Investigating Lightning Flash Rates with Rotating Storms in PERiLS and Oklahoma

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Background

Research has found relationships between lightning flash rates and severe thunderstorms:

- Lightning jumps often precede severe weather by 5-20 minutes[1].
  - Lightning jump: Rapid increase in total (cloud-to-ground + cloud-to-cloud) flash rate.
- 85% of lightning jumps in supercells were found to be associated with an increase in mesocyclone rotation[2].

Problem: Limited research specifically studying relationships between a storm's lightning flash rate and tornadogenesis.

- An analysis of four QLCS events found more total lightning with tornadic events[3].

Possible Physical Relationship:

- Lightning forms in the mixed-phase region of the cloud (0°C to -40°C) [4].
- Strong updrafts generate turbulence that mix up charge regions, increasing flash rate.
- Strengthening midlevel updraft modulating lightning production will also intensify the midlevel mesocyclone.
  - A mesocyclone is an early step in the mesocyclone-tornado formation process.

[1] Williams, E. R., and Coauthors, 1999: The Behavior of Total Lightning Activity in Severe Florida Thunderstorms, Atmos. Res., 51, 245-265, https://doi.org/10.1016/S0169-8095(99)00011-3.
[2] Stough, S. M., L. D. Carey, C. J. Schultz, and P. M. Bitzer, 2017: Investigating the Relationship between Lightning and Mesocyclonic Rotation in Supercell Thunderstorms. Wea. Forecasting, 32, 2237–2259, https://doi.org/10.1175/WAF-D-17-0025.1.
[3] Williams, B. M., and L. D. Carey, 2015: Assessing the Utility of Total Lightning and the Lightning Jump to Assist in the QLCS Tornado Warning Decision Process. Preprints, *95th American Meteorological Society Annual Meeting*, Phoenix, AZ, Amer. Meteor. Soc., 11.3. [Available online at: https://ams.confex.com/ams/95Annual/webprogram/Paper259488.html.].
[4] Schultz, C. J., L. D. Carey, E. V. Schultz, and R. J. Blakeslee, 2015: Insight into the Kinematic and Microphysical Processes that Control Lightning Jumps. Wea. Forecasting, 30, 1591–1621, https://doi.org/10.1175/WAF-D-14-00147.1

Methods

- Storms from eight PERiLS cases & four OK cases.
- Lightning data from lightning mapping arrays (LMAS).
  - LMA: Network of receivers triangulate origin of VHF emission from lightning flashes.
- Cells were tracked with Tobac tracking algorithm based on flash extent density & manually adjusted.
- A lightning jump was defined with the 2-sigma algorithm.
- Non-tornadic cells selected had a minimum peak azimuthal shear of 0.01 s-1.

Poster PDF:

Questions?

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Data

Radar and Lightning Flash Initiation Density (per km^2) for Two Significant Tornado Cases

Rolling Fork Supercell
KDGX 0.5 Deg.

Norman QLCS
KTLX 0.5 Deg.

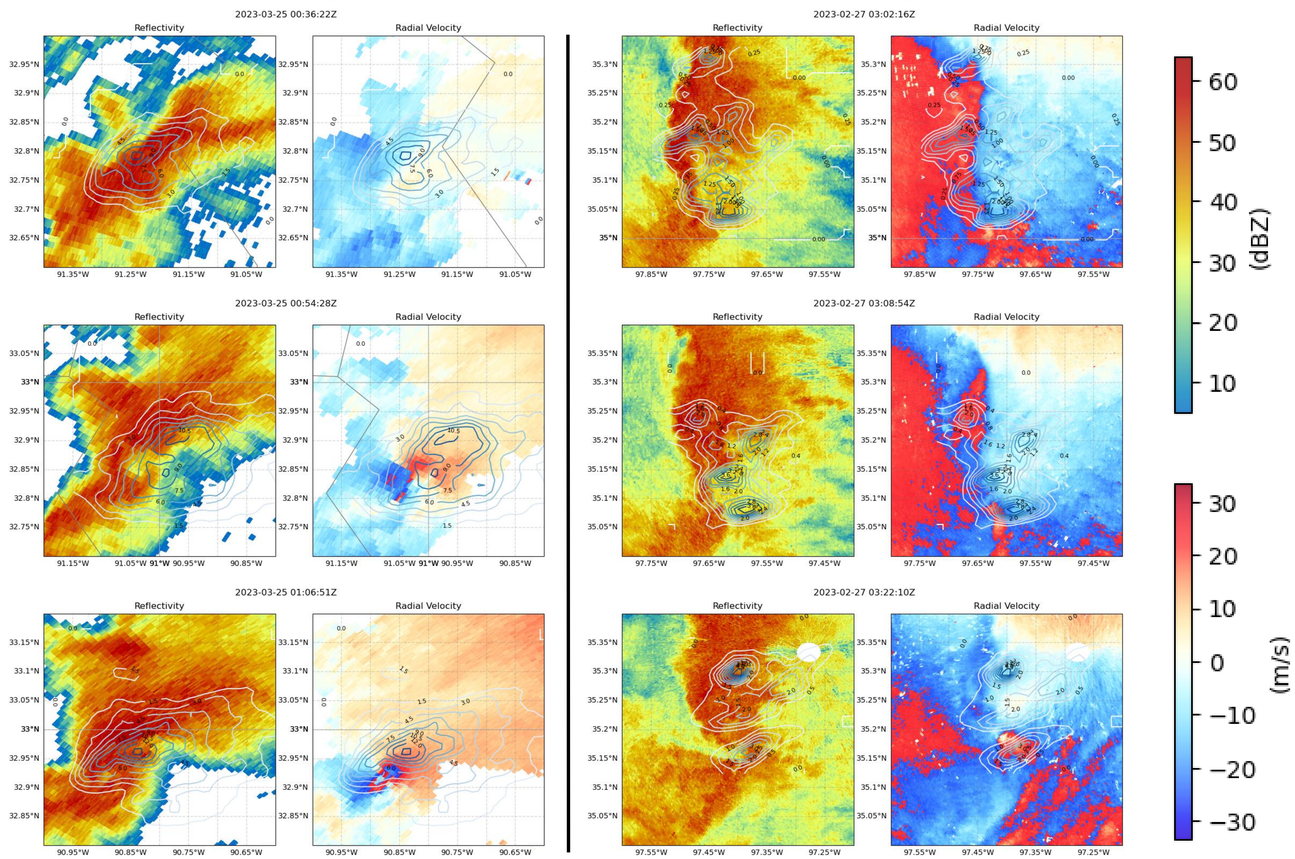


Figure 1: Progression of two storms that produced significant tornadoes: The March 2023 Rolling Fork, MS supercell (left), and the February 2023 Norman, OK QLCS (right). The top panels are 15+ minutes before tornadogenesis, the middle panels are 5-10 minutes before tornadogenesis, and the bottom panels are 5-10 minutes after tornadogenesis. The contoured flash initiation density include all flashes within five minutes (left) and two minutes (right) of the time of the radar image.

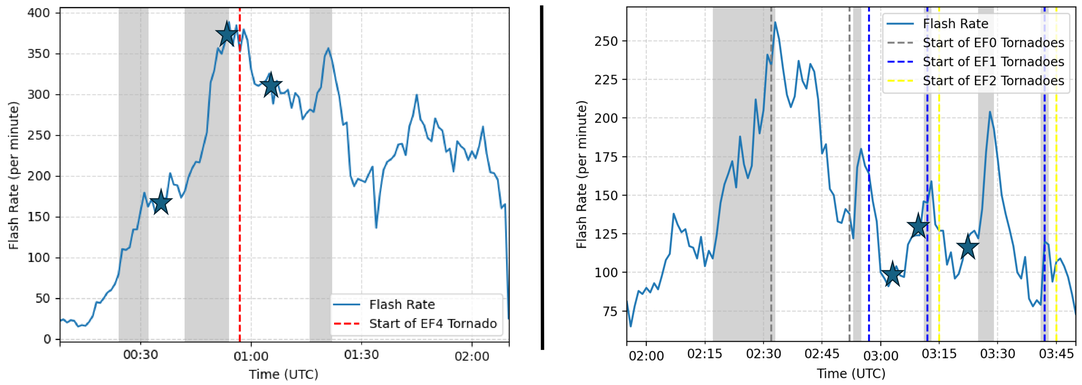


Figure 2: Corresponding lightning flash rate time series with the Rolling Fork supercell (left) and Norman QLCS (right). Shaded are 2σ lightning jumps. Stars mark the time and flash rate at the times of the three corresponding radar images.

Results

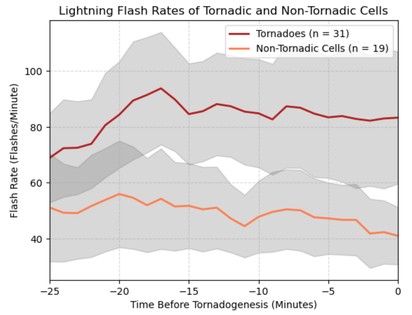


Figure 3: Comparison of flash rates between tornadic and non-tornadic storms. Shaded is the 95% confidence interval.

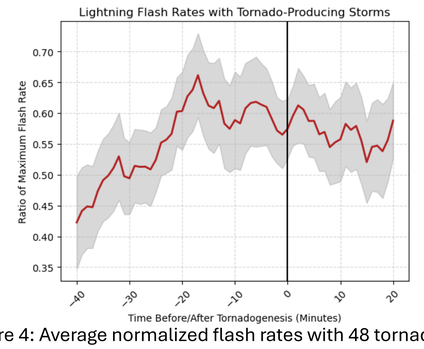


Figure 4: Average normalized flash rates with 48 tornadoes. 95% confidence interval shaded.

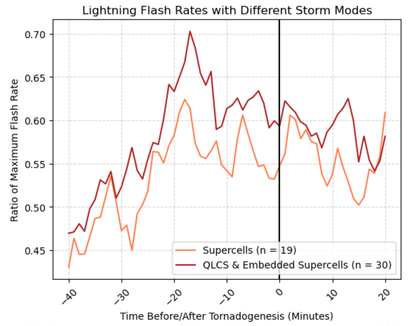


Figure 5: Averaged normalized flash rates with different tornadic storm modes.

Conclusions

- Lightning flash rates often increase 20-30+ mins before tornadogenesis, peaking 15-20 mins before tornadogenesis, and plateauing after the peak.
  - The difference in flash rate changes at these different times was statistically significant.
- Tornadic storms might have higher flash rates than non-tornadic cells.
- Flash rate temporal patterns are similar in samples of different storm modes.
- Lightning jumps are not strongly correlated to tornadogenesis in the sample.
- More LMA data of storms should be gathered to increase the sample size in future studies.