Microbursts within landfalling tropical cyclones, and the associated environmental conditions

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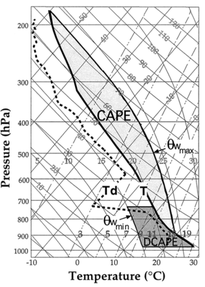
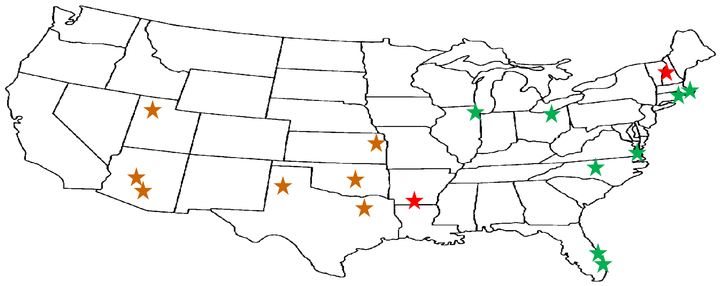
Introduction/Motivation

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 lapse rates at the 500 MB level with moist 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.



$$\mathrm{DCAPE} \equiv g \int_{z_{\mathrm{sfc}}}^{z_n} \frac{\overline{\theta}(z) - \theta(z)}{\overline{\theta}(z)}\, dz.$$



★ = Hurricane Microburst ★ = East, Wet Microburst ★ = West, Wet Microburst

Figure 1: Top Left: (Fig. 1 from Gilmore and Wicker 1998) Skew-T that represents what a wet microburst would look like at the time of observation. Top Right: Equation (Eq. 1 from Gilmore and Wicker 1998) for DCAPE which was a key value in determining wet microburst potential; the stronger the DCAPE's are, the greater the chances for microbursts to occur. Bottom Center: Gives the location of select wet microbursts that have occurred from 2006-2016 and compares them to those that occurred with Hurricane Sandy and Hurricane Ike.

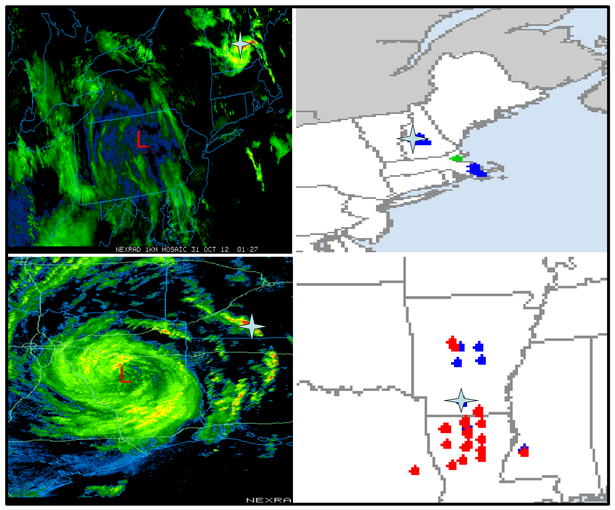
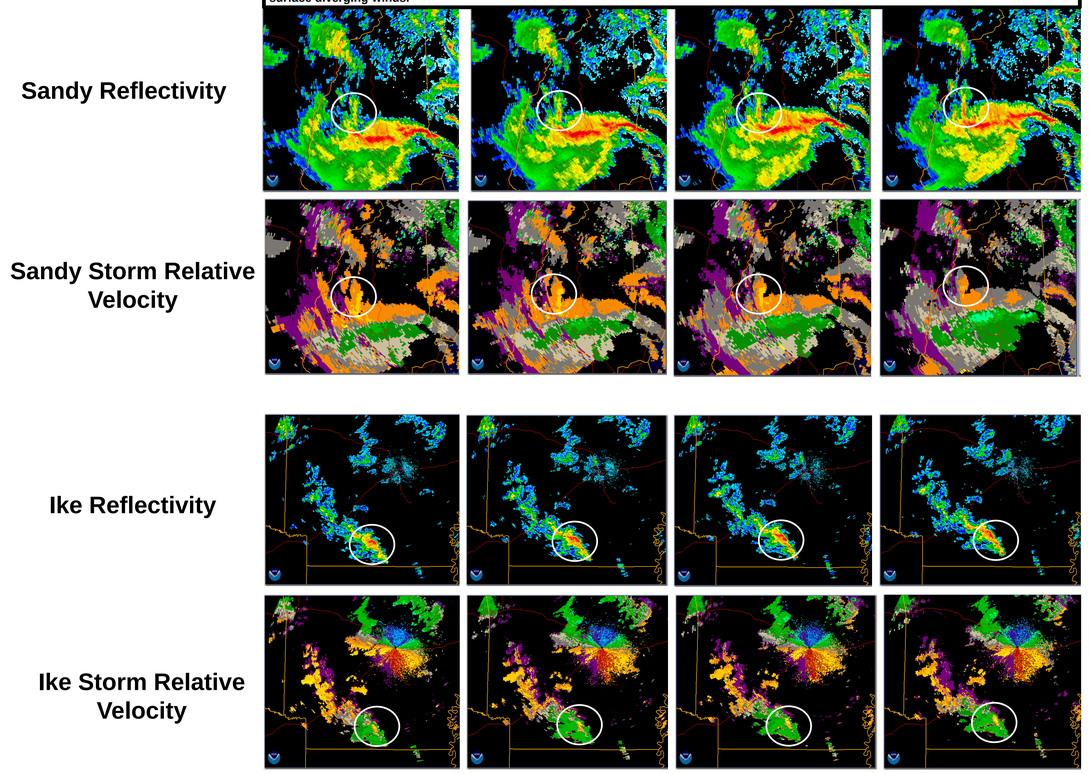


Figure 2: Left: Composite radar imagery showing the centers (marked with Ls) of Hurricane Sandy and Hurricane Ike and the locations where the microbursts occurred (marked with silver stars) . To verify this, we used severe wind and damage reports (right) from the NOAA Storm Prediction Center to isolate possible storms that had the greatest probability of producing a wet microburst.

Radar Analysis

Figure 3: Radar analysis of possible wet microbursts within Sandy and Ike. The purpose of this was too verify any signatures indicating surface diverging winds.



Skew-T Analysis

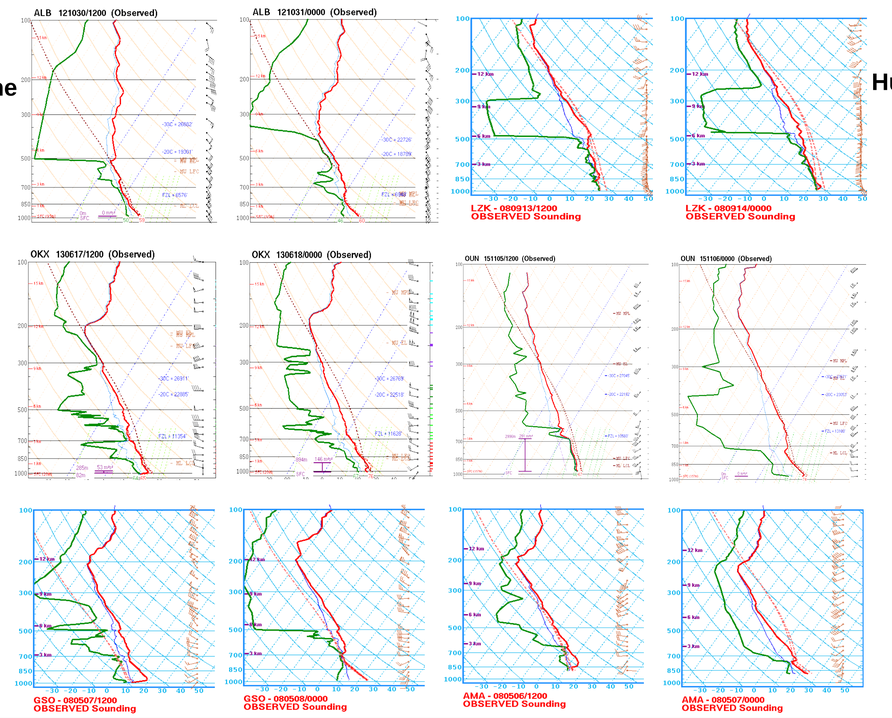


Figure 4: Skew-T analysis to further our support of microbursts to occur. Top: 12 and 00Z proximity soundings for microbursts observed in Sandy and Ike. Middle and Bottom: 12 and 00Z proximity soundings (left) from sample east wet microbursts and (right) sample west wet microbursts (Fig. 1).

DCAPE and Lapse Rates Analysis

12Z Skew-T — TCs — 00Z Skew-T

Name	SFC - 3km	3 - 6km	DCAPE
Bonnie	6	5.4	564
Charley	5.3	5.2	467
Cindy	4.7	5.5	391
Gustav	5.2	5.5	429
Ike	5	5.1	498
Rita	6.5	4.4	347
	6.3	5.3	181
Sandy	5.7	7	354
	7.3	5.1	194
Standard Deviation	0.781420043	0.65054583	121.9427107
Mean	5.78	5.38	380.5

Name	SFC - 3km	3 - 6km	DCAPE
Bonnie	5.5	5.2	315
Charley	4.9	5.4	248
Cindy	6.3	0	332
Gustav	5.5	5.4	295
Ike	5.6	5.6	358
Rita	4.7	5	0
	6.2	5.1	293
Sandy	5.6	6.4	461
	6.5	6.5	222
Standard Deviation	0.573703584	1.82337362	118.3000997
Mean	5.64	4.95	280.4

East — 12Z Skew-T — West

Name	SFC - 3km	3 - 6km	DCAPE
FL	6.1	5.5	1284
RI	5.8	6.1	1075
OH	3.7	5.6	660
OH	5.6	5.7	116
IL	4.6	7.3	1339
NC	6	5.9	683
NY	5.6	5.7	581
FL	6.5	6.5	606
NC	4.5	5.6	739
KY	4.5	6.5	836
Standard Deviation	0.856095789	0.542586399	345.1818217
Mean	5.29	6.04	791.9

Name	SFC - 3km	3 - 6km	DCAPE
TX	4.9	7.3	947
KS	3.2	6.1	444
OK	5.7	6.8	867
OK	5.1	7.3	1201
KS	2.6	7	364
TX	3.8	7.3	653
AZ	?	?	?
NM	6.2	6.8	1400
AZ	6.8	6.3	809
UT	6.5	7.2	1260
Standard Deviation	1.409316444	0.421637021	339.1740876
Mean	4.97	6.9	794.5

East — 00Z Skew-T — West

Name	SFC - 3km	3 - 6km	DCAPE
FL	7.4	6.1	1412
RI	6.5	6.1	1548
OH	7.9	5.8	705
OH	4.5	5.8	239
IL	8.2	6.8	919
NC	6.9	6.1	687
NY	7.3	6.3	1046
FL	7.8	6.2	946
NC	7.8	5.2	385
KY	8.6	6.1	1355
Standard Deviation	1.09585583	0.387943295	411.4060768
Mean	7.29	6.05	924.2

Name	SFC - 3km	3 - 6km	DCAPE
TX	8	8.6	1177
KS	5.7	6.6	945
OK	7	5.9	950
OK	9.2	6.9	1287
KS	9.2	7.4	1284
TX	4.9	5.8	489
AZ	?	?	?
NM	9.9	6.5	1296
AZ	9.2	7	1293
UT	10.2	8.6	1684
Standard Deviation	1.778957942	0.962635272	313.2242521
Mean	8.14	7.03	1156.11

Results/Conclusions

Similarities between TC and Wet Microburst Skew-T's:

- Shallow 40–50 mb inversion in the morning hours (e.g., Atkins and Wakimoto 1991)
- Typical DCAPE values are much smaller in the TC cases than other microbursts, indicating overall more saturated vertical profiles
- For the TC cases, lapse rates of 5–6 °C/km are found between SFC–3 km and 3 km–6 km, similar to those seen in the east wet microbursts
- Mean TC lapse rates are generally less than wet microbursts that have occurred in the Great Plains and western U.S. (west cases)
- "Inverted V" signatures are still seen in most of the TC cases, but are less pronounced than in non-TC wet microburst cases
- There is evidence of large dry pockets and subsidence in the upper troposphere (500 mb and above) in TC microburst cases

Conclusions:

- 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.
- Speculation is that in the outer most region of TCs, adiabatically and/or diabatically-driven descent may promote dry air in the mid-troposphere as seen in the soundings.

Future Work

- Investigate the use of higher-resolution reanalysis data for the environmental characteristics of TC microburst cases
- Run convection-allowing numerical model simulations (e.g., WRF) on one or more TC microburst cases to examine whether it can adequately reproduce the characteristics of the thunderstorms which resulted in the microbursts.

References

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Gilmore, M. S., and L. J. Wicker, 1998: The influence of midtropospheric dryness on supercell morphology and evolution. *Mon. Wea. Rev.*, **126,** 943-958.

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