4.2 COOL SEASON SIGNIFICANT (F2-F5) TORNADOES IN THE GULF COAST STATES

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1. INTRODUCTION

Tornadoes pose a significant severe weather threat during the cool season in the Gulf Coast states. Galway and Pearson (1981) found that 68% of all December through February tornadoes in the United States occur in the Gulf Coast/Southeast states. They also noted that long track tornadoes in winter outbreaks accounted for a higher percentage of deaths compared to long track spring outbreak tornadoes. While strong wind fields are often present in association with dynamic shortwave troughs that impact the region, uncertainty regarding low-level moisture and atmospheric instability can make forecasting such events quite challenging for operational forecasters (Vescio and Thompson 1993). The purpose of this study is to help identify a set of patterns, parameters, and conditions that are commonly associated with the development of cool season tornadoes in the Gulf Coast States, with a focus on significant (F2 and greater) tornadoes.

2. METHODOLOGY

F2+ tornado events were examined from 20 cool seasons (1984-1985 to 2003-2004) for a geographic domain including far eastern Texas, southern Arkansas, Louisiana, Mississippi, Alabama, Georgia, and northern Florida (Fig. 1). For the purposes of this study, the cool season was defined as October 15-February 15. Severe Plot (Hart 1993) was used to obtain official National Weather Service Storm Data reports of F2+ tornadoes that satisfied the spatial/temporal domain criterion. Severe Plot provided the date, time, intensity, and touchdown location for each F2+ tornado.

Hourly surface temperature, dewpoint, and wind direction/speed were obtained from archived surface data for each F2+ tornado. Upper air maps were produced for 6 hr intervals (00 UTC, 06 UTC, 12 UTC, and 18 UTC) for each tornado day using North American Regional Reanalysis (hereafter NARR, Mesinger et al. 2006) data and a General Meteorology Package (GEMPAK) interface. These maps included: 300 mb winds and geopotential heights; 500 mb winds, geopotential heights, temperature, and absolute vorticity; 700 mb winds, geopotential heights, and temperature; 850 mb winds, geopotential heights, and temperature; precipitable water, surface temperature and dewpoint, and MSLP; 0-3 km AGL helicity; and lowest 180 mb Most Unstable CAPE (MUCAPE). Aside from direct utilization for this study, the NARR maps were also compiled and organized to serve as an analog reference for operational forecasters.

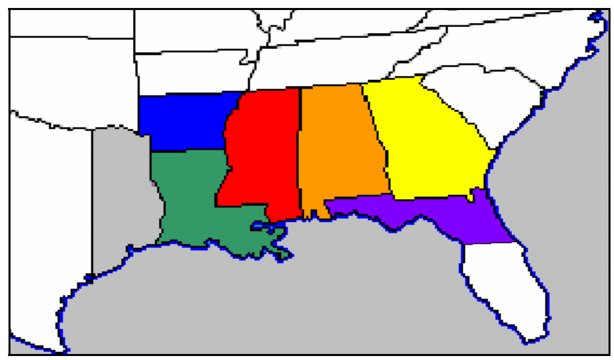

Fig. 1. Map of study domain.

3. ABBREVIATED CLIMATOLOGY

The period and domain of study incorporated a total of 239 individual F2+ tornadoes (Fig. 2). Of these 239 tornadoes, 181 were rated F2 intensity (76%), 48 were F3 (20%), 10 were F4 (4%), and none were F5. The 239 tornadoes spanned 100 separate convective days (12 UTC-12 UTC) between October 15-February 15 from 1984-1985 to 2003-2004.

While a typical afternoon severe weather and tornado peak is observed, a relatively high number of F2+ tornadoes have occurred during the late evening and overnight hours (Fig. 3). This is consistent with a number of regional severe weather climatologies and Fike's (1993) finding that nocturnal tornadoes are maximized during the cool season.

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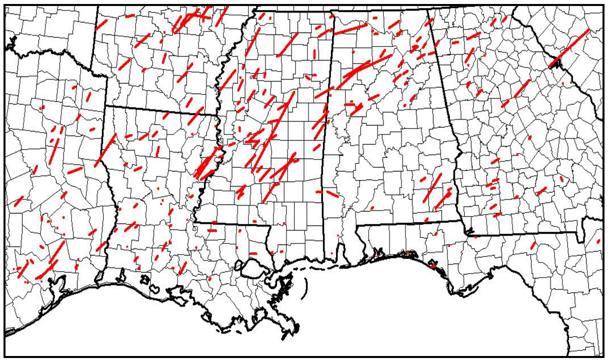

Fig. 2. Map of all F2-F5 tornadoes (with tracks denoted via red lines) between October 15-February 15 from 1984-1985 to 2003-2004.

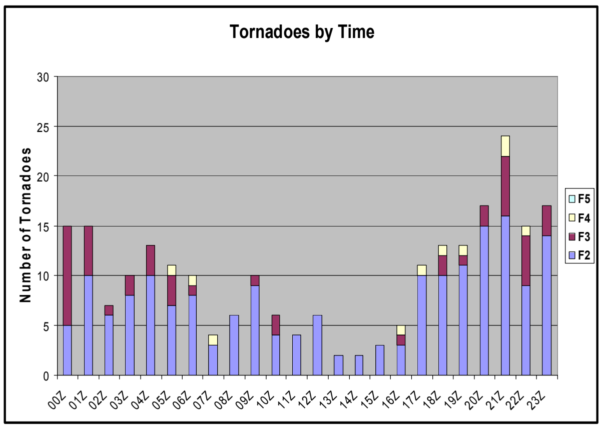

Fig. 3. Cool season Gulf Coast F2-F5 tornadoes by hour (UTC) for October 15-February 15 from 1984-1985 to 2003-2004.

4. UPPER AIR COMPOSITE ANALYSIS

NARR data were utilized in this study to composite upper air patterns and tendencies associated with F2+ tornadoes in the Gulf Coast States during the cool season. While inherently subjective in many cases, several characteristics and trends were noted.

4.1 500 mb

Typically downstream of a transitory upper trough, it was found that 72% of cases were associated with the immediate anticyclonic south fringe of a 500 mb jet. While removed from the strongest mid level wind speeds, a majority of tornadoes occurred with wind speeds of 40 kt or greater at 500 mb. An example of this 500 mb pattern is seen in Figure 4. In approximately 20% of the cases, the tornadoes coincided with the “nose” and/or occurred directly beneath the 500 mb jet axis. The remaining events generally occurred closer to the center of the mid level circulation (i.e. within 300-500 km) of the upper trough, typically with a synoptic scale cyclone that was beginning to occlude. While many events were found to occur on the anticyclonic side of a mid-level jet, the strength (wind speeds) of the jet did not discriminate between isolated tornado events versus larger outbreaks.

4.2 850 mb

Approximately 77% of tornado events were associated with a south or southwesterly 850 mb low level jet, occurring in/near an 850 mb jet axis characterized by wind speeds of 30 knots or greater. An example of this 850 mb pattern is seen in Figure 5.

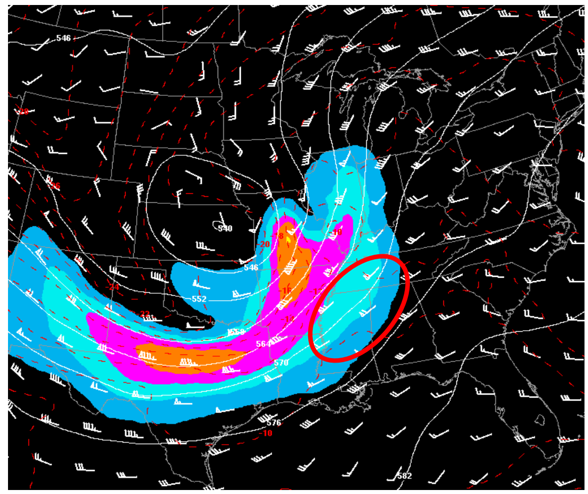

Fig. 4. NARR 500 mb analysis for 12 UTC 24 November 2001. Geopotential heights (standard convention) with wind barbs and shading (beginning at 50 kt with graduated colors every 10 knots) and temperatures (°C) in dashed red. Red oval denotes approximate location of 14 F2+ tornadoes on 24 November 2001.

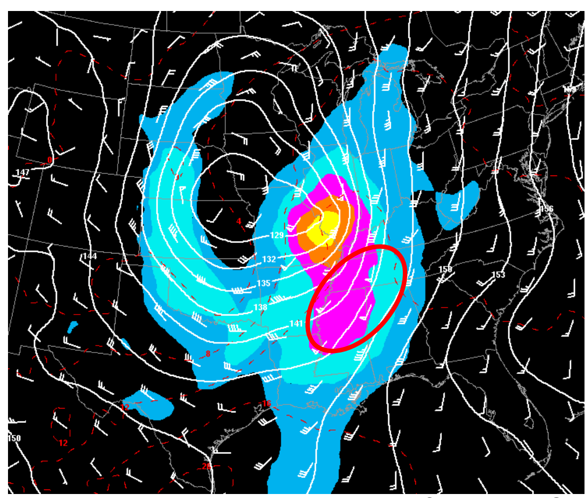

Fig. 5. NARR 850 mb analysis for 12 UTC 24 November 2001. Geopotential heights (standard convention) with wind barbs and shading (beginning at 30 kt with graduated colors every 10 knots) and temperatures (°C) in dashed red. Red oval denotes approximate location of 14 F2+ tornadoes on 24 November 2001.

5. SURFACE CHARACTERISTICS

Both NARR derived surface analysis and raw surface data plots were utilized to examine surface characteristics associated with F2+ tornadoes. Proximity surface observations of temperature, dewpoint, and wind/speed direction were gathered from the nearest inflow surface (ASOS/AWOS) observation within 0-1 hr preceding each tornado event. The NARR data was utilized to examine surface low and frontal characteristics.

It was found that the majority of F2+ tornadoes occurred within a broad warm sector ahead of a synoptic scale low pressure system and attendant cold front (55% of cases), or along a warm front (20% of cases). The parent surface low, typically a few hundred kilometers to the northwest, was found to be relatively steady state (± 0-2 mb in 12 hours) in 53% of cases. A weakening surface low (>2 mb change in 12 hours) was associated with 8% of the events. It should be noted that the inherent resolution of the NARR data did not provide for thorough analysis of potential sub-synoptic lows, which was beyond the scope of this current study.

F2+ cool season tornadoes were commonly associated with surface dewpoints of 65 °F or greater (62% of cases), with a median value of 66 °F (Fig. 6). In fact, less than 10% of the events had surface dewpoints ≤ 60 °F. While Gulf of Mexico buoy data were not directly incorporated into this project, a concurrent study by Evans and Guyer (2006, this volume) features promising findings regarding western Gulf of Mexico buoy dewpoint trends 48-72 hours preceding significant cool season severe weather/tornado episodes.

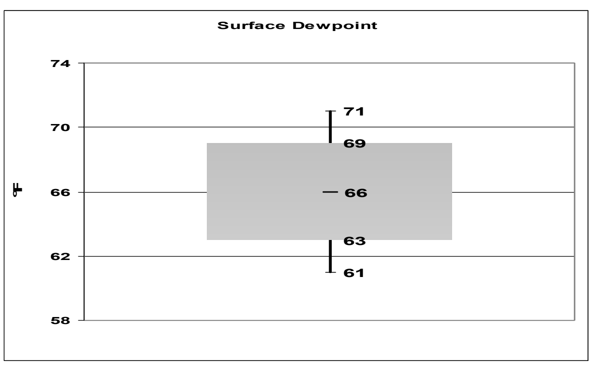

Fig. 6. Box and whiskers diagram of surface dewpoints (°F) observed with cool season Gulf Coast F2+ tornadoes. Box representative of the 25th and 75th percentiles, with the outer whiskers representing the 10th and 90th percentiles of events.

6. PROXIMITY SOUNDINGS AND DERIVED PARAMETERS

To approximate the representative mesoscale environment for Gulf Coast F2+ tornadoes, observed rawinsonde data with spatial and temporal proximity constraints of 200 km and ± 3 hr was used in this study. While there were 100 tornado events over the 20 cool seasons, such proximity constraints resulted in mesoscale environment approximations not being available for all severe event/tornado days. The proximity sounding database consisted of 57 soundings (amongst 50 tornado days) associated with one or more F2+ tornadoes within the Gulf Coast domain. These soundings were manually quality controlled for erroneous data. Since a number of days featured more than one F2+ tornado, gathered proximity soundings were constrained to one per observation cycle (00 UTC, 12 UTC, 18 UTC, 06 UTC) per rawinsonde location. In an attempt to improve the representative nature of the near storm environment data, the proximity soundings were modified for the closest surface inflow observation of temperature, dewpoint, and wind speed/direction within 0-1 hr preceding the tornado. For multiple tornado events, the utilization of particular surface conditions was prioritized by the highest F-scale rating, followed by a temporal and spatial proximity of the tornado to the rawinsonde. Median and 25th/75th percentile information for temperature, dewpoint, and wind speed information for mandatory levels is given in Fig. 7.

75th percentile median 25th percentile	**500 mb**	**700 mb**	**850 mb**	**925 mb**
Temperature (°C)		6 **5** 3	14 **13** 12	18 **17** 16
Dewpoint (°C)		0 **-4** -11	13 **10** 9	17 **16** 13
Wind Speed (kt)	62 **53** 48	49 **40** 33	44 **37** 29	37 **33** 26

Fig. 7. Common temperatures (°C), dewpoint (°C), and wind speed (kt) information for 500 mb, 700 mb, 850 mb, and 925 mb as represented by the 75th percentile (top number in each box), median (middle bold number), and 25th percentile (bottom number).

Similar to the relatively high surface dewpoints discussed earlier, high dewpoints and low dewpoint depressions were found to typically exist through the 925 mb and 850 mb levels (Fig. 7). Accordingly, lowest 100 mb mean mixing ratios were typically between 12.0 and 15.0 g/kg (Fig. 8). The mean precipitable water (PW) value observed with F2+ tornadoes was around 1.5 inches, with values between 1.2 and 1.8 inches accounting for 73% of cases (Fig. 9). Mid level lapse rates were found to not be particularly steep, with 700-500 mb lapse rates of 6.0 - 6.8 °C/km accounting for the majority of cases. This suggests the absence of an appreciable elevated mixed layer for most F2+ tornado events during the cool season.

Environmental data derived from proximity soundings confirmed that cool season Gulf Coast tornadoes generally occur in modest instability and high vertical shear environments. The majority of F2+ tornadoes were associated with 100 mb mixed layer

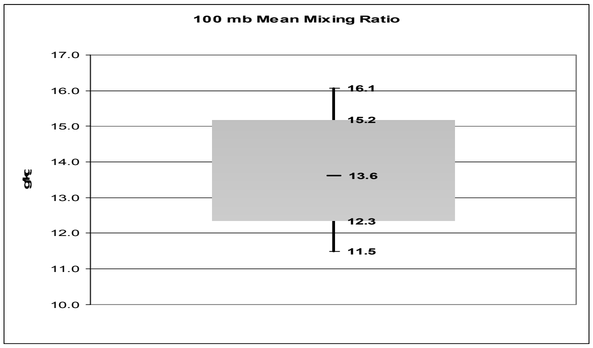

Fig. 8. Same as Fig. 6, except 100 mb mean mixing ratio (g/kg).

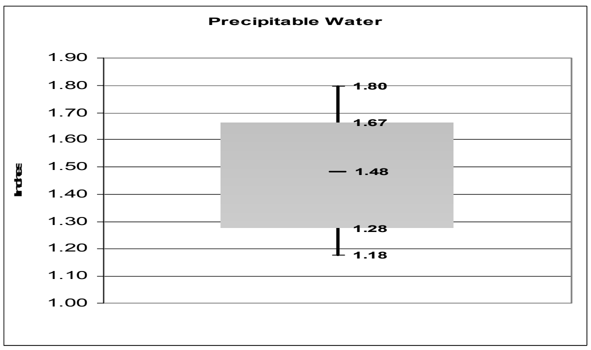

Fig. 9. Same as Fig. 6, except precipitable water (inches).

(ML) CAPE values between 900-1700 J/kg, while 25% percent of the cases were associated with 100 mb MLCAPE of 870 J/kg or less (Fig. 10). These results confirm that moderate amounts of instability (greater than 1000 J/kg) are not a necessity for F2+ tornadoes in the Gulf Coast States during the cool season. While total CAPE can appear modest, especially in comparison other supercell tornado environments in the warm season and/or Plains states, the relatively high degree of 0-3 km MLCAPE is noteworthy. The median 0-3 km MLCAPE was around 100 J/kg, with 75% of F2+ tornadoes associated with 70 J/kg or higher of 0-3 km MLCAPE (Fig. 11). This relatively high concentration of low level buoyancy coincides with warm/moist low level thermodynamic profiles (and low LCL heights) as discussed earlier.

Wind fields through the middle and upper troposphere are typically strong across much of the Gulf Coast States during the winter months due to the southward migration of the polar jet and a stronger subtropical jet. While sufficient moisture and instability may be potentially limiting ingredients for significant organized severe weather during the cool season, the background existence of strong vertical shear is much more common. Proximity sounding data revealed that very strong vertical wind shear was commonly associated with F2+ tornadoes, with 76% of cases associated with 0-6 km bulk shear of ≥ 45 kt (Fig. 12). Only 10% of F2+ tornadoes in this study were associated with 0-6 km bulk shear of 40 kt or less. Aside from the general presence of strong vertical shear

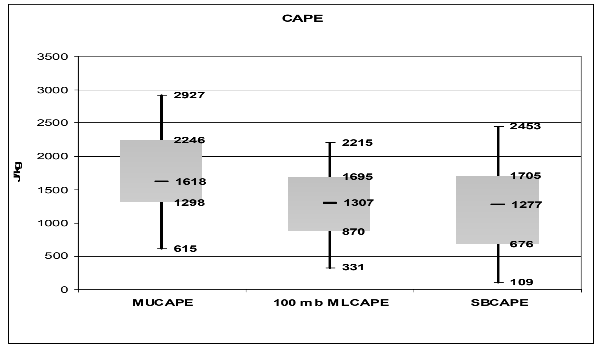

Fig. 10. Same as Fig. 6, except for Most Unstable (MU) CAPE, 100 mb mixed layer (ML) CAPE, and Surface Based (SB) CAPE (J/kg).

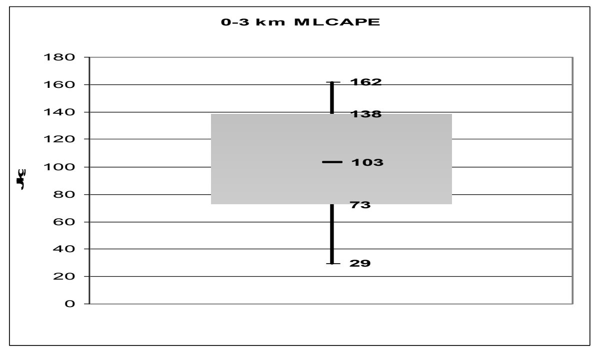

Fig. 11. Same as Fig. 6, except 0-3 km MLCAPE (J/kg).

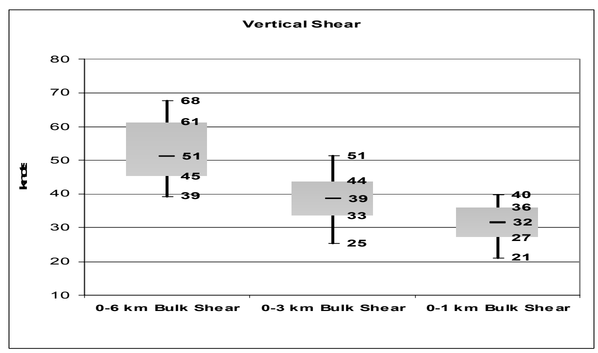

Fig. 12. Same as Fig. 6, except 0-6 km bulk shear, 0-3 km bulk shear, and 0-1 km bulk shear (kt).

through the low to mid troposphere, the high degree of shear in the lowest 1-2 km was especially evident. Around 90% of the cases featured 0-1 km bulk shear greater than 20 kt, with 27-36 kt most common (Fig. 12). Derived Storm Relative Helicity (SRH) values were typically (~75% of cases) in excess of 200 m^2/s^2 for both 0-3 km SRH and 0-1 km SRH (Fig. 13). These low level bulk shear and SRH values correlate well with the common presence of a strong southerly low level jet (as discussed in section 5) during F2+ tornado episodes, with large/anticyclonically curved hodographs in the lowest 1-2 km.

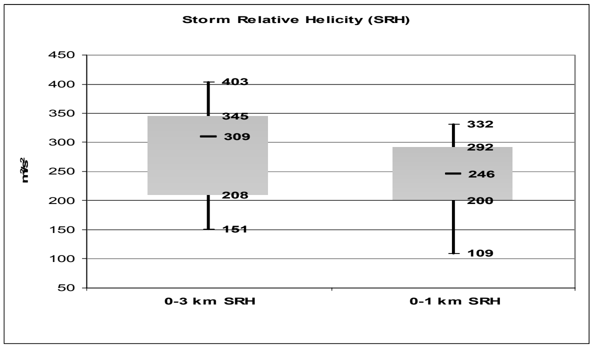

Fig. 13. Same as Fig. 6, except 0-3 km (left) and 0-1 km (right) Storm Relative Helicity (SRH - m^2/s^2).

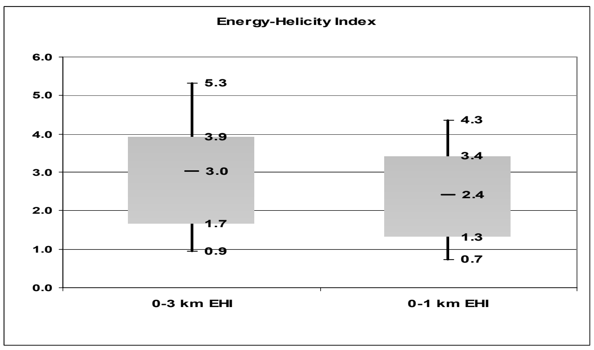

Fig. 14. Same as Fig. 6, except 0-3 km (left) and 0-1 km (right) Energy-Helicity Index (EHI).

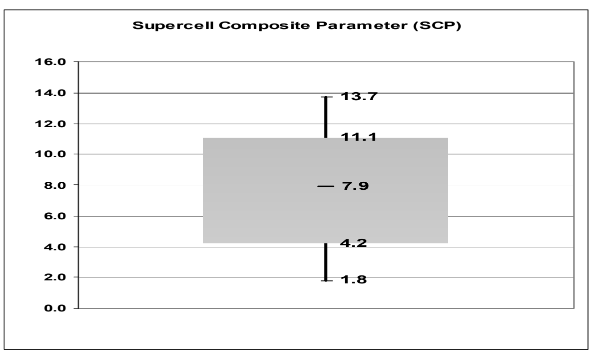

Fig. 15. Same as Fig. 6, except Supercell Composite Parameter (SCP).

Combined thermodynamic and kinematic parameters were also examined. Energy-Helicity Index (EHI) values of 1.5 were common for F2+ tornadoes, with 76% of cases ≥ 1.5 for 0-3 km EHI, and 73% of cases ≥ 1.5 for 0-1 km EHI (Fig. 14). Storm Prediction Center (SPC) derived composite parameters were also examined. Around 70% of F2+ tornadoes were associated with Supercell Composite Parameter (SCP – Thompson et al. 2004) values of 5.0 or greater (Fig. 15). The Significant Tornado Parameter (STP) was derived using both an effective layer with CIN (STPC - Thompson et al. 2004), as well as the original fixed layer computation with no CIN (Thompson et al. 2003).

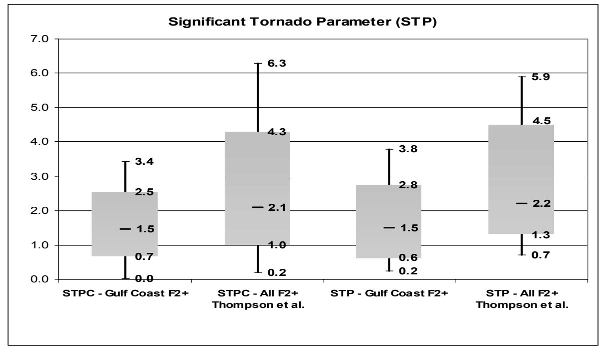

Fig. 16. Same as Fig. 6, except Significant Tornado Parameter (STP) of Gulf Coast F2+ tornadoes vs. a more diverse F2+ tornado dataset by Thompson et al. (2003, 2004, updated 2006). Left half, using the effective layer with CIN (STPC - Thompson et al. 2004). Right, original STP using a fixed layer and no CIN (Thompson et al. 2003).

Results for both computations of the STP suggested that F2+ Gulf Coast cool season tornadoes were associated with values of 1.0 or greater in 69% cases for STPC, and 65% for STP. STP/STPC values for Gulf Coast F2+ tornadoes were found to be considerably lower in comparison to the more diverse significant tornado dataset (including cool season and warm season over a broader portion of the United States) of Thompson et al. (2003, 2004, updated 2006 via personal communication) (Fig. 16).

7. CONCLUSIONS

Similar to previous studies (i.e. Galway and Pearson 1981), this study fundamentally confirmed the predominance of high vertical shear/low instability regimes associated with Gulf Coast F2+ tornadoes in the cool season. Vertical shear profiles tend to be very strong for F2+ cool season events in the Gulf Coast states, represented by deep layer (0-6 km) bulk shear values typically greater than 45 kt. The wind speeds and vertical shear in the lowest few km are especially noteworthy, with strong 850 mb and 925 winds contributing to a pronounced speed shear component. Strong low level wind speeds/vertical shear are associated with the existence of a low level jet (i.e. 850 mb) of 40 kt or greater, with 0-1 km bulk shear typically 20 kt or higher. Surface dewpoints were found to typically be 65 °F or greater in most cases. Even with these dewpoints, a lack of an elevated mixed layer resulted in only modest instability (100 mb MLCAPE <1000 J/kg). However, relatively high and concentrated values of low level buoyancy (i.e. represented by 0-3 km CAPE >100 J/kg) may be indicative of the warm/moist low levels sufficient for cool season tornadoes. As such, numerical guidance forecasts and operational diagnosis of low level dewpoints and/or mixing ratios appear to be paramount for anticipating Gulf Coast F2+ tornadoes during the cool season.

Future work will incorporate weak tornadoes (F0-F1) and non-tornadic null cases. Comparisons and contrasts will be made between thermodynamic and kinematic parameters in an attempt to better discriminate between environments favorable for significant tornadoes (F2 and greater) vs. weak tornadoes and/or non-tornadic storms during the cool season.

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8. REFERENCES

Evans, J. S., and J. L. Guyer, 2006: The relationship of cool season significant tornado events and buoy data in the western Gulf of Mexico. *Preprints*, 23rd Conf. on Severe Local Storms, St. Louis, MO, Amer. Meteor. Soc., this volume.

Fike, P. C., 1993: A climatology of nocturnal severe local storms outbreaks. Preprints, 17th Conf. on Severe Local Storms, St. Louis, MO, 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.

Mesinger F., G. DiMego, E. Kalnay, K. Mitchell, P. Shafran, W. Ebisuzaki, D. Jovic, J. Woollen, E. Roger, E. Herbery, M. Ek, Y. Fan, R. Grumbline, W. Higgins, H. Li, Y. Lin, G. Manikin, D. Parrish, and W. Shi. 2006: North American Regional Reanalysis. *BAMS*, 87, 343–360.

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. Forecasting, 18, 1243–1261.

Thompson, R.L., R. Edwards, and C.M. Mead, 2004: An update to the supercell composite and significant tornado parameters. *Preprints*, 22nd Conf. on Severe Local Storms, Hyannis MA., Amer. Meteor. Soc.

Vescio, M. D., and R. L. Thompson, 1993: Some meteorological conditions associated with isolated F3-F5 tornadoes in the cool season. Preprints, 19th Conf. On Severe Local Storms, Minneapolis, MN, Amer. Meteor. Soc., 2-4.