Hydrometeor Characterization of Lightning Regions Relative to Downdraft Processes

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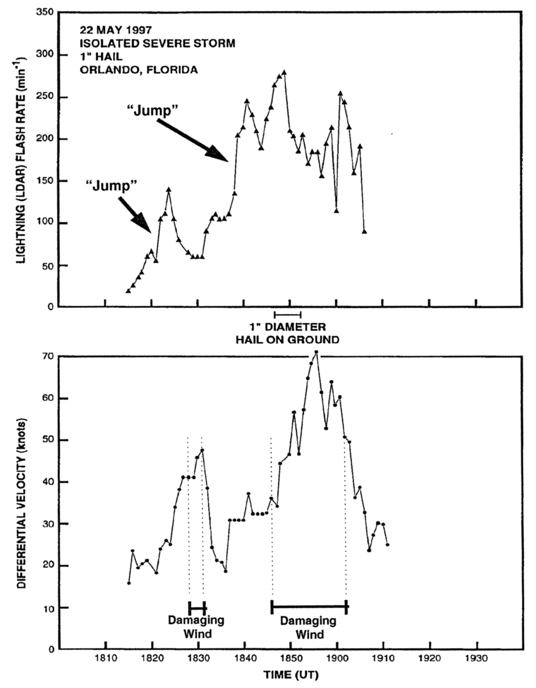
Introduction

Rapid increases in lightning flash rate, termed lightning jumps, often precede the onset of severe phenomena (Williams et al. 1999; Gatlin and Goodman 2008; Schultz et al. 2009, 2011, 2015, 2016; etc.)



Williams et al. 1999 Fig. 5

Physical connection based on updraft properties

- Mixed-phase contribution to non-inductive charging mechanism (Takahashi 1978, Carey and Rutledge 2000)
- Hail, *convective winds, tornadogenesis* related to updraft and *downdraft* intensity

Further understanding of relationship between lightning and severe weather requires more information about **how lightning is related to downdraft properties**

1. Spatial relationships of lightning with respect to thunderstorm vertical motions and microphysics
2. Evolution of microphysics with respect to notable lightning trends, including lightning jumps and lightning dives (Sharp 2005, Steiger et al. 2007, Vacek 2017)

HID Considerations

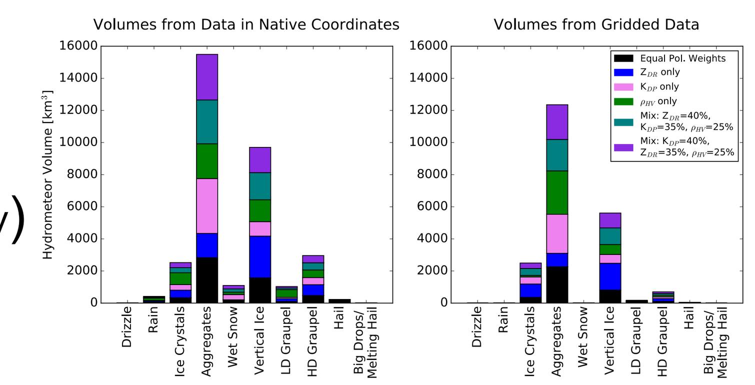
Retrieved precipitation and non-precipitation ice quantities necessary for lightning analysis vary as a result of:

- weighting of polarimetric quantities
- method of volume calculation

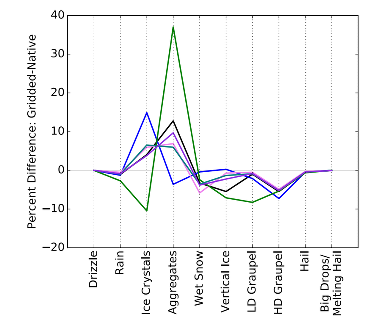
$$\mu_i = \left[\frac{(W_{Z_{dr}}\beta_{Z_{dr},i} + W_{K_{dp}}\beta_{K_{dp},i} + W_{\rho_{hv}}\beta_{\rho_{hv},i})}{W_{Z_{dr}} + W_{K_{dp}} + W_{\rho_{hv}}}\right]\beta_{T,i}\beta_{Z_h,i},$$

Dolan et al. 2013 Eq. 8

Sensitivity analysis with varying pol. (Z_{DR}, K_{DP}, ρ_{HV}) weighted emphasis



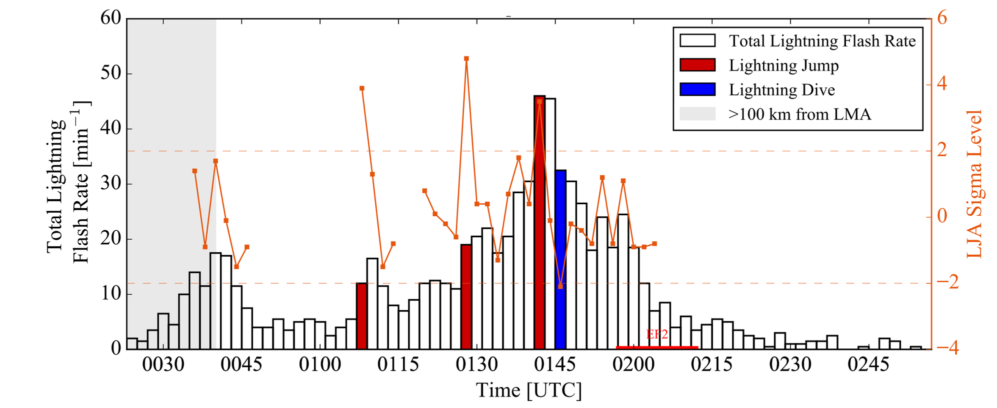
- Z_{DR} (K_{DP}) emphasis results in more (less) vertical ice and HD graupel vs. aggregates and LD graupel
- Gridding limits graupel volume

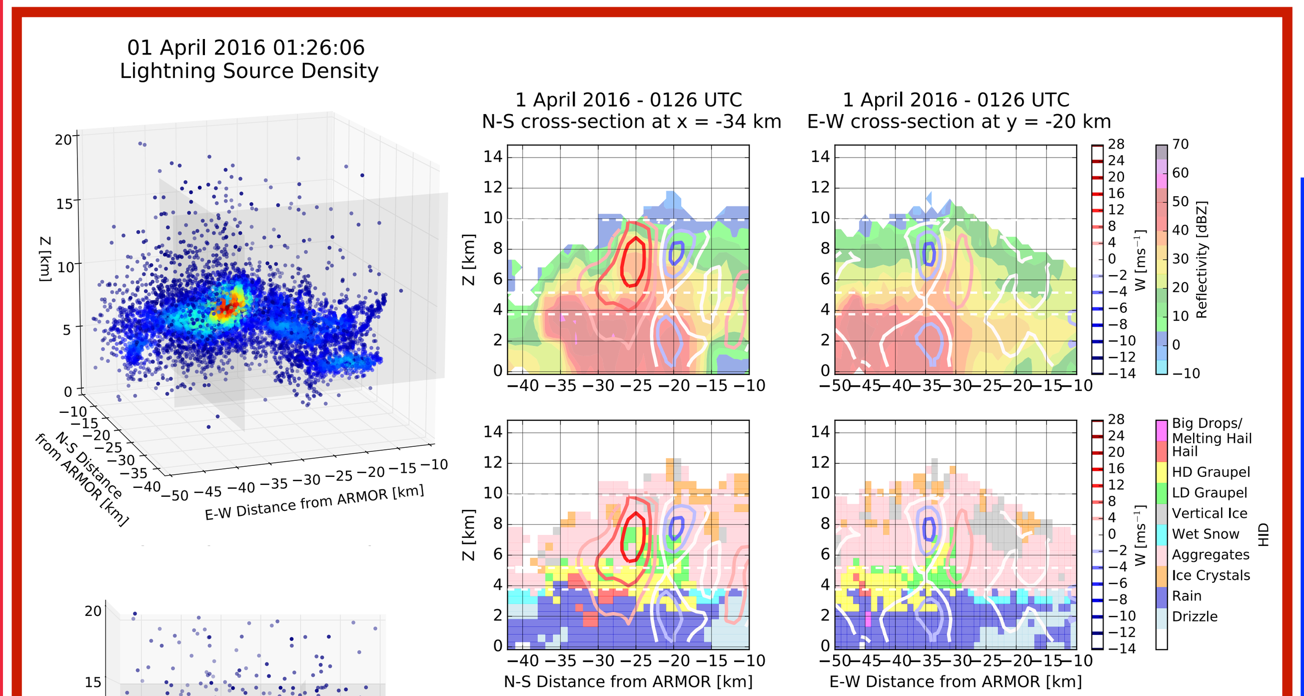


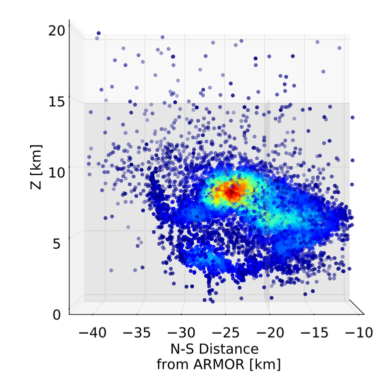
Sub-Storm Scale Analysis

Supercell on 1 April 2016 in North Alabama

- Lightning jumps at 0108 UTC, **0128 UTC**, 0142 UTC
- Lightning dive at **0146 UTC**
- Tornado first reported at 0157 UTC

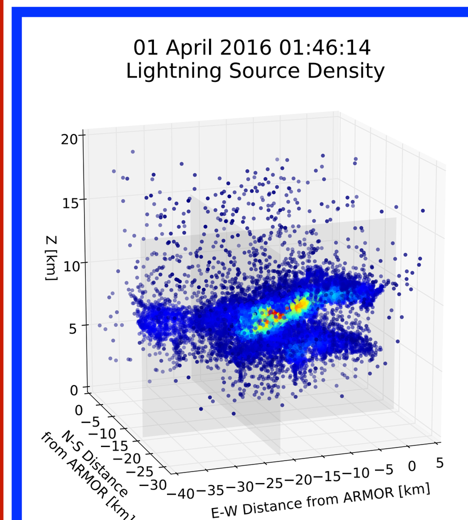


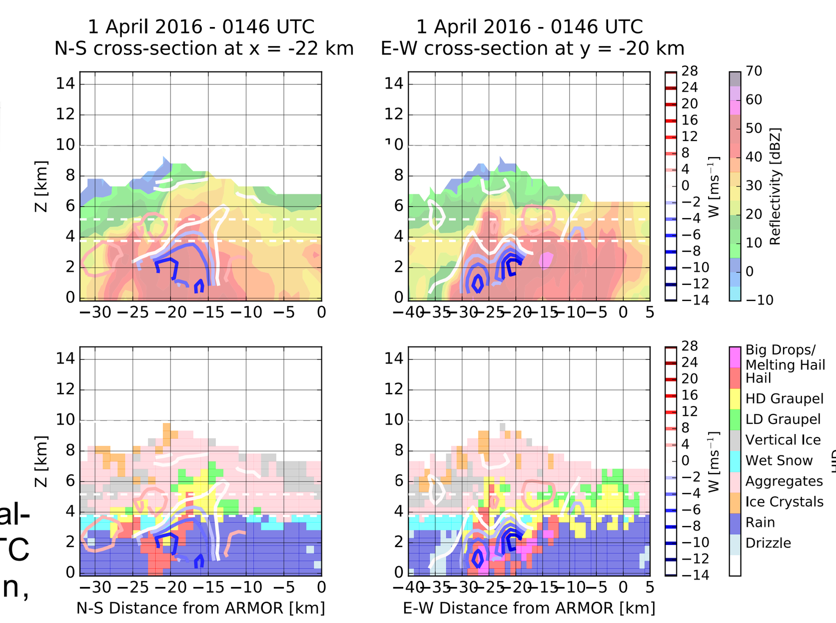




Lightning VHF sources most concentrated to south of strongest mixed-phase updraft

Secondary source density maxima near -10°C, in region of ~0 m s^{-1} vertical motion between downdraft regions





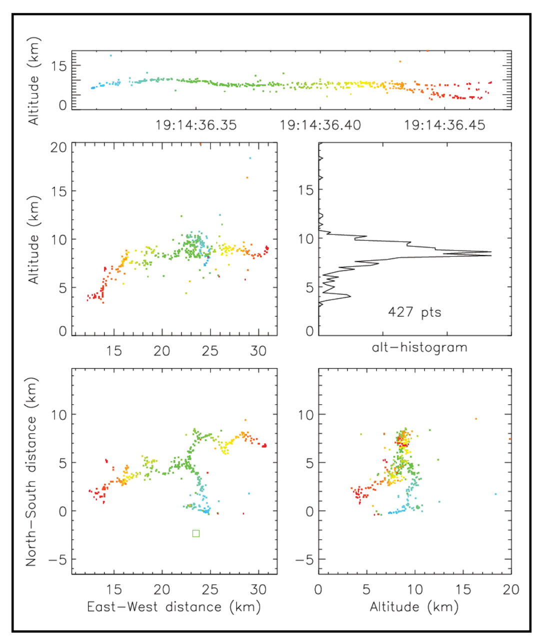
Note:
Incomplete/compromised dual-Doppler analysis at 0146 UTC due to signal attenuation, reduced storm topping

Reduced area of large source density near time of lightning dive; secondary level of sources near 0°C and descending graupel regions.

Data and Methods

Total lightning data from the North Alabama Lightning Mapping Array (NALMA) (Koshak et al. 2004)

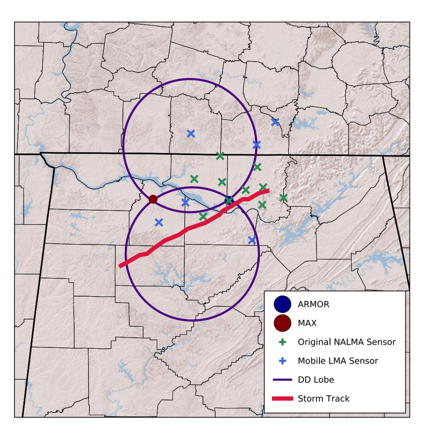
- Original 10 sensors supplemented with 6 mobile TTU, NASA sensors to detect lightning's emission of VHF radiation sources
- Sources clustered into flashes using spatial and temporal thresholds (McCaul et al. 2005, 2009)
- 2-sigma lightning jump algorithm used to identify and quantify a lightning jump (dive) when change in flash rate is higher (lower) than the recent average by ≥ 2.0 sigma (≤ 2.0 sigma) (Schultz et al. 2009, 2017)



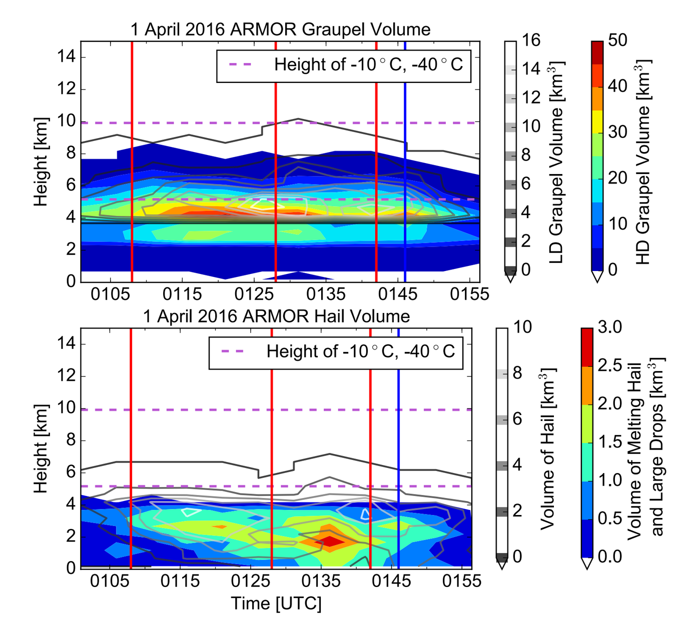
Stough 2015 Fig.3.3

C-Band radar data from the Advanced Radar for Meteorological and Operational Research (ARMOR) gridded with 1.0 km horizontal and 0.5 km vertical spacing using Py-ART software (Knupp et al. 2014, Helmus and Collis 2016)

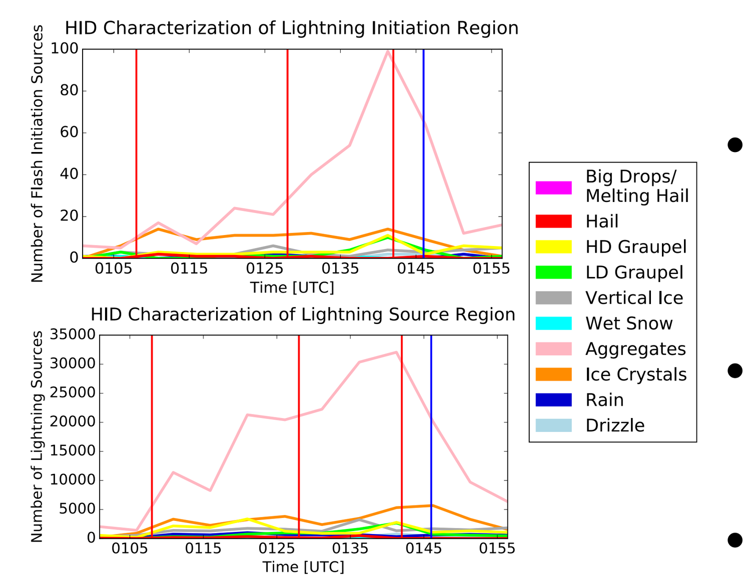
- Dolan et al. (2013) method used for hydrometeor identification (HID)
- Dual-Doppler vertical wind retrieval from ARMOR, Mobile Alabama X-band (MAX) radar using NCAR CEDRIC software (Vacek 2017) (Miller and Frederick 1998)



Temporal HID and Lightning Trends



- Region of greatest graupel volume consistent during time of lightning jump periods
- Reduction of graupel volume near and below -10°C prior to lightning dive
- Increase in hail volume near to the time of 3rd lightning jump (indication of sustained updraft)
- Increase in volume of melting hail/large drops during lightning dive



- Greatest increase in number of flash initiations associated with graupel prior to/during lightning jumps
- Marked decrease in number of flash initiations associated with aggregates prior to lightning dive
- Generally, number of lightning sources in aggregate and ice crystal regions decreases prior to/during lightning dive
- Weak trends in number of lightning sources associated with graupel regions

- Additional analysis: combined HID and vertical motion analysis in lightning initiation and propagation regions, additional cases with multi-Doppler sampling
- Numerical modeling to facilitate interpretation of fine-scale hydrometeor properties and analysis of related microphysical and thermodynamic processes

Acknowledgments

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