An Analysis of Tropical Cyclone Supercells with Variable Electrification

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Introduction

Tropical Cyclones (TCs) are one of the most damaging and life-threatening weather phenomena on Earth posing a multitude of threats to human safety including strong winds, storm surge, and tornadoes. Supercell thunderstorms along TC outer bands present unique challenges in operational settings due to their rapid development and shallow updraft characteristics on radar. While recent research from Schenkel et. al (2023) suggests lightning within TCs does not necessarily aid in distinguishing tornadic and non-tornadic cells, why storms are electrically active versus not there was not examined. With non-inductive charging, which is the primary mechanism of electrification, both graupel and ice crystal content in updrafts can influence the occurrence of cloud-to-ground lightning strikes. The primary focus of this research will address *potential relationships between radar-inferred updraft characteristics and electrification in pre-tornadic supercells.*

Methods

By utilizing a dataset from Schenkel et. al (2023) alongside radar data from the nearest WSR-88D, our methods include the analysis of 2 lightning and 2 non-lightning producing pre-tornadic supercells. For the chosen cases, the radar data is gridded to 500 m horizontal resolution and averaged within 2.7 km of the mesocyclone center. This allows us to construct time-height cross-sections and further interrogate the role of various hydrometeors in electrification via polarimetric variables.

Mesocyclone ID	Date	Hours (UTC)	Electrified?	TC	Radar	Avg. Distance from Radar (KM)
201306-020	2013-06-06	09-10	Yes	Andrea (2013)	KAMX	110 KM
201306-018	2013-06-06	06-07	No	Andrea (2013)	KAMX	105 KM
201708-053	2017-08-27	00-01	Yes	Harvey (2017)	KHGX	46 KM
201708-058	2017-08-27	14-15	No	Harvey (2017)	KHGX	44 KM

Lightning Cases

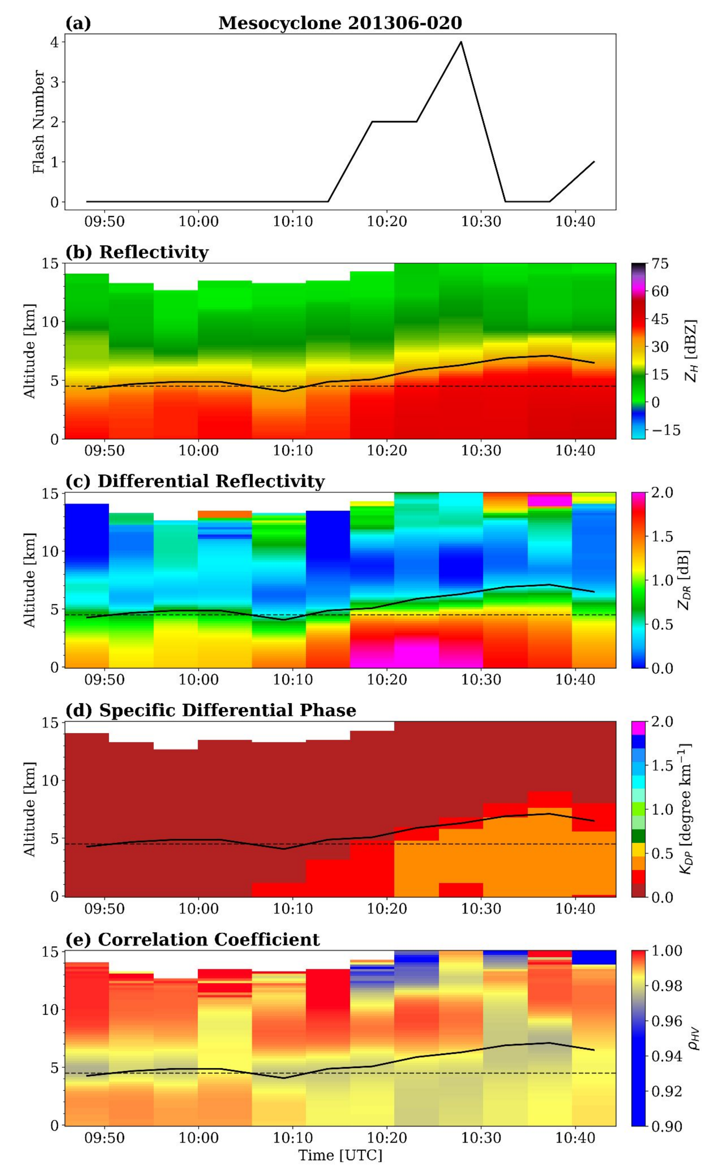

Fig. 1 Time series of **a)** number of flashes within 10 km and 10 minutes of the radar observation for mesocyclone 201306-020. Time-height series of **b)** reflectivity, **c)** differential reflectivity, **d)** specific differential phase, and **e** correlation coefficient with the maximum height of 30 dbz in solid black and the melting level estimated using the nearest observed sounding in dashed black.

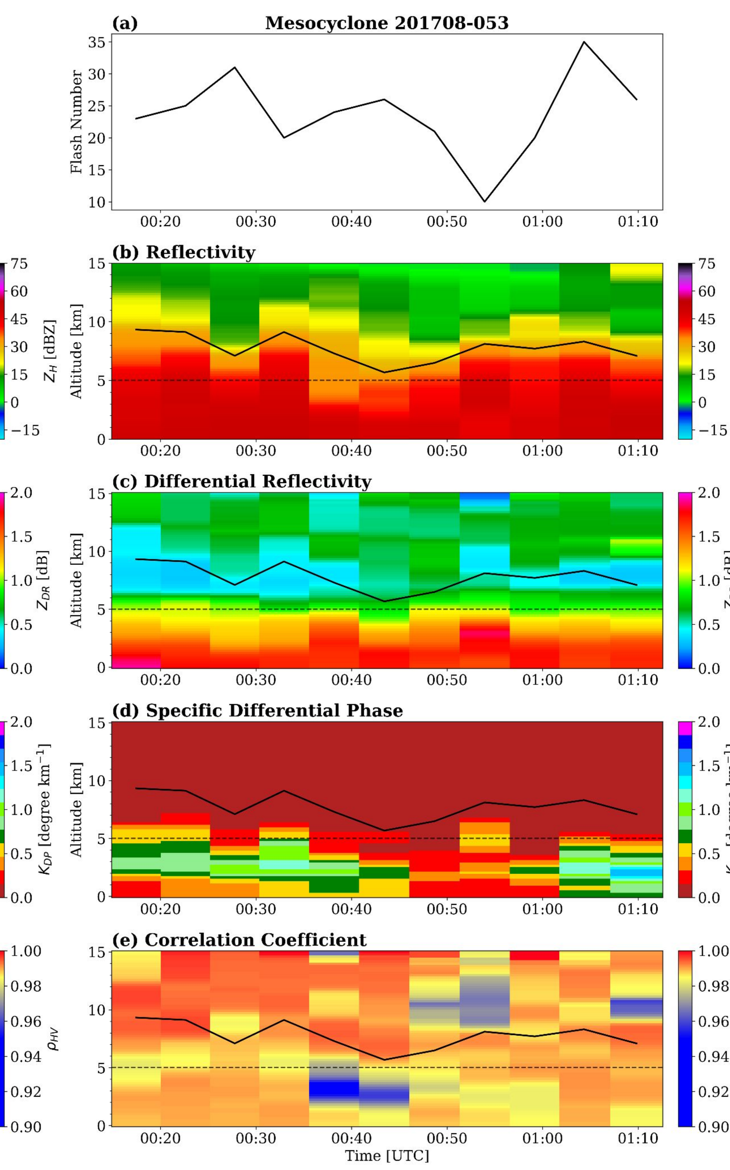

Fig. 2 Same parameters as **Fig. 1** for mesocyclone 201708-053

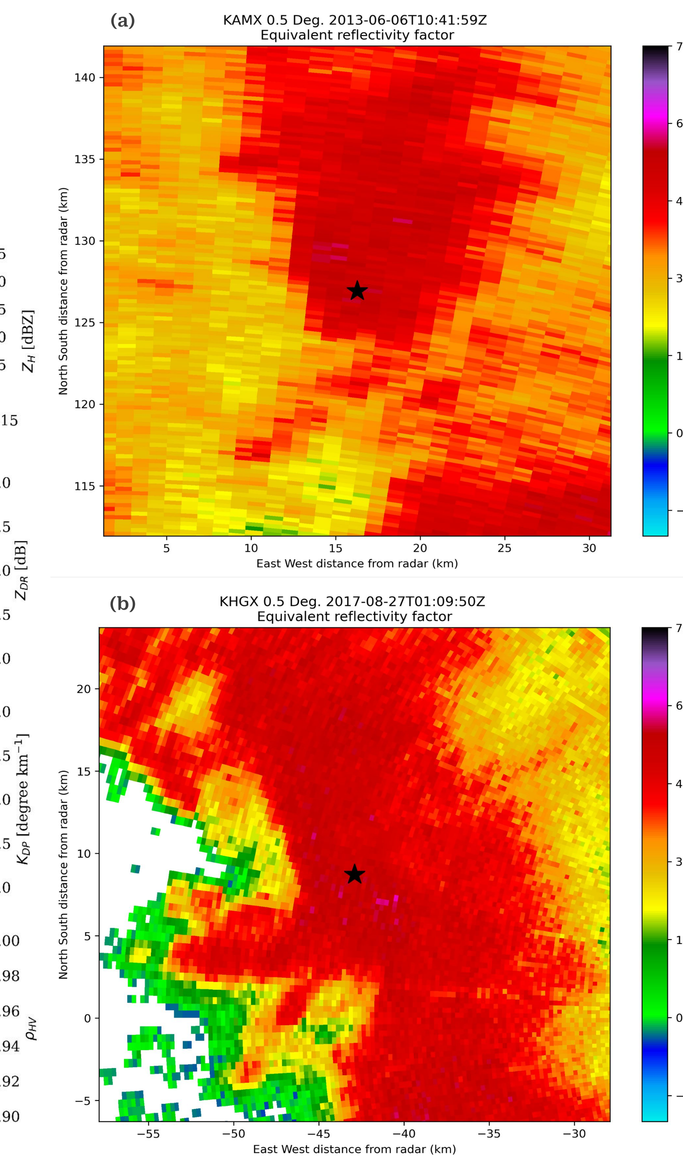

Fig. 3 Plan position indicator (PPI) of reflectivity for **a)** mesocyclone 201306-020 and **b)** 201708-053 at the time of tornadogenesis (final timestep of this analysis)

Non-Lightning Cases

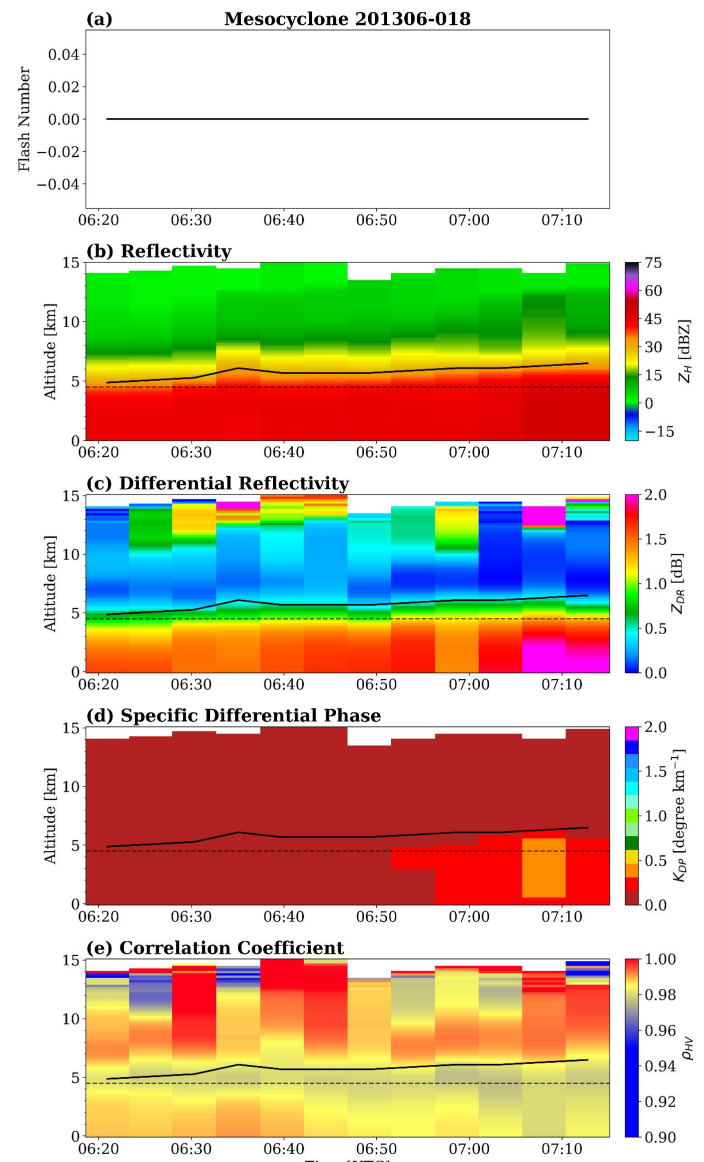

Fig. 4 Same parameters as **Fig. 1** for mesocyclone 201306-018

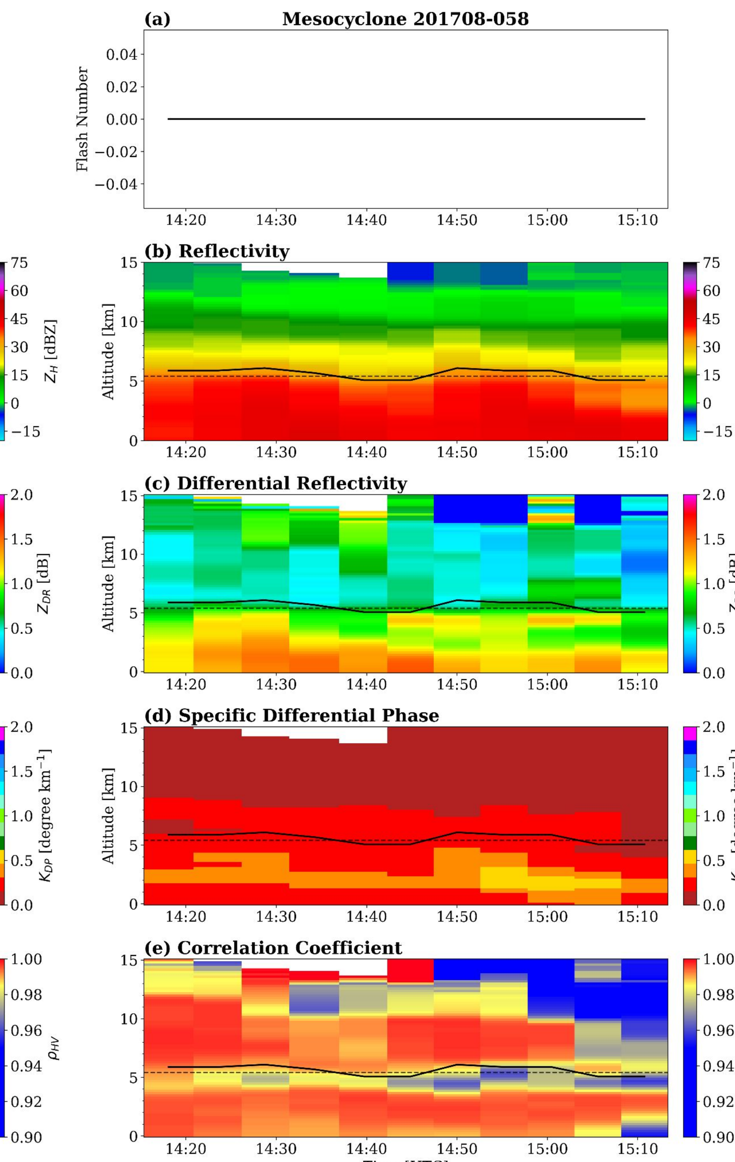

Fig. 5 Same parameters as **Fig. 1** for mesocyclone 201708-058

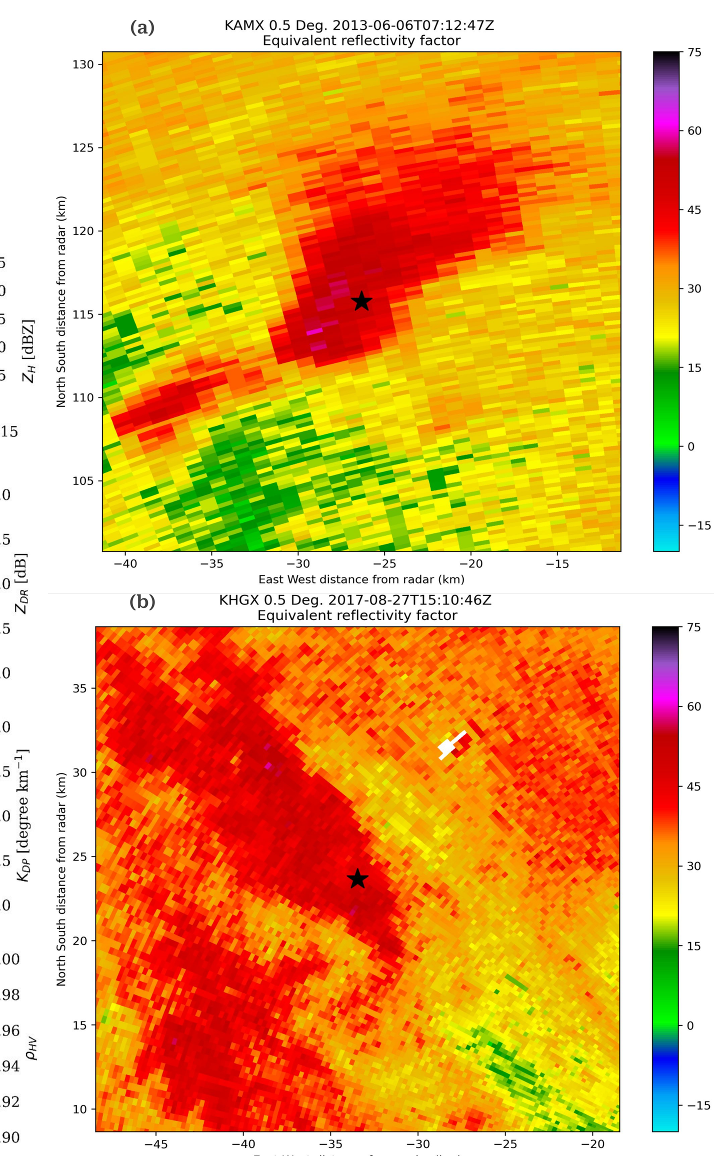

Fig. 6 PPI of reflectivity for **a)** mesocyclone 201306-018 and **b)** 201708-058 at the time of tornadogenesis (final timestep of this analysis)

Discussion

The 30 dBZ contour is used as a proxy for updraft intensity in this study. In general, the 30 dBZ echoes extend farther into the column in lightning producing storms. In both lightning cases, the 30 dBZ echoes extend well beyond the melting level during times of flash intensity. In both of the non-lightning cases, the 30 dBZ echoes are approximately the height of the melting layer. These differences suggest that stronger inferred updraft intensity is associated with electrification. In the lightning cases, higher values of Specific Differential Phase (K_{DP}) are seen above the melting level, suggesting that supercooled water is likely above the melting level. In the non-lightning cases, K_{DP} tends to be lower at altitudes above the melting level. Correlation Coefficient (ρ_{HV}) is the relative uniformity of observed particles by a radar scan, with values closer to one representing uniform, liquid hydrometeors. To better distinguish between types of hydrometeors, differential reflectivity (Z_{DR}) can be used as positive values over 2 dB are associated with rain with values lower being indicative of wet graupel. In both lightning cases, there is greater crystal habit diversity with ρ_{HV} around 0.96 as well as higher concentrations of graupel depicted by lower values of Z_{DR}.

Conclusions

- Based on the polarimetric analysis, we find that lightning-producing TC supercells are associated with 1) deeper reflectivity, 2) higher K_{DP}, 3) higher Z_{DR}, and 4) instances of reduced ρ_{HV} above the melting level.
- Differential reflectivity indicates higher concentrations of water-coated graupel are interacting with updrafts in the lightning cases, supporting non-inductive charging and lightning strikes.
- Overall, TC supercells are known to be much shallower than traditional supercells, but the electrified supercells from our study have significantly deeper updrafts capable of producing lightning through their interactions with the melting layer.

References

Schenkel, B. A., Calhoun, K. M., Sandmæl, T. N., Fruits, Z. R., Schick, I., Ake, M. C., & Kassel, B. F. (2023). Lightning and Radar Characteristics of Tornadic Cells in Landfalling Tropical Cyclones.

ENTLN lightning data were provided by Earth Networks to NOAA/NSSL as part of a cooperative agreement. The data may be acquired directly from Earth Networks for academic use.