An Updated U.S. Geographic Distribution of Concurrent, Collocated Tornado and Flash Flood Events And a Look at those Observed During the First Year of VORTEX-SE

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INTRODUCTION

- While both tornadoes and flash floods individually present public hazards, when the two threats are both concurrent and collocated (referred to here as TORFF events, short for "tornado and flash flood"), a unique set of concerns arise that can further jeopardize public safety.
- Among these unique concerns for dual threat scenarios is a conflict between recommended lifesaving action for each individual hazard, which can increase confusion and lead to sub-optimal precautionary responses.
- This research will serves to focus on analyzing TORFF events that occur in the Southeastern U.S. and examine one event that occurred during the first year of the VORTEX-SE field project.

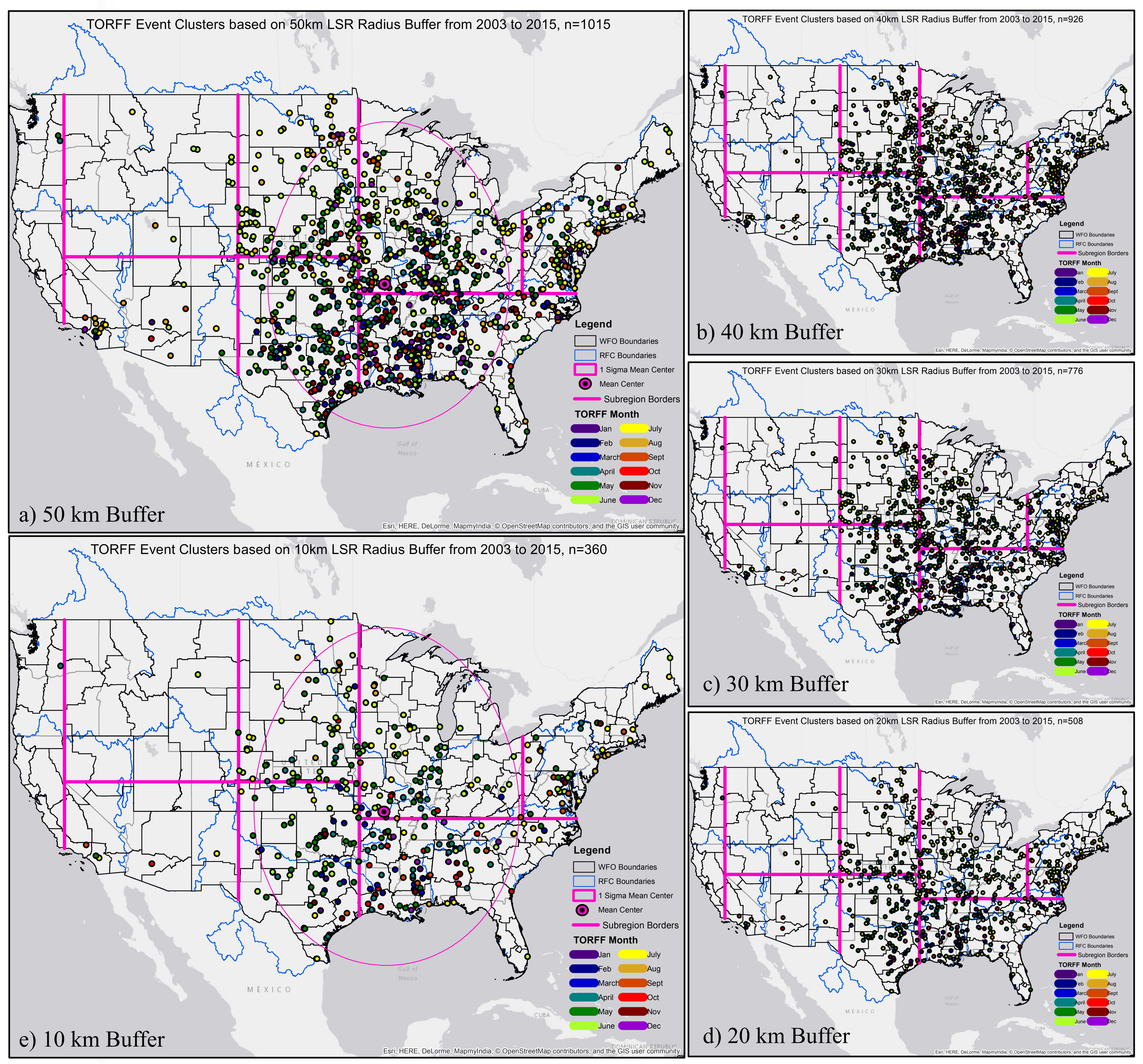

Fig. 1: (a-e) *Geographic distribution of concurrent, collocated tornado and flash flood events from 2003 to 2015 (colored by month) based upon intersections between tornado tracks and 50, 40, 30, 20, and 10 km, respectively, buffers placed around flash flood local storm reports. Pink dot (a,e) represents the geographic mean center, pink ellipse (a,e) represents one spatial standard deviation away from mean center, and the black and blue lines represent NWS WFO and RFC boundaries, respectively.*

DATA AND METHODS

- Expanding on methods in Nielsen et al. (2015, WAF), the spatial intersections of tornado tracks and various radii centered on flash flood local storm reports (LSRs) within 3 hours of one another were identified over the U.S. and the Southeast from 2003-2015, using the ArcGIS, and clustered into events (Fig. 1).
- Two complementary methods were employed, similar to Nielsen et al. (2015), to explore the meteorological conditions that separate TORFF from tornado only events (TOR): a full field analysis using the North American Regional Reanalysis (NARR; Messinger et al. 2006, BAMS), and local standardized anomalies (LSAs) were created using NOAA's Second Generation Global Ensemble Forecast System (GEFS/R; Hamill et al. 2013, BAMS) to asses local departures from climatology.
- A modeling case study, using a member of the NCAR's real-time convection allowing ensemble (Schwartz et al. 2015, WAF), of the Dermott, AR TORFF event that occurred on 31 March 2016 during the 1st year of VORTEX-SE was also performed.

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Southeast U.S. Climatology and Classification

Questions to investigate:

How often do TORFF events occur in the U.S. and the Southeast? What meteorological characteristics distinguish TORFF and TOR events in the Southeast?

	U.S.	*SE*	*SGP*	*NGP*	*MDWST*	*NE*	*SW*	*ROCK*	*PCST*	*HI*
Before Sunset	669 (65.9)	136 (50.6)	148 (64.9)	115 (81.6)	162 (67.5)	76 (75.3)	20	9	2	1
Before and After Sunset	142 (14.0)	60 (22.3)	29 (12.7)	12 (8.5)	32 (13.8)	8 (7.9)	1	0	0	0
After Sunset	204 (20.1)	73 (27.1)	51 (22.4)	14 (9.9)	46 (45.6)	17 (16.8)	1	0	0	2
Total	1015	269	228	141	240	101	22	9	2	3

Table 1: Breakdown of the number TORFF events from 2003-2015 at the 50 km LSR buffer by geographic region and timing relative to sunset. Values in parentheses within each geographic region represent the percentage of events within that region in each category relative to sunset.

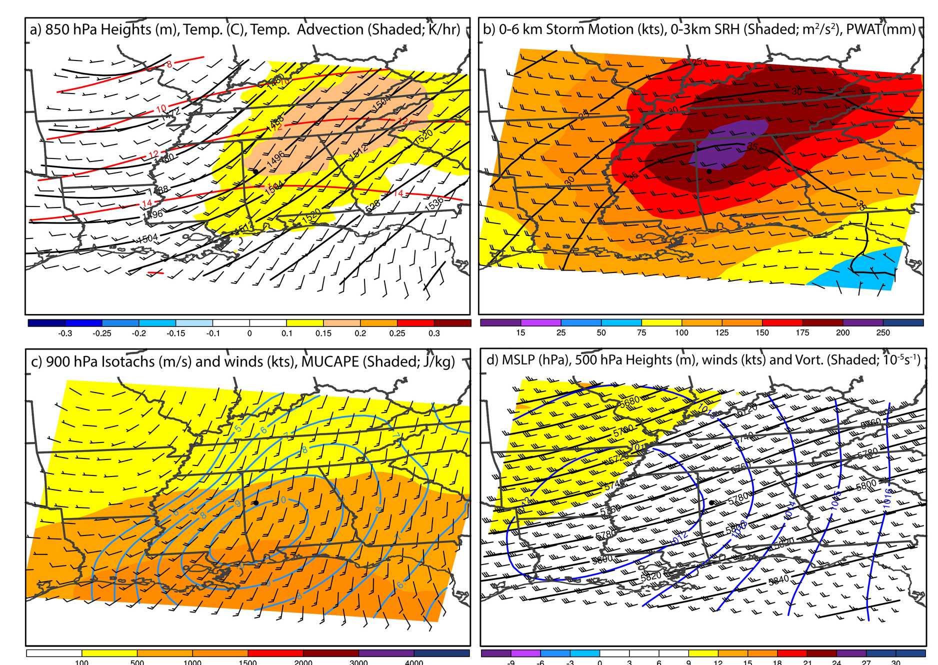

Fig. 2: *Event centered composite for the 269 TORFF events in the S.E. from 2003-2015 at the 50 km LSR buffer. (a) 850-hPa warm air advection (K h^{-1}; fill contours), temperature (°C; red lines), geopotential height (m; black contours), winds (kt; wind barbs), and the mean event location (black dot); (b) 0—3km Storm Relative Helicity (m^{2}s^{-2}; fill contours), Precipitable water (mm; black contours), and storm motion (kt; barbs); (c) MUCAPE (J Kg^{-1}; fill contours), 900 hPa winds (kt; barbs), and 900 hPa iostachs (m s^{-1}; light blue contours); (d) Mean Sea Level Pressure (hpa; blue contours), 500-hPa vorticity (10^{5}s^{-1}; fill contours), heights (m; black contours), and winds (kt; barbs).*

- At the 50 (10) km flash flood LSR buffer, 1015 (360) TORFF events occurred from 2003-2015 (Fig. 1a,b). Of those 269 occurred in the Southeast United States (Table 1).
- Most cases, throughout the U.S., occurred before sunset with the second most frequent category being nocturnal events. TORFF events that spanned from day to night were the least frequent.
- Event centered composites from the FFA show that verified TORFFs in the S.E. are associated with warm air advection at 850-hPa (Fig. 2a), fairly intense 0—3km SRH (Fig. 2 b), precipitable water over 35 mm (Fig. 2b), 10 m/s LLJ, and located upstream of the 500-hPa trough axis (Fig. 2d).

- MUCAPE values are below 1000 J/Kg at event center, but higher upstream associated with presumed inflow region.

	U_{10}	U_{850}	U_{500}	V_{10}	V_{850}	V_{500}	ω_{850}	T_{2M}	Q_{2M}	PWAT	CAPE	CIN	T_{850}
(1)TORFF_All	**-0.17**	**0.31**	**0.29**	**0.57**	**0.87**	**0.74**	**-1.23**	**0.30**	**1.10**	**1.19**	**1.34**	**-0.13**	**0.42**
(2)TORFF_SE	**-0.22**	**0.59**	**0.41**	**0.93**	**1.35**	**1.04**	**-1.71**	**0.34**	**1.17**	**1.35**	**1.23**	**-0.20**	**0.51**
DIFF(2-1)	-0.05	**0.28**	*0.12*	**0.36**	**0.48**	**0.30**	**-0.48**	0.04	0.07	*0.16*	*-0.11*	-0.07	0.09

Table 2: *Results of the mean LSAs calculated in this study. The TORFF_SE (TORFF_All) row depicts the mean anomaly from the sample of identified TORFF cases within (CONUS) the S.E. U.S. compared to the climatological environment. The DIFF row represents the difference in the mean LSAs between identified S.E. (269 cases) and CONUS (1015 cases) TORFF cases over 2003-15. Positive values indicate that TORFF_SE events were more positively anomalous. Anomaly differences statistically significantly different from zero (α = 0.05) are depicted in boldface; differences significant at 99% are additionally underlined; differences significant at 90% are italicized.*

- This LSA method in Nielsen et al. (2015) showed that TORFF events, compared to TOR cases, are characterized by stronger synoptic-scale forcing for ascent, stronger meridional vertical wind, and more low-level moisture. Here we isolate any differences in the Southeast.
- TORFF events that occur in the Southeast (i.e., TORFF_SE in Table 2) posses stronger signals for synoptic scale forcing for ascent than TORFF events aggregated CONUS wide (i.e., TORFF_All in table 2; see terms in Table 2 highlighted by blue box).
- Over the Southeast, TORFF events are associated with high moisture throughout the column relative to the mean, but the standardized moisture values are comparable to TORFF events that occur elsewhere in the United States (see terms in Table 2 highlighted by green box).
- Southeast TORFF events are characterized by higher meridional winds speeds at all levels, higher mid-troposphere wind speeds, and higher vertical wind shear, especially at low-levels (see terms in Table 2 highlighted by orange box), than TORFF events that occur in other regions of the country. Speaks to the importance of the lower-level jet in the Southeastern United States.
- Convective instability for TORFF events in the Southeast is lessened compared to TORFF events that occur CONUS wide (see terms in Table 2 highlighted by magenta box).

31 March 2016 Dermott, AR TORFF during VORTEX-SE

Question to investigate:

What were the meteorological characteristics of this event?

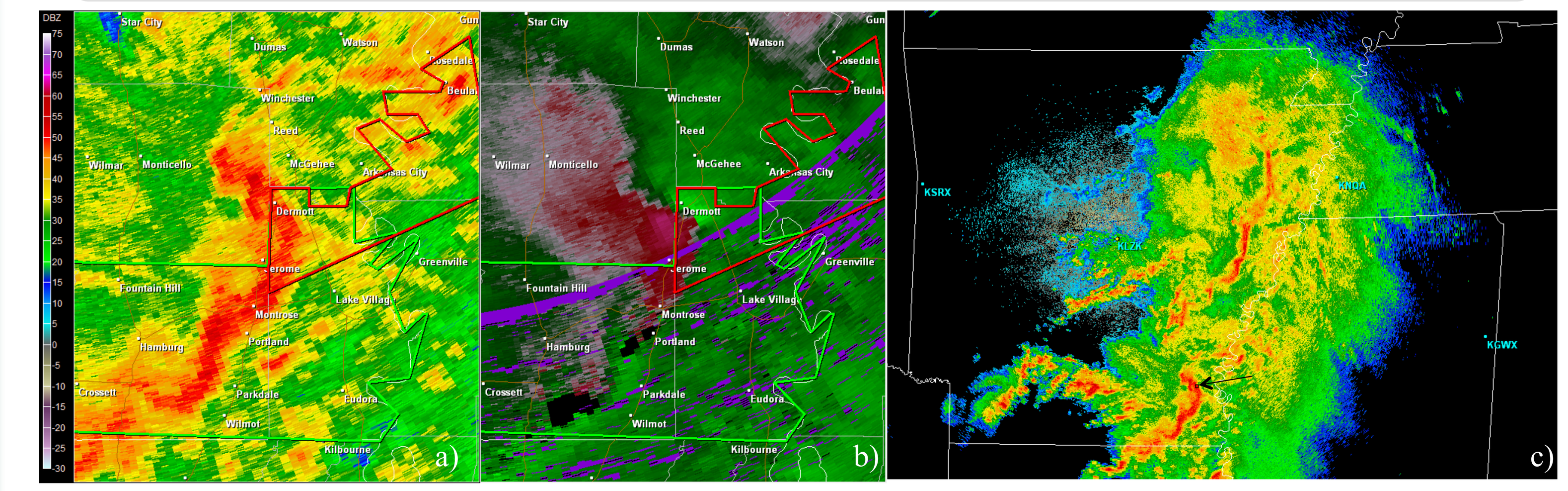

Fig. 3: *Radar images of (a) reflectivity and (b) radial velocity from the Little Rock, AR radar valid 0413 UTC 31 March 2016 showing the storm and circulation responsible for the EF-1 tornado and flash flood event. (c) zoomed out regional radar view of the system from the Little Rock, AR radar valid 0413 UTC 31 March 2016, arrow denotes Dermott, AR.*

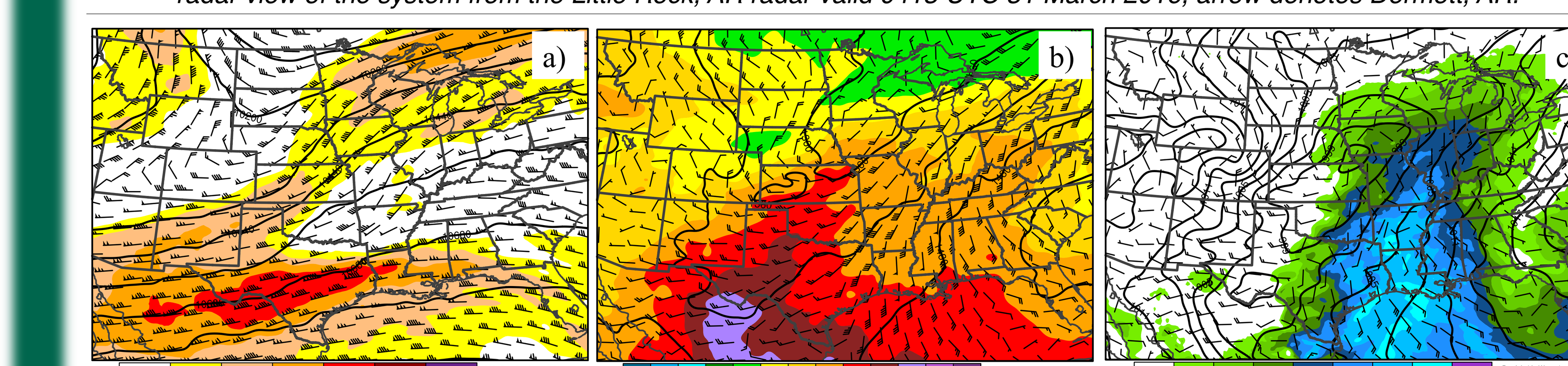

Fig. 4: *(a) 250-hPa heights (contours), winds (barbs), and isotachs (fill); (b) 850-hPa heights (contours), temperature (fill), and winds (barbs); (c) MSLP (contours), 10m winds (barbs), and precipitable water (fill) valid 0000 UTC 31 March 2016 from the RAP analysis.*

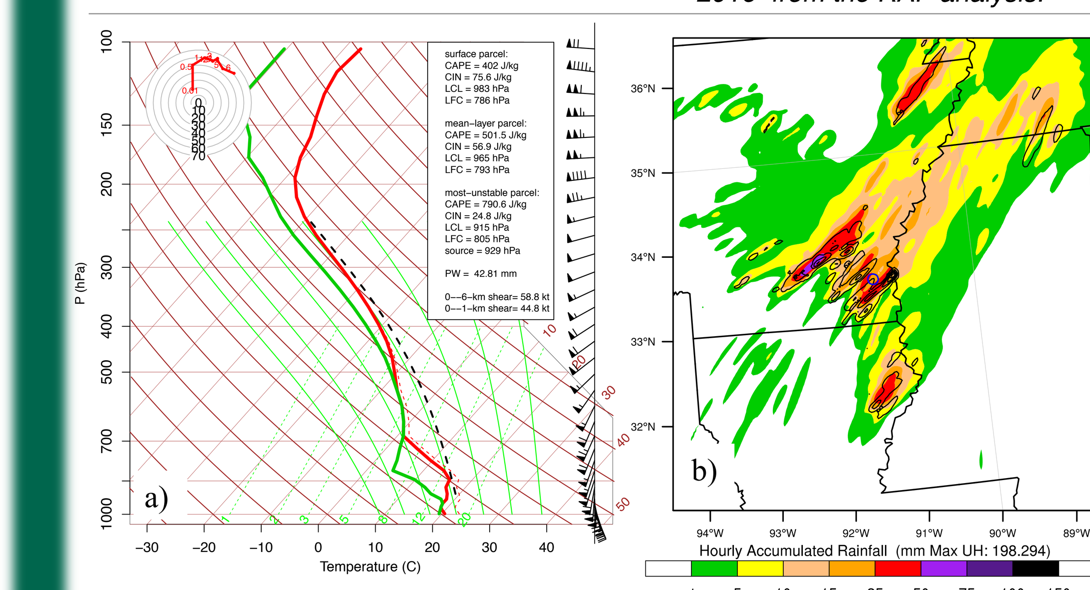

Fig. 5: *(a) model sounding for Dermott, AR valid 0400 UTC 31 March 2016 from Member 2 of the NCAR Ensemble initialized 0000 UTC 31 October 2016, parcel path is more most unstable parcel. (b) Hourly precipitation accumulation (fill) and maximum updraft helicity (UH) contoured every 20 m^2/s^2 valid 0600 UTC 31 October 2016 from Member 2 of the NCAR Ensemble initialized 0000 UTC 31 October 2016. Blue circle denotes location of Dermott, AR.*

- An EF-1 tornado passed through the town of Dermott, AR near 0415 UTC on March 31st where flash flooding occurred within 15-min of the tornado passage (Fig. 3).
- Convection originally initiated near 1500 UTC 30 March 2016 near the TX, OK, and AR border ahead of a developing surface cold front (Fig. 4) and rapidly grew upscale as it moved east during the overnight hours and into March 31st.
- Intense low-level wind shear was present through the entire period, with model (Fig. 5a) and observational soundings diagnosing 0—1km wind shear values between 40-50 kts.
- Highest modeled rain rates occurred coincident with regions of the highest updraft helicity throughout the system's life cycle (Fig. 5b).
- The modeled precipitation accumulations were correlated with rotating updrafts in this case.

CONCLUSIONS and ACKNOWLEDGEMENTS

- 269 TORFF events occurred in the Southeast U.S. from 2003-2015, which accounts for about 27% of the country wide total over the same period.
- Southeast TORFF events seem to be characterized by higher shear, especially at low-levels, and stronger synoptic scale forcing for ascent than other TORFF events around the country.
- The Dermott, AR TORFF event, observed during the 1st year of VORTEX-SE, was characterized by intense 0—1km shear and rotation on various scales.
- Future work includes investigating the influence of rotation on precipitation processes that lead to extreme rain rates.
- For more information about TORFF events and methods described here see Nielsen et al. (2015): "Double Impact: When Tornadoes and Flash Floods Threaten the Same Place at the Same Time" DOI:10.1175/WAF-D-15-0084.1

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