S170 **Microbursts within landfalling tropical cyclones, and the associated environmental conditions.**

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1. INTRODUCTION/MOTIVATION

Tornadoes in the outer spiral bands of tropical cyclones (TCs) have been well-documented. While hurricanes and microbursts have been widely studied separately for many years, however, there has not been any work examining potential microbursts during TCs. Microbursts are sudden, powerful descending air currents that are produced by thunderstorms. When microburst winds reach the surface, they spread out horizontally, causing property damage and a threat to aviation. Previous work has shown microbursts are characterized by dry adiabatic environmental lapse rates at the 500-hPa level, with moist adiabatic environmental lapse rates directly below it and a subsidence inversion near the surface.

Examining landfalling TCs from 2004–2015, 10 possible cases were found using a combination of severe wind reports and radar. Using both sounding and reanalysis data, the environmental conditions favorable for microburst occurrences within TCs are investigated.

2. DATA AND METHODOLOGY

The main objective for this study involved comparing radar reflectivity and storm relative velocity signatures, sounding analysis, and severe wind reports from TCs to those of non-TC wet and dry microbursts. Data from the NWS Storm Prediction Center (SPC) Database was used from 2004–2015, to produce a list of microburst events that took place during TCs in any part of the United States.

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A total of 10 TC cases and 20 non-TC cases were selected for further analysis. Each case was identified from NOAA Storm Prediction Center severe wind damage reports. These reports ranged from trees down, any light poles that were blown down, and any structural damage. Subsequently, archived radar data was used to confirm microburst signatures in all suspected cases (section 3).

For each event, low-level and mid-level lapse rates and DCAPE from archived radiosonde data were recorded (section 4). The soundings revealed that common traits were also found between TC and non-TC wet and dry microbursts.

We also used the National Center for Environmental Prediction (NCEP) North American Regional Reanalysis (NARR, Mesinger et al. 2006), visualized with the Unidata Integrated Data Viewer (IDV), to investigate specific humidity and vertical motion (section 5). This allowed us to investigate how strong the downdraft signatures were in comparison to our sounding analysis.

Finally, we used archived infrared satellite imagery to verify where each microburst occurred relatives to each TC center. This aided our sounding analysis (section 4).

3. RADAR REFLECTIVITY AND STORM RELATIVE VELOCITY SIGNATURES

Once all of the SPC storm reports were collected, we examined radar data to look for microburst signatures. Using storm relative radial velocity, we were looking for outbound and inbound velocity pixels moving away from each other with time. This demonstrates the diverging air that occurs when downdrafts hit the surface, and typically cannot be seen on satellite imagery or radar reflectivity.

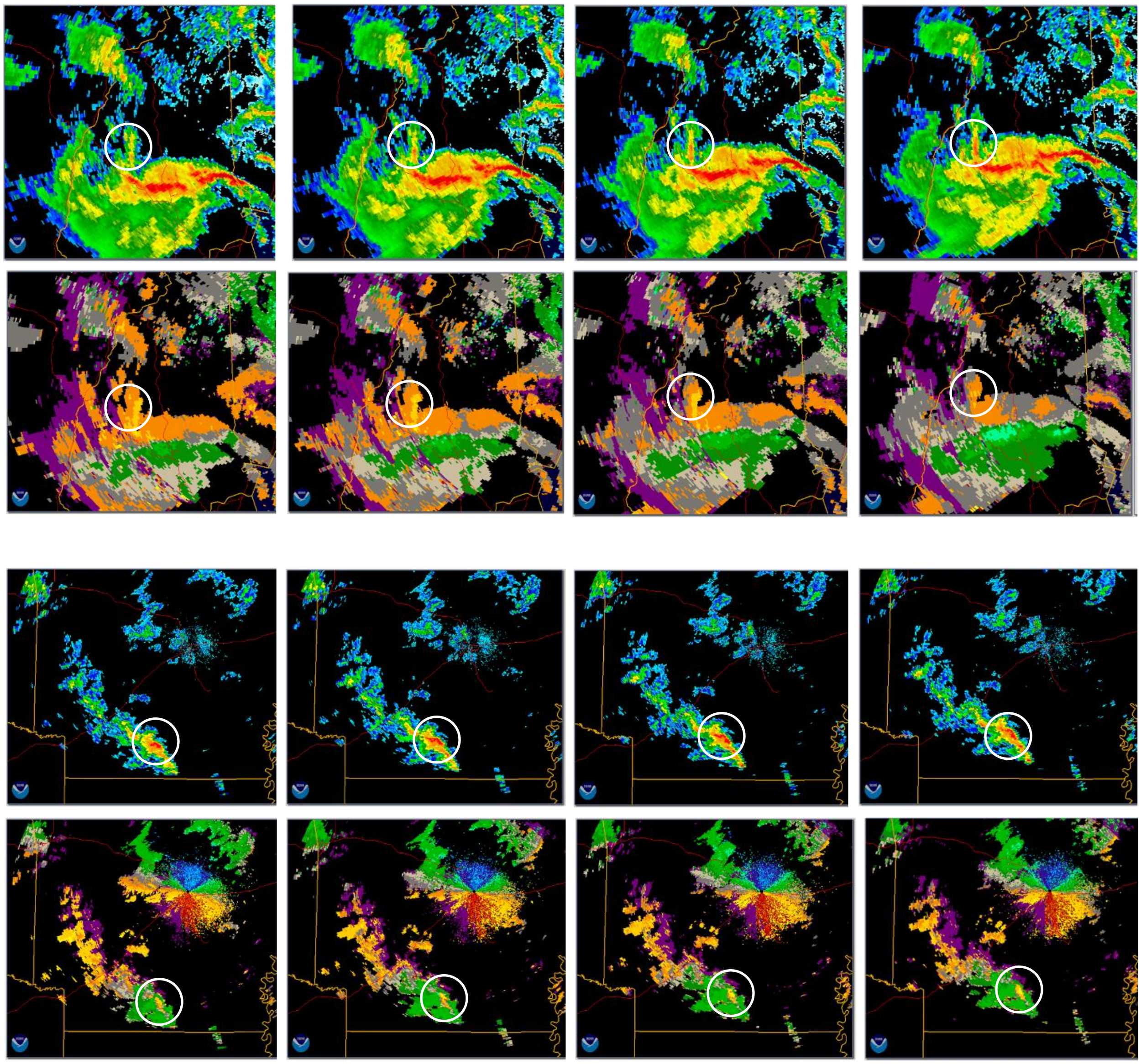

Fig. 1: First two rows-: The TC Sandy microburst in New Hampshire, as indicated by the white circle for base reflectivity (top) and storm relative velocity (bottom), with time moving forward from left to right; last two rows: Bottom two rows: As in the top two rows, but for the TC Ike microburst in southern Arkansas.

4. SOUNDING ANALYSIS

During the analysis of the data, the lapse rates provided a major clue. Caplan and Bedard, Jr. (1990) found that lapse rates of 8°C km $^{-1}$ were commonly found within dry microbursts, while wet microbursts tend to be associated with lapse rates of 5–6°C km $^{-1}$.

Figure 2 shows what a typical observation sounding looks like at the time of a microburst. Between the 300-hPa and 500-hPa levels, there is a dry airmass on top of a moist airmass. This has been commonly found in all microbursts. In the crash report of Delta Airlines Flight 191, (Caracena et al. 1986) stated that dry air was observed at 500 hPa, while moist air was found at 850 hPa level. These ingredients favor strong downdrafts.

Through satellite and radar imagery analysis, we found that each of our TC microbursts that was studied occurred in the outermost spiral bands region of each TC. This could potentially enhance the dry air that was seen at the 500-hPa level by being located near the sinking air outflow region of the TC.

When air descends, it warms adiabatically; however, in the TC Sandy microburst case, adiabatic warming probably was not the only thing causing the air to dry and warm. Since, the microburst occurred in New Hampshire over the Appalachian Mountains, there is a good cause to suggest adiabatic warming was occurring with southeasterly downslope flow on the northwestern side of the Berkshires and White Mountains.

With further analysis, all TC cases revealed lapse rates at the surface–3 km and 3–6 km to be in the range of 5–6 °C km $^{-1}$. Although sinking air was present near the microburst locations (section 5), there was sufficient moisture in the outer spiral bands for thunderstorms to develop. This would increase the chances for microbursts to occur.

At the time of occurrence, there is a “Inverted V” signature near the surface. This signature is typical with microbursts as the rain-cooled downdraft descends and accelerates into and because of near-surface dry air. During the event, K index values of 30+ have been noticed from the 12 UTC soundings and subsequently drop into the 20’s and teens by the 00 UTC soundings\.

Figure 3 shows proximity soundings that were observed during TC Sandy and TC Ike, while Fig. 4 shows proximity soundings for non-TC microbursts. Comparing the non-TC soundings from Oklahoma in 2015 (Fig. 4) and the soundings during TC Ike in 2013 (Fig. 3), both 12 UTC soundings show an immense amount of moisture between the surface and 700 hPa.

Above this layer there is a gradual then sharper decrease in moisture. The 00 UTC soundings are quite different between the non-TC cases (Fig. 4) and TC Ike (Fig. 3). At the time of the occurrence during the non-TC microburst, the sounding is incredibly dry while the microburst with TC Ike still shows the immense tropical moisture. However, during both events, the “Inverted V” signature was observed near the 900–950-hPa layer although it is less pronounced in the Ike sounding compared to its non-TC counterpart.

Comparing TC Sandy (Fig. 3) with the non-TC microburst in Greensboro, North Carolina (Fig. 4), nearly identical structures are observed. At 1200 UTC, the dewpoint near 500 hPa decreases rapidly from -13 to -32 °C, suggesting sinking air (adiabatic warming). Similar structures were observed in both 00 UTC soundings.

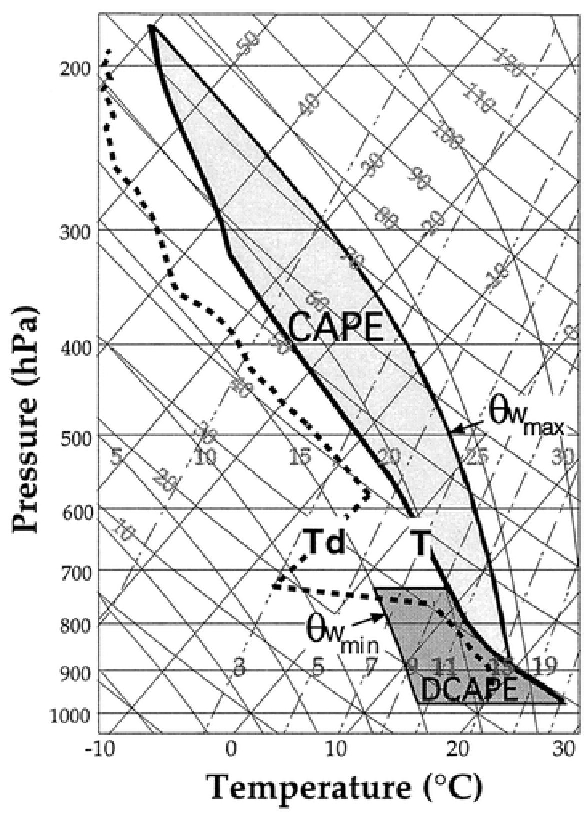

Fig. 2: Textbook microburst sounding example, taken from Gilmore and Wicker (1998).

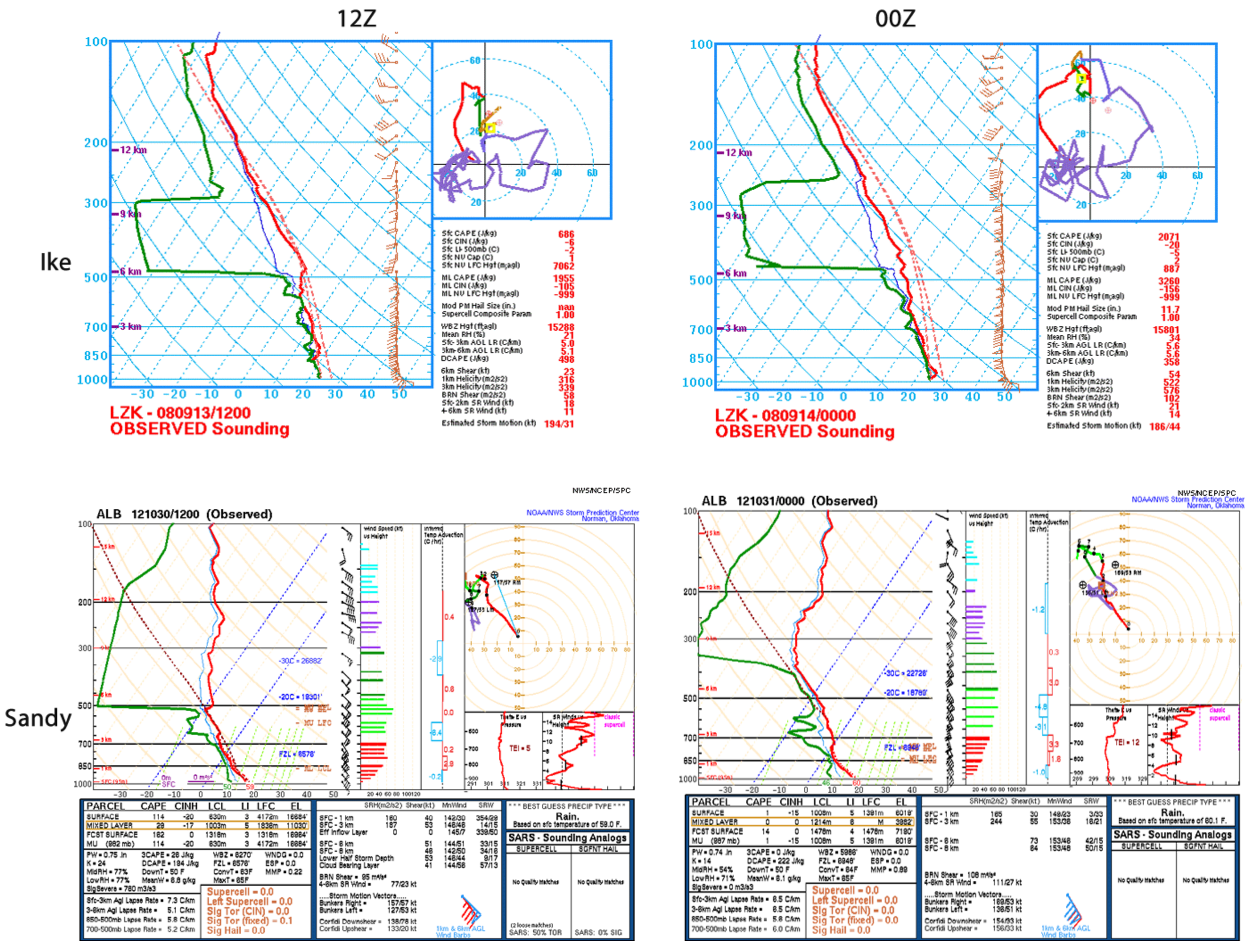

Fig. 3: Left: 12 UTC observed proximity soundings prior to the TC Ike (top) and Sandy (bottom) microbursts in Arkansas and New Hampshire, respectively. Right: 00 UTC observed proximity soundings following the TC Ike (top) and Sandy (bottom) microbursts.

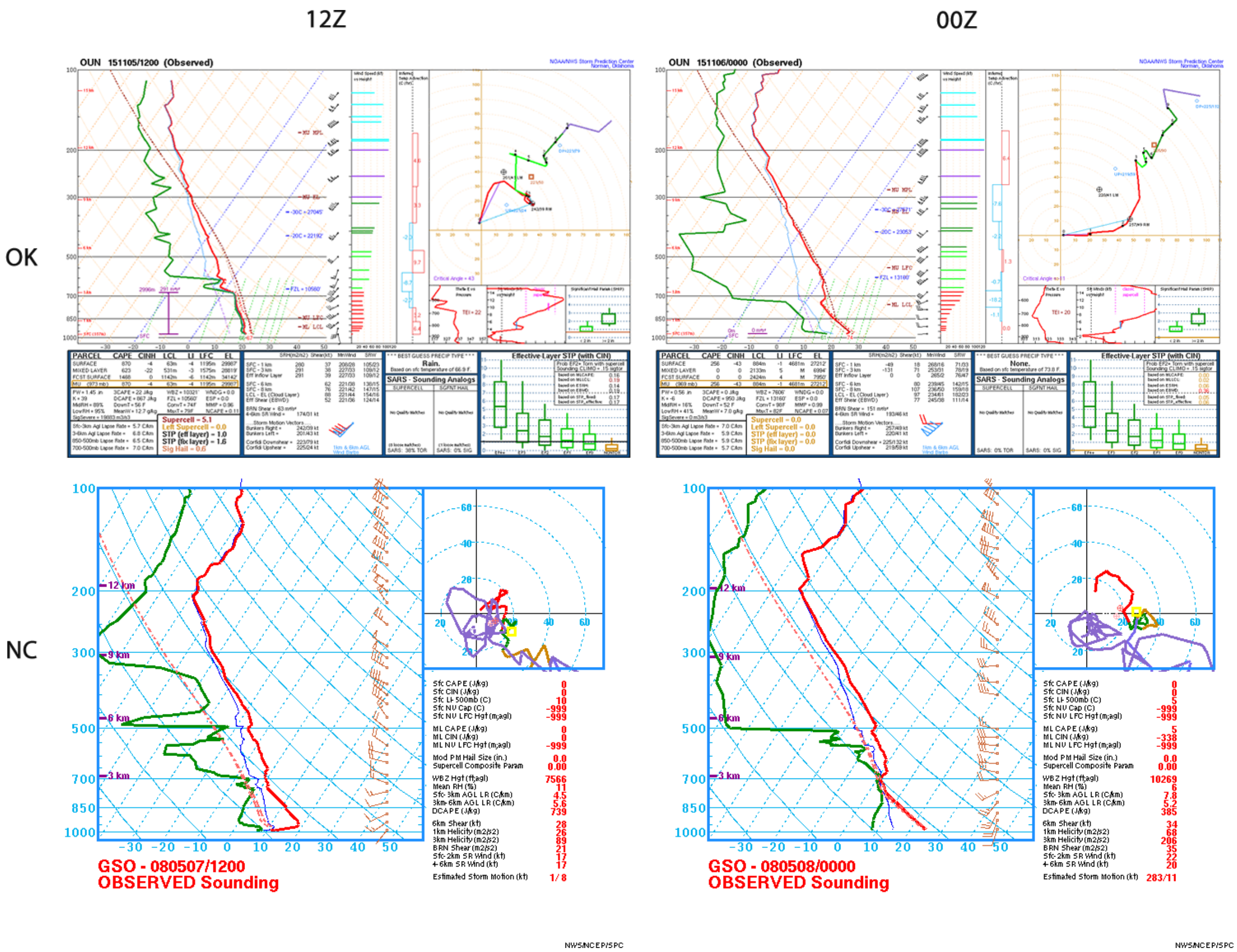

Fig. 4: Proximity soundings for two non-TC microburst cases. Top: Norman, Oklahoma (KOUN) soundings before (12UTC) and after (00 UTC) a wet microburst near Moore, Oklahoma. Bottom: Greensboro, North Carolina (KGSO) soundings before (12 UTC) and after (00 UTC) and after a wet microburst in central North Carolina.

4. HUMIDITY AND DOWNDRAFTS

Downdrafts are one of the fundamental aspects of a microburst. To investigate our microburst cases, we used the NCEP NARR visualized with IDV to examine specific humidity and vertical motion.

Specific humidity is defined as the ratio of the mass of water vapor to the mass of the total air. Therefore, when using the NARR data, we were looking for areas of moist and dry air. In Fig. 5, the whiter the color the more moist air there is, while darker colors indicate drier air.

As TC's make landfall, they bring an abundance amount of moisture into the environment. Sawada and Iwasaki (2010) found if there is no evaporative cooling and melting/sublimation is occurring, the larger values of moisture can increase the overall downdraft potential. Therefore, this enhances the potential of microbursts to occur.

Figure 5 shows that occurrence of a microburst, the original spot of that thunderstorm which produced it collapses. Usually, this reveals an area that is darker and drier compared than before. This matches what was seen in Fig. 3 at the 700 hPa level for the 00 UTC Albany observed sounding.

For vertical motion, positive values represent descending air with larger values indicating stronger instances of such. For Ike and Sandy, vertical motion values of +2 µb s^{-1} were found (Fig. 5). Although this number is relatively small, it still suggests that the microburst occurred in a region of descent.

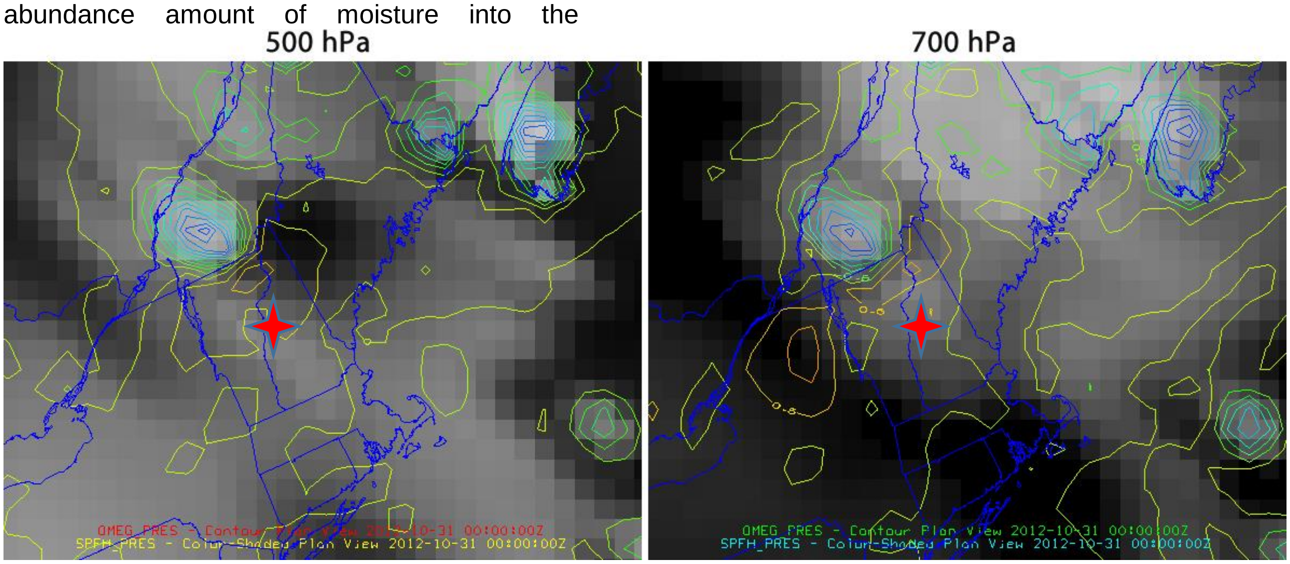

Fig. 5: (left) 500-hPa and (right) 700-hPa specific humidity (shaded) and omega (contours, descent in warm (colors) 00 UTC 31 October 2012, near the time of the TC Sandy microburst in New Hampshire (marked with a red star).

6. SUMMARY AND FUTURE WORK

The combined satellite and radar analysis indicates that 10 out of 10 cases occurred in the outer bands of each TC. Eight of those cases occurred in the outer-most band of the TCs. Using a combination of observed soundings and NARR data, we analyzed environmental characteristics of TC microburst cases.

Future work will include running high-resolution, convection-allowing Weather Research and Forecasting (WRF) model simulations on one or more TC microburst cases to examine whether it can adequately reproduce the characteristics of the thunderstorms which resulted in the microbursts.

7. REFERENCES

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