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The Relationship of Cool Season Significant Tornado Events and Buoy Data in the Western Gulf of Mexico

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1. INTRODUCTION

Although significant tornadoes (F2 or greater) across the Gulf of Mexico (GoM) coast states are not uncommon during the cool season (October-February), forecasting these events can be quite challenging as the region is often affected by strong, fast moving baroclinic weather systems which do not produce tornadoes. Oftentimes, the primary ingredient differentiating the more active severe thunderstorm producing systems is the presence of rich gulf moisture (i.e. surface dewpoints [T_d] at or above 60^o F). A concurrent preliminary study by Guyer et al. (2006, this volume) found that surface T_d in proximity of cool season gulf coast F2+ tornadoes to be commonly associated (62% of cases) with $T_d \geq 65^o$ F, with only 10% of cases $\leq 60^o$ F. Despite the close proximity of the GoM to coastal land areas, prior frontal passages and/or extended periods of offshore low level flow across the gulf coast may impede the return of gulf moisture ahead of most cool season weather systems. However, when gulf moisture is able to surge northward towards the lower Mississippi River valley, the severe weather potential generally increases.

Currently, forecasters at the Storm Prediction Center and local National Weather Service forecast offices are tasked with forecasting the development of severe thunderstorms up to 8 days in advance. This is complicated by the frequency of strong, progressive systems during the cool season, and the limited ability of operational numerical prediction models to accurately forecast the return of higher gulf moisture, especially beyond a day or two. Studies by Weiss (1992) and Janish and Lyons (1992) highlight the importance of accurate numerical guidance regarding return flow events in severe thunderstorm forecasting during the cool season.

Several studies have examined moisture return in the wake of surface cold fronts penetrating into the GoM. Readers can reference Thompson et al. (1994) for an overview of conceptual and analytical models regarding the phenomena over the western gulf basin. This study will investigate relationships between significant tornado events and the existence of richer moisture over the western GoM during the cool season from 1993-2004. Hourly data from gulf buoy 42002 (located at 25.17 N, 94.42 W) are examined, with an emphasis on surface T_d trends in the days prior to significant tornado occurrences. Gulf buoy 42002 was chosen as a focus for this study due to its location away from the shallower shelf-waters, and its placement within common return flow patterns over the western GoM (Crisp and Lewis 1992). Data from buoy 42019 (27.91 N, 95.36 W) was also collected in order to examine similar moisture trends nearer the gulf coast.

Accurate forecasts of low level moisture can be the most difficult challenge with cool season severe thunderstorm forecasts. Thus, it is hoped a thorough examination of buoy data from the western GoM will aid in recognizing potential gulf moisture surges ahead of these systems. We primarily want to examine the usefulness of buoy observations for severe thunderstorm forecasts.

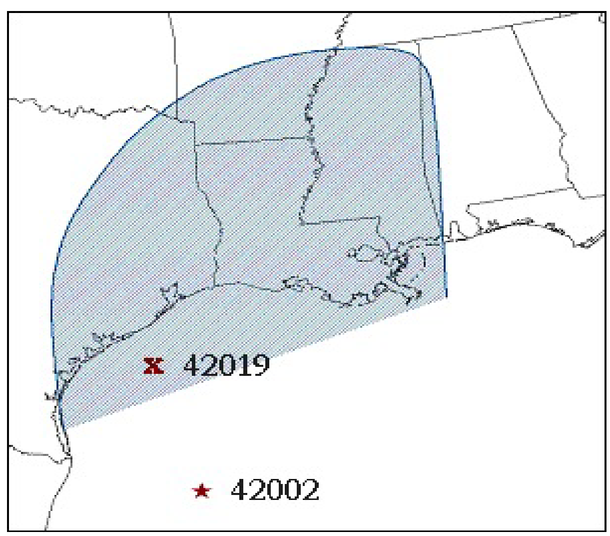

Fig. 1. *Domain examined in this study (hatched blue lines) along with locations of buoys 42002 and 42019.*

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2. METHODOLOGY

Hourly standard meteorological data were downloaded via the National Buoy Data Center (http://www.ndbc.noaa.gov/maps/west_gulf_hist.shtml) from 1993 through 2004 for buoy 42002. This included barometric pressure, wind direction and speed, air temperature, water temperature and dew point temperature at the surface. The same data were also collected for buoy 42019, but only from 2000 to 2004 when surface T_d observations were available. Once this was collected, 45 significant tornadoes (hereafter, SIGTOR) over eastern Texas, southern Arkansas, Louisiana and Mississippi (Fig. 1) were gathered from October 15 1993 through February 2004 for each cool season. In addition to the SIGTOR cases, a comparison dataset was gathered of 10 severe thunderstorm events which produced 50+ reports of either hail >.75” in diameter, winds ≥ 50 kt, wind damage or F0-F1 tornadoes within the same months and area discussed above (hereafter, SVR). Surface analyses were then consulted for each case to obtain proximity T_d from each SIGTOR, and near the beginning of SVR events.

From this data box and whisker plots were developed in order to illustrate the complete data set. In addition, wind rose diagrams were created to illustrate common wind directions for rapid moisture return occurrences (defined here as surface T_d increases ≥ 5^o F in 6 hr).

3. RESULTS

It is readily discernible in Fig. 2a that buoy 42002 surface T_d increase steadily beginning at 48-72 hr in advance of a SIGTOR, with little change >72 hr ahead of time. In addition, surface T_d vary widely beyond 72 hr. Taken at face value, median values are surprisingly high (from 60-65^o F) beyond day 5 in the cool season. However, separating the autumnal events from the winter cases (Fig. 2b), one can see this is an artifact of the vast majority (73%) of SIGTOR for this study occurring from October 15 through November. As would be expected, Fig. 2b indicates T_d are considerably lower from December through February (clear boxes) with medians nearly 10^o F lower compared to October and November (color boxes). This is consistent with the cooler mean SST over the GoM during the winter, and accounts for some of the large increase in T_d spread beyond 72-96 hr within the combined plot (Fig. 2a). As the event time nears, the range of buoy values narrows considerably and increases to a more tropical value (>70^o F) near the time of the event.

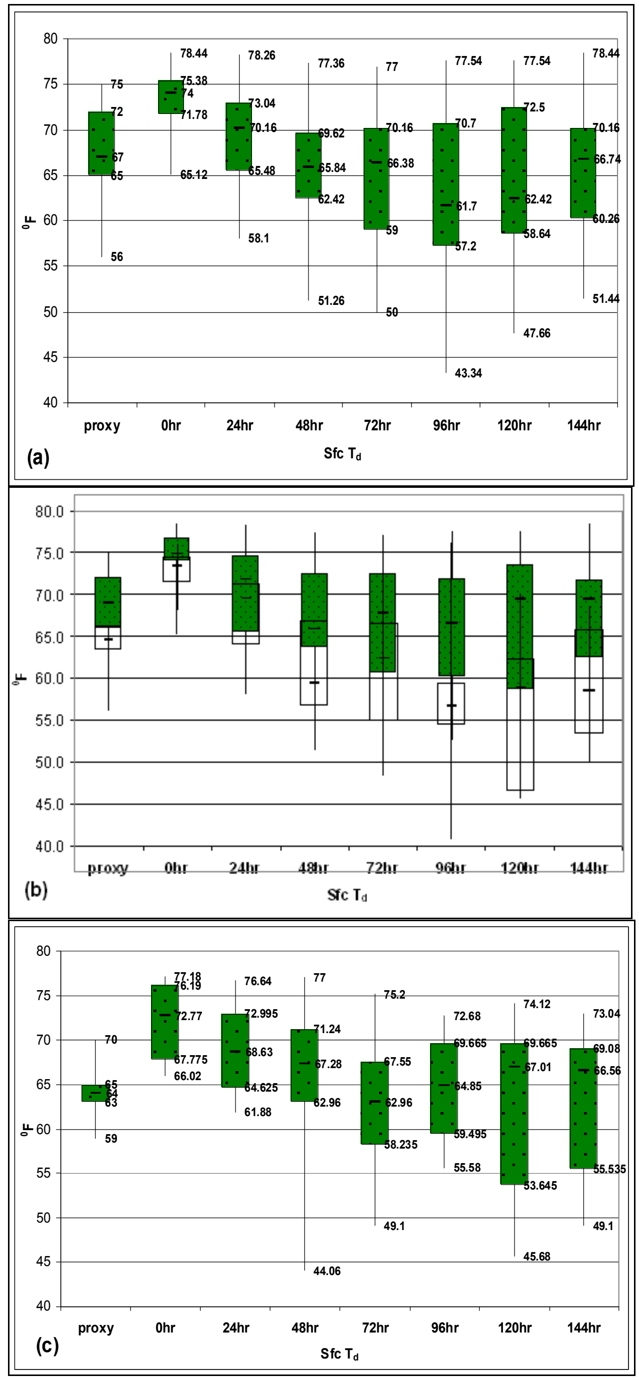

Fig. 2. *Event proximity and 0hr buoy 42002 Td on left, with buoy Td (*^{o} F*) increasing by 24hr from left to right. Each box and whisker indicates maximum and minimum on either end of line, along with middle 50% values and median within box. a) all SIGTOR, b) SIGTOR separated by months. Oct/Nov color, Dec-Feb clear boxes, c) all SVR.*

This holds true throughout the cool season, and indicates nearly all the SIGTOR events occurred within, or near the leading edge of, a rich tropical moisture plume at the surface. It is also apparent that T_d preceding the October/November events remain rather steady and increase only a few degrees each period through 24 hr. On the other hand, the winter cases in Fig. 2b indicate a much larger increase becoming evident starting at 72 hr, where median values increase nearly 15^o F by 24 hr. Surface T_d equal to the eventual values in proximity to the SIGTOR event are common throughout the forecast period with the autumn events; however they begin to appear at buoy 42002 only 48-72hr in advance during the winter.

A comparison with 10 SVR events can be found in Fig. 2c. Surface T_d trends and values are quite similar between the datasets, with a steady increase evident beginning around 72 hr. Though buoy values at the time of the SVR event are similar to the SIGTOR cases, the values in proximity to the actual event are noticeably lower. In fact, the 25th percentile value of 65^o F for all SIGTOR cases matches the 75th percentile for the SVR events.

Another interesting observation is the small decrease in surface T_d at 96-120 hr associated with SIGTORs (Fig. 2a); this is occurs in both the autumn and winter events (Fig. 2b). This may be indicative of several SIGTOR cases having preceding frontal intrusions 4-5 days ahead of the event which penetrated the western GoM as far south at buoy 42002. This signal is even noticeable with the 10 SVR events, though the minimum is centered closer to 72 hr.

Trends in surface T_d are similar for buoy 42019 (Fig. 3), when compared with 42002, though actual values have a much larger range and are cooler on average. This is not surprising given its location just 60 nautical miles south of Freeport, TX, where cool season frontal passages are more prevalent. The 25th percentiles are nearly 10^o F cooler at 48 hr and 72 hr than those at 42002, though by 24 hr and especially at 0 hr the values are nearly identical.

Typical monthly plots for an autumn case (Fig. 4) and a winter case (Fig. 5) show increasing surface T_d beginning a few days prior to occurrence of a SIGTOR or SVR event. The figures also suggest these events occurred around the time Θ_e at buoy 42002 was nearing or exceeding super-equilibrium status as defined by Thompson et al (1994).

An examination of wind rose plots associated with T_d increases described in section 2 are shown in Fig 6. Not surprisingly southeasterly winds are by far the predominant wind direction associated with rapid T_d increases, defined as ≥ 5^o F in 6 hr (Fig. 6a). This is consistent with the Crisp and Lewis (1992) GoM return flow patterns, and with Thompson et al (1994) who found higher Θ_e air concurrent with a November severe event which originated from the Yucatan Straits and northwestern Caribbean. In addition, a clear easterly component out of the central GoM is also evident. When the wind rose plots are separated by season (Fig. 6b), the easterly component remains favorable for rapid T_d increases through-

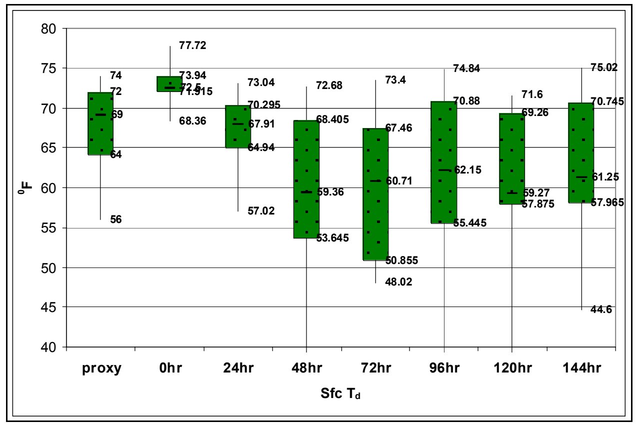

Fig 3. *Same as Fig. 2a but for buoy 42019.*

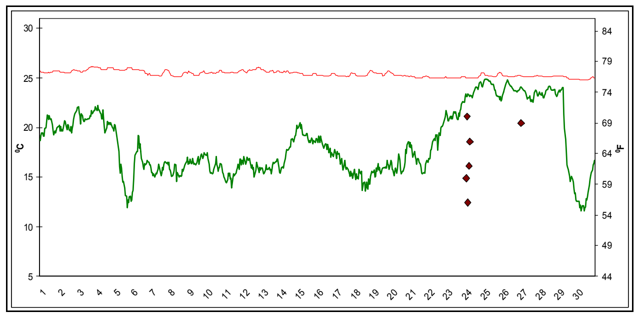

Fig 4. *Monthly plot of 42002's SST (red) and T_d (green) for Nov. 2001. ^{o}C is along left Y-axis with ^{o}F on right, with day of month on X-axis increasing from left to right. SIGTOR reports (red diamonds) plotted using their actual proximity T_d and time of occurrence.*

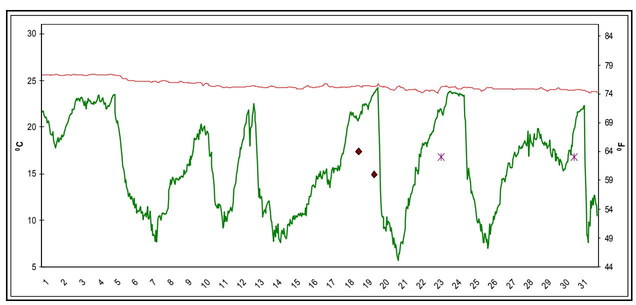

Fig 5. *Same as Fig. 4, but for Dec. 2002. SVR events indicated here as purple asterisks.*

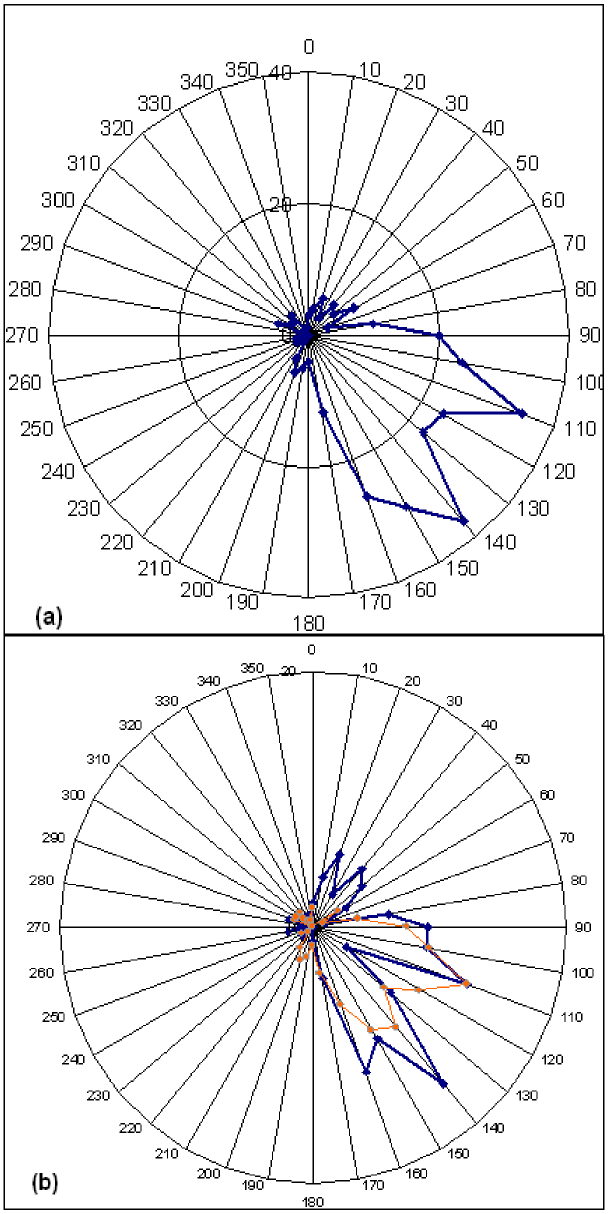

Fig 6. *Wind rose plots for buoy 42002 revealing number of cases with specific wind directions accompanying rapid surface dew point increases ≥5^{o}F/6hr. (a) all SIGTOR. (b) separated by month- Oct/Nov (blue) and Dec-Feb (orange).*

out the cool season. However, T_d increases due to northeasterly winds become less favorable during the winter months.

4. CONCLUSIONS

It is not uncommon early in the cool season, particularly through November, for the western GoM to remain quite warm and moist a week before a SIGTOR event. During the autumn months, T_d 25^{th} percentile values remained at or above 60^{o} F through 8 days prior to a SIGTOR. This is consistent with finds from Edwards and Weiss (1996) who showed a clear relationship between above average SST anomalies and increased severe reports across roughly the southeastern quarter of the U.S.

During the winter months (December-February) prior penetrations of Continental Polar air masses increase the forecast challenge and create much uncertainty regarding the return of tropical air ahead of advancing weather systems. Fig. 2 suggests forecasters can realistically expect air mass recovery to occur, or become evident, at buoy 42002 sometime between 48-72 hr preceding a significant tornado event. This appears valid for both the SIGTOR and SVR data sets. If this signal fails to materialize ahead of a cool season frontal system, our findings suggest uncertainty for a SIGTOR event should increase.

Since anticipating boundary layer moisture quality is of prime importance during the cool season in the gulf coast region, it is hoped these buoy trends and tendencies will help improve operational severe weather forecasts.

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