Polarimetric Characteristics of Tornado Debris Fallout During the May 28 2019 Lawrence/Kansas City, KS Tornado

Erik Y. Wang[1], David J. Bodine[2], James M. Kurdzo[2], James Barham[3], Chris Bowman[3], Pamela Pietrycha[3]

[1]Phillips Academy, Andover, MA, U.S.A

[2]Advanced Radar Research Center, University of Oklahoma, Norman, OK, U.S.A

[3]National Weather Forecasting Office, Pleasant Hill, MO, U.S.A

Background

The 28 May 2019 EF4 tornado that affected Lawrence and Kansas City was observed by the National Weather Service's Kansas City WSR-88D dual-polarization radar (KEAX). The tornado produced a polarimetric signature called the tornado fallout signature when debris fell into the forward flank downdraft, along with a centralized tornado debris signature, or TDS (Ryzhkov et al 2005). The resulting debris are then dispersed by the storm-scale flow and fall out at low altitudes (Van den Broeke et al 2015, Bodine et al 2013); these concentrated regions of debris are characterized by low values of horizontal radar reflectivity factor Z_{HH}, low differential reflectivity Z_{DR}, and very low cross correlation coefficient ρ_{HV}. The Kansas City tornado created a debris plume that gradually drifted northward of the primary TDS. There were several local reports of debris falling out of the sky over half an hour after the tornado had dissipated, up to 75 kilometers away from the tornado's path. The debris plume also drifted over the Kansas City International Airport, just prior to a ground stop being issued. All departures and arrivals from the airport were suspended for some time due to large, dangerous pieces of debris falling out onto the runway.

Track of Debris Fallout Signature

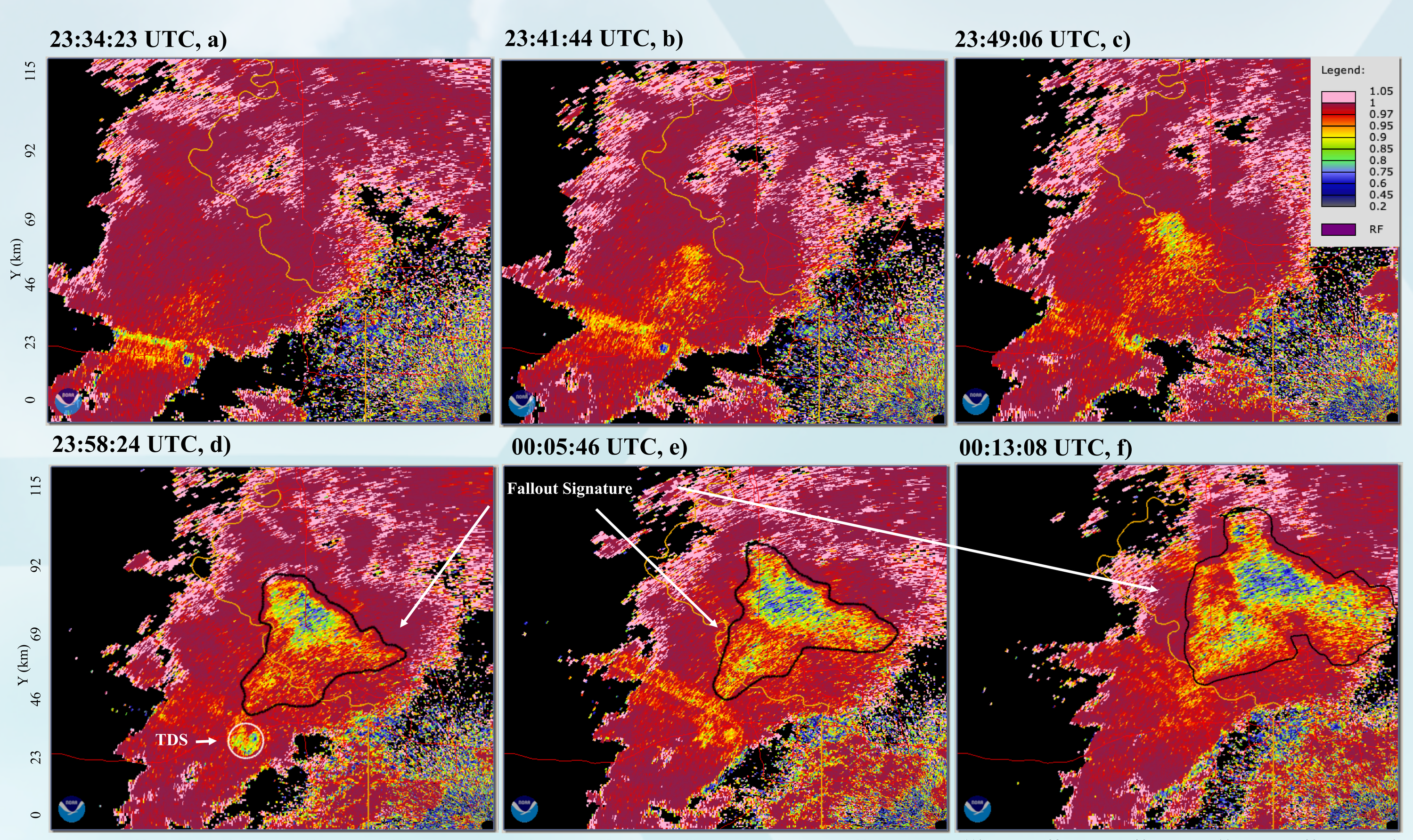

Fig. 1: The track of the tornado debris fallout signature, outlined in times d-f (23:58:24 UTC-00:13:08 UTC), highlights the development of the fallout signature and the associated increase in debris volume over time. The TDS outlined with the white circle and is consistently positioned southwest of the fallout signature, indicated with the three white arrows. These images are from the base (0.5 degree) radar elevation from KEAX.

- At 23:34 UTC, the first traces of the debris fallout signature is visible at low altitudes. 23:05 UTC marks the official starting time of the tornado, but the debris had been lofted with significant volume until 23:34 UTC.
- The fallout signature is regularly positioned northeast of the TDS, indicating the forward flank downdraft's environmental winds influencing the transport of the lofted debris.

Changes in Fallout Area

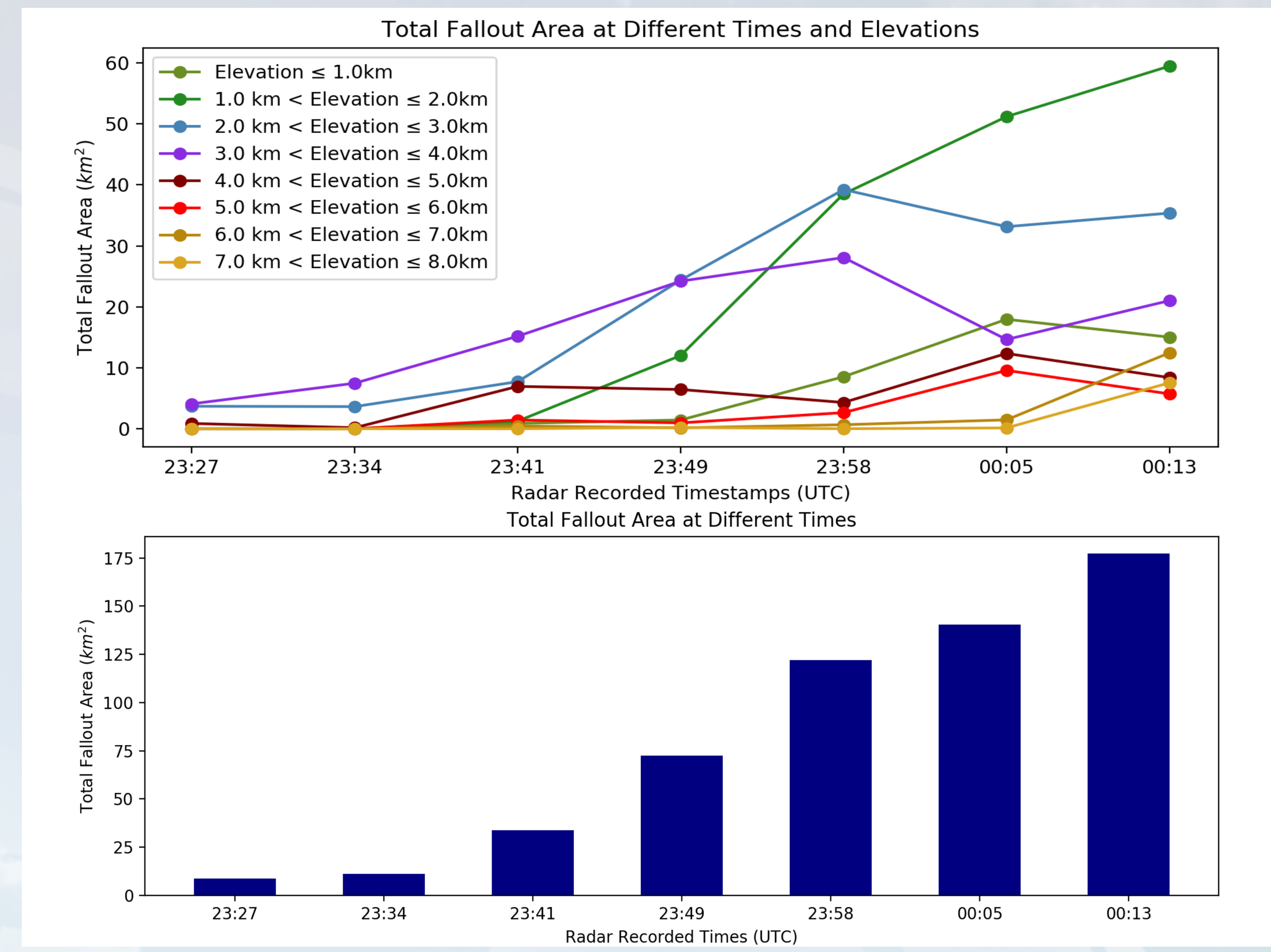

Fig. 2: Different timestamps ranging from 05/28/2019 at 23:27 UTC to 05/29/2019 00:13 UTC showing the progression in total fallout area in km², filtered out over one-kilometer elevation divisions.

- Higher elevations maintain the same amount of fallout area throughout the sweeps until 00:13 UTC, whereas the other sweeps see larger increases in fallout areas at earlier times.
- The largest areal amount of debris is seen to be suspended between 1 – 2 km at 00:13 UTC and this elevation also shows the largest increase of debris between any two radar scans.
- Initially, the largest area of debris is seen to descend from 3 – 4 km, to 2 – 3 km, and finally < 2 km (after 23:58 UTC).

Polarimetric Characteristic Distribution

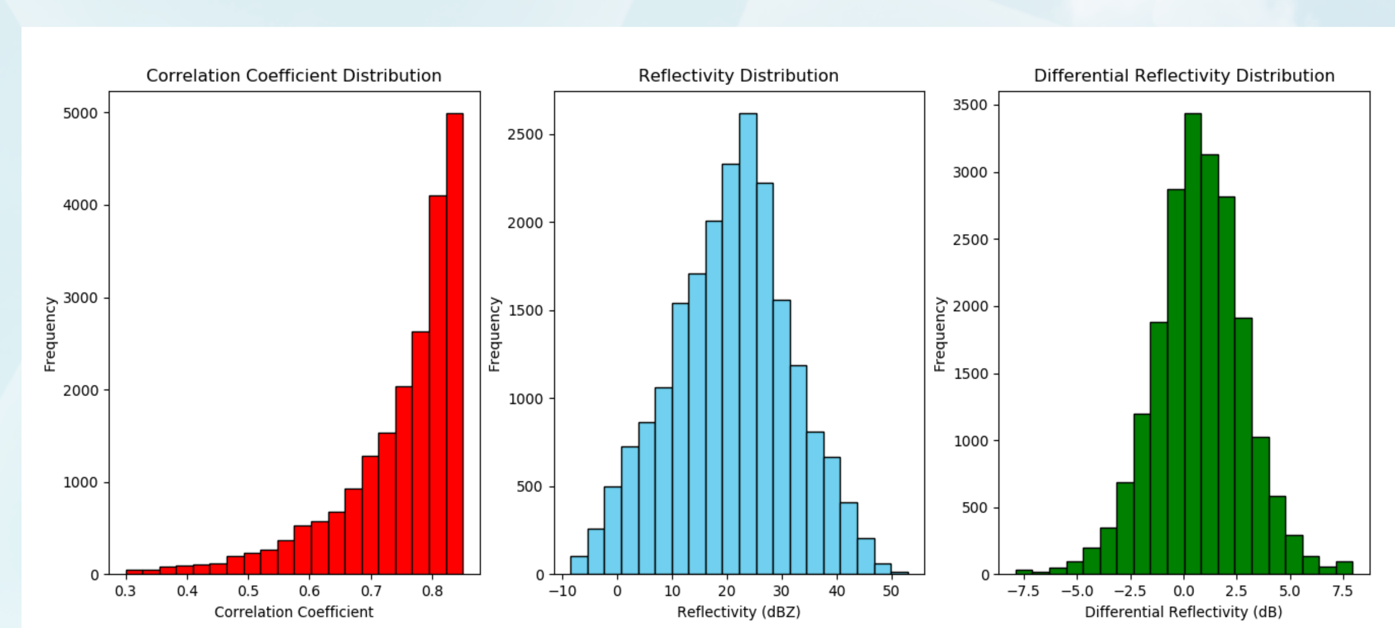

Fig. 3: (From left to right) Total distribution of ρ_{HV}, Z_{HH}, and Z_{DR}, moment estimates within the tornadic fallout signatures from 05/28/2019 23:27:01 UTC to 05/29/2019 00:13:08 UTC.

- The correlation coefficient has a higher concentration of higher values, suggesting small or less-concentrated debris than the primary TDS.
- The reflectivity plot shows a much wider distribution and lower mean due to the broad dispersion of debris, which is counter to more narrow distributions of higher values seen in the primary TDS.
- Z_{DR} is near-zero mean, suggesting debris fallout is randomly oriented.

Vertical Structure of Debris Fallout Signature

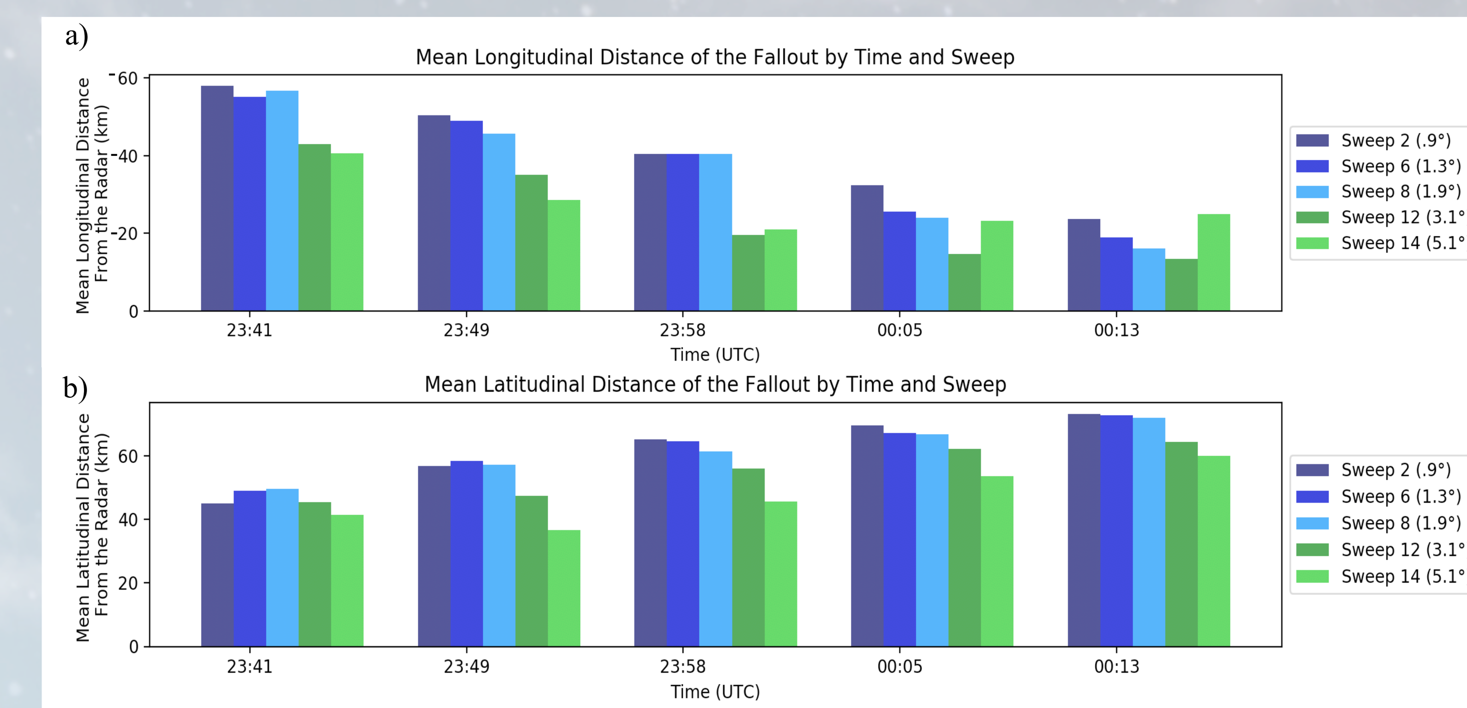

Fig. 4: Average longitudinal and latitudinal distance from KEAX, sorted by sweep (radar elevation angle) and time from the 28th evening to the 29th early morning.

- 23:27 UTC and 23:34 UTC are not shown due to a lack of significant, centralized, and concentrated fallout signature presence during those times.
- Later times, such as 00:05 UTC and 00:13 UTC indicate a rapid change in longitudinal position of the fallout signature at higher elevations.
- The fallout signature's non-linear vertical structure indicates strong southwesterly flow aloft and vertical shear ejecting the debris away from the main updraft.

Effects on Airport Operations

Fig. 5: Debris collected by the Kansas City Airport's ground staff and the National Weather Service on the airport's runway.

- Debris was falling out onto the airport's runways as planes were taking off, creating significant safety hazards due to the possibility of aircraft engine ingestion of these large debris.
- This tornado was the first known case of fallout debris that impacted airport operations.

Conclusions and Future Work

- The debris fallout signature of the 28 May 2019 Kansas City EF4 tornado is analyzed by use of the National Weather Service's dual-polarimetric KEAX radar.
- Debris particulates are identified by analysis of ρ_{HV}, Z_{HH}, and Z_{DR}. The fallout signature is analyzed by radar elevation angle, time, and distance from KEAX.
- The tornado debris fallout signature's movement is discussed, as well as the vertical structure of the fallout signature in relation to environmental southwesterly flow aloft.
- The Kansas International Airport had no way to detect the debris near the runways and was unable to predict the time and frequency of this debris.
- Future work will determine the amount of time aircraft must be grounded for ahead of the debris fallout and help prepare airport crew for the falling debris.
- The relationship between along-path tornado damage will also be analyzed.

Research Acknowledgments:

David Bodine is supported by NSF AGS-1823478.