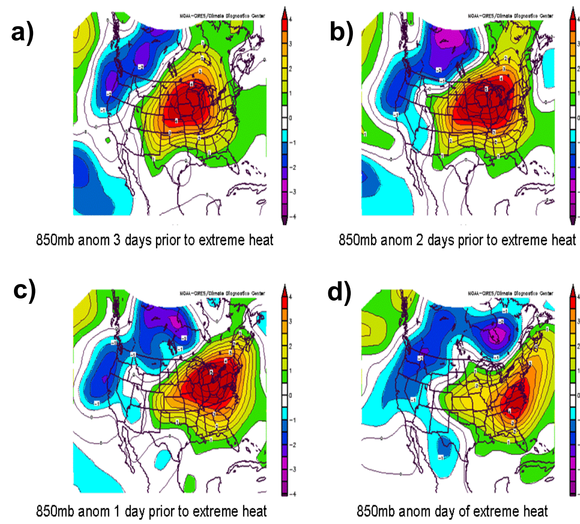

Figure 6. The composite 850 hPa T anomalies ranging from three days prior to an extreme heat day (upper left) to the day of the event (lower right).

At mid levels, the composites of the 500 hPa GH indicate a large ridge over much of the eastern 2/3 of the United States at D-3 (Fig. 7a), while troughs are noted extending from central Canada southwestward to the Pacific Northwest as well as in the Canadian Maritimes. The maximum height anomalies then slowly drift south to a position over the Ohio Valley by the day of the event (Figs. 7b-7d).

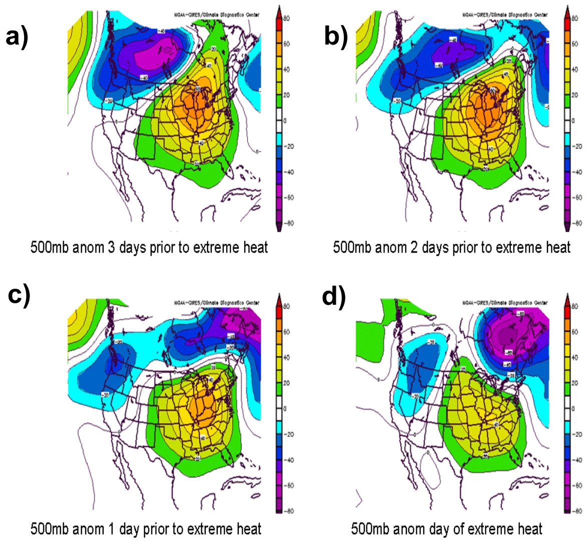

Figure 7. As in Figure 6, except for 500 hPa GH anomalies.

F2 and Greater Tornadoes

From 1950 to 2007, F2 or greater tornadoes occurred in the CHS county warning area on 15 different dates (tornadoes associated with landfalling tropical cyclones were not included as the synoptic set up for those events is significantly different). The majority of the dates were in the climatologically favored spring months of March, April, and May, although a couple of events did occur in the fall (Fig. 8).

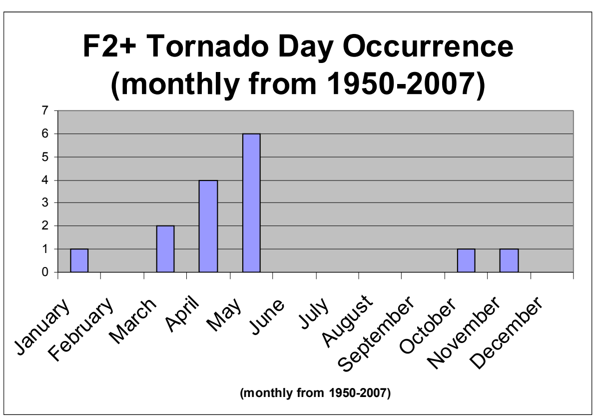

Figure 8. The monthly distribution of days with F2 or greater tornadoes in the CHS CWA from 1950-2007.

The composites of the mean 500 hPa GH field indicates a trough extending from the northern Rockies southwestward to off the southern California coast at D-3 (Fig. 9a). The southern extent of the trough deepens over the four corners area by D-2 (Fig. 9b), then progresses across the southern tier of the country to a position in the lower Mississippi by the day of the event (Figs. 9c-9d). The maps also indicate some northern stream energy moving into the Great Lakes area, helping to develop more of a full latitude trough across the eastern half of the CONUS. The anomalies help to show the weaknesses in both the polar and subtropical jet streams (Fig. 10).

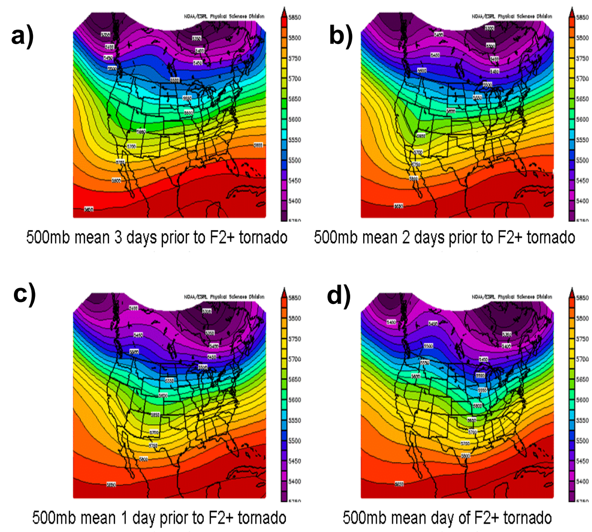

Figure 9. The composite 500 hPa GH mean ranging from three days prior to an extreme heat day (upper left) to the day of the event (lower right).

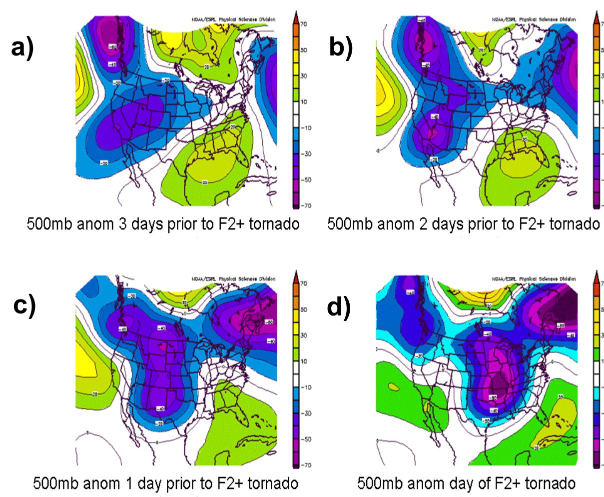

Figure 10. The same as figure 9, except for the 500 hPa GH anomalies.

The 300 hPa VW mean shows a couple of important details. First, two different maxima in the overall enhanced west southwesterly flow, one over northern Mexico and another over the eastern Ohio Valley and the Mid-Atlantic, can be seen at D-2 (Fig. 11b). These local maxima evolve into a pattern which enhances divergence aloft over the CHS CWA as the area is near the right entrance region of the northern jet over the northeastern states and also near the left exit region of the small maxima over the northern gulf coast (Fig. 11d).

The VW anomalies also show some interesting signals. At 300 hPa, the majority of the westerly anomalies can be seen in association with the subtropical jet stream, extending from the Pacific Ocean off the northern Mexico coast into the Ohio Valley at D-3 (Fig. 12a). By the day of the event, the amplification and evolution into a deeper trough is evident with the maximum anomaly on the eastern side of the trough over the Ohio Valley (Figs. 12b-12d).

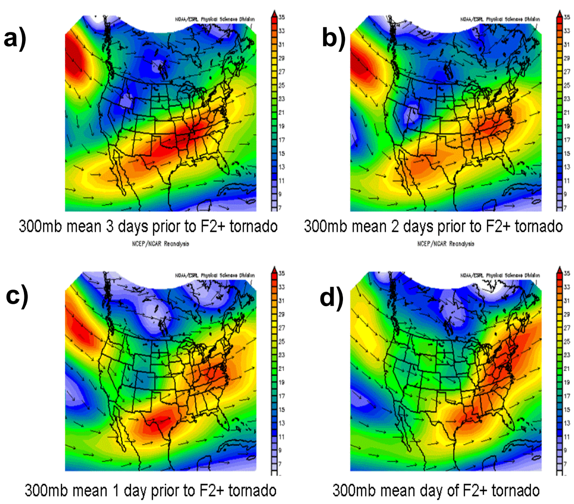

Figure 11. The same as Figure 9, except for the 300 hPa VW mean.

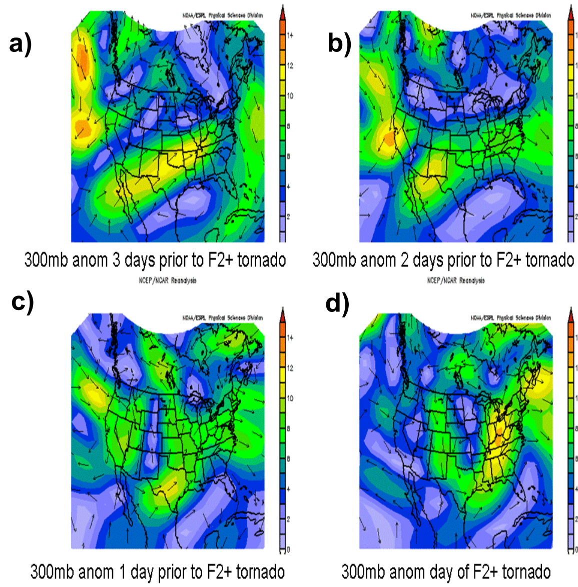

Figure 12. The same as Figure 9, except for the 300 hPa VW anomalies.

In the low levels, the evolution of a temperature boundary can be seen. At D-3 (Fig. 13a), there is a warm anomaly up the entire eastern seaboard at 925 hPa. This warm anomaly is ahead of a mean cold front, which can be seen on the vector wind fields with a mean position across the eastern Great Lakes and into the Ohio Valley (Fig. 14a). By D-2, the mean front moved through the northeastern United States and the temperature anomalies became negative from the Mid-Atlantic northward into New England (Fig. 13b). However, the mean front did not make it through the southeastern United States and has instead stalled over the southern Mid-Atlantic, so South Carolina and Georgia remain in the warm sector. At D-1 (Fig. 13c), a warm anomaly ridge south of the mean front extends from the western Gulf of Mexico northeastward into South Carolina. Also notice that southerly wind anomalies at 925 hPa over the Gulf of Mexico have increased markedly and are beginning to stretch northeastward along the Georgia and South Carolina coastlines (Fig. 15c). By the day of the event, both the vector wind (Fig. 14d) and temperature anomalies (Fig. 15d) at 925 hPa have become maximized over northern Florida, southern Georgia, and southern South Carolina.

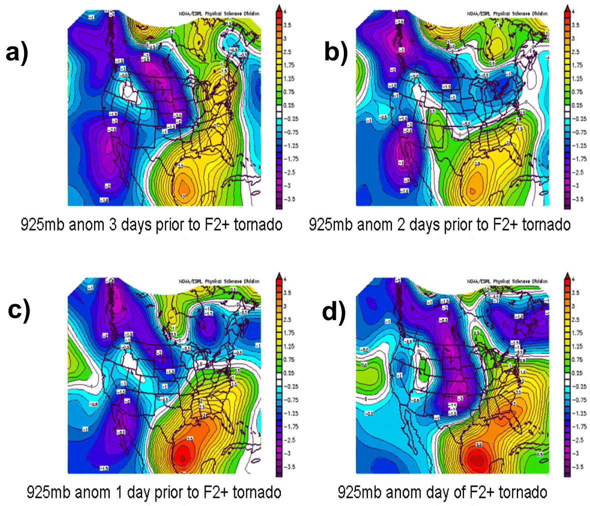

Figure 13. The same as Figure 9, except for the 925 hPa T anomalies.

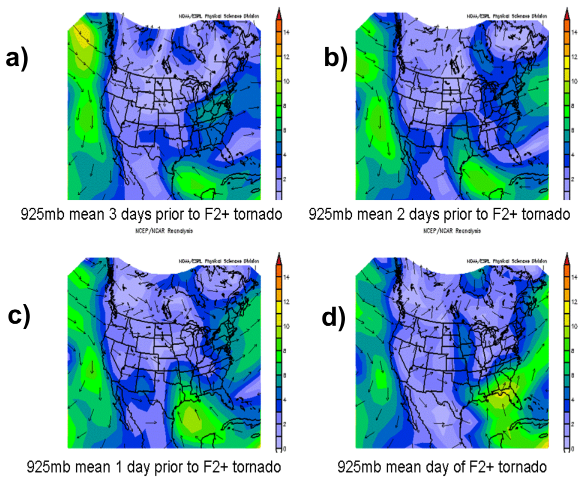

Figure 14. The same as Figure 9, except for the 925 hPa VW mean.

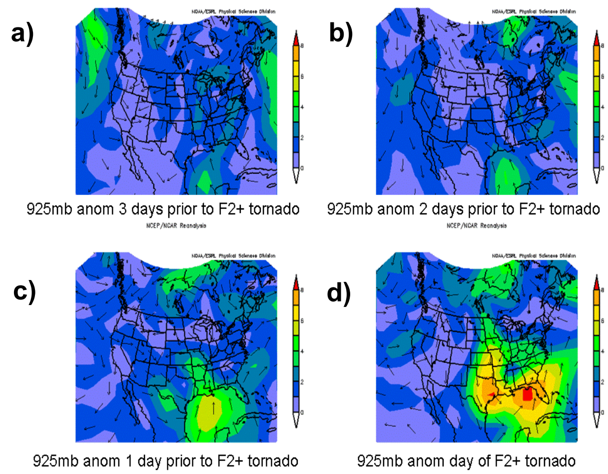

Figure 15. The same as Figure 9, except for the 925 hPa VW anomalies.

Summer Hail

While hail is fairly common in the summer months of June, July, and August in southern Georgia and southeastern South Carolina, large hail of greater than 1 ¾ inch in diameter is not. In fact, from 1950 to 2005, there were only 26 dates (less than 1 every other year) when 1 ¾ inch hail or greater was reported in the summer months. Of those, almost half (12 out of 26) occurred in the month of June. This early summer trend is likely due to the possibility of mid level lapse rates still reaching fairly unstable levels (6.5°C/km or larger), on occasion, in June.

The composites for these events showed some interesting and unexpected results. For instance, at 500 hPa, while there was a small cold anomaly over southern South Carolina and southeastern Georgia, a slightly stronger signal actually showed up over the desert southwest (Fig. 16d). However, in both cases the values were less than 1°C, which is not a strong enough indicator to be useful to a forecaster. Similarly, a weak trough at 500 hPa was apparent in the mean field on the event day (not shown), but the height anomalies were less than 10 m.

The lower levels showed a mean front often accompanied the events, with 925 hPa GH anomalies traceable from the far northern plains and south central Canada on D-3 (Fig. 17a) across the great Lakes, and into southern New England on the day of the event (Figs 17b-17d). Vector winds indicated a front accompanied the lower heights with a slight increase in warm advection ahead of the front over the southeast on the day of the event (not shown). Again, however, the magnitudes were relatively small.

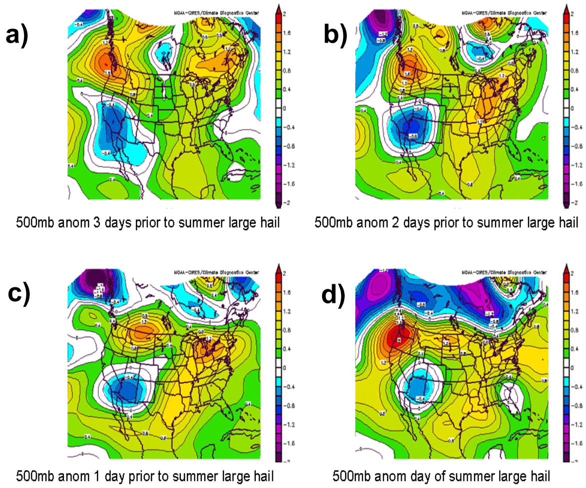

Figure 16. The composite 500 hPa GH anomaly ranging from three days prior to an extreme heat day (upper left) to the day of the event (lower right).

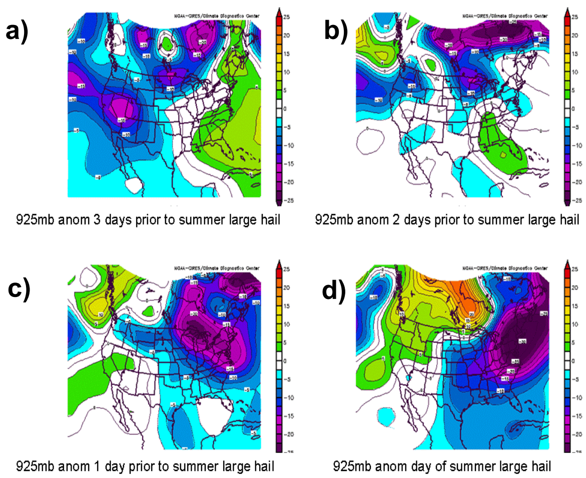

Figure 17. The same as Figure 16, except for the 925 hPa GH anomalies.

4. SUMMARY AND CONCLUSIONS

To both assist new forecasters and refresh seasoned forecasters at the NWS CHS, a synoptic climatology of high impact events was developed. The dates for specific events were mined from various databases and then refined to avoid duplicates or errors. Those dates were then used to create analog maps through the NCAR/NCEP Reanalysis home page. Maps for both means an anomalies ranging from three days before the event to the day of the event were made.

Some of the notable signals mentioned in this manuscript include

- Surface high pressure building from southern Canada almost due southward into northern Gulf Coast for extreme cold events.

- The existence of a precursor cold air mass several days prior to extreme cold events.

- The transit of low-level temperature anomalies from the Great Lakes into the Mid-Atlantic leading up to an extreme heat event.

- The existence of a strong southern stream disturbance near southern California several days in advance of significant tornado events.

- The evolution of a dual jet structure at 300 hPa leading up to significant tornado events.

- The appearance of significant southerly wind and warm anomalies in the Gulf of Mexico 2 days before significant tornado events.

5. FUTURE WORK

This manuscript and related poster just scratch the surface of the available results. A future, more comprehensive document is the ultimate goal of this research. Also, a similar project using the higher resolution North American Regional Reanalysis is desired.

Acknowledgements

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