Exploring the Use of Radar for Physically-based Nowcasting of Lightning Cessation

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Introduction

- Lightning can lead to a decrease in operational efficiency due to timing uncertainty of the last flash
  - Minutes or scrubbed launch = $$$$$$
- Current nowcasting methods include lightning advisories for a set spatial/temporal domain
  - Based on statistical studies
  - Overestimate to be cautious
- Determine if a physically meaningful *and operationally useful* trend exists that reflects interactions between in-cloud electric fields and microphysics using:
  - 3-D Lightning
  - Polarimetric Radar
- Decrease any excess downtime involved with current advisory system

Background

Past studies have used traditional radar reflectivity, cloud-to-ground lightning, and 3D lightning to investigate related lightning cessation applications.

- Bateman et al. (2003) developed an algorithm now known as VAHIRR (volume averaged height integrated radar reflectivity) using electric field mill data from the ABFM experiment and ground-based radar reflectivity.
- Stano et al. (2010) tested various statistical methods to evaluate potential lightning cessation applications at KSC using the KSCS LDAR.

The notion that ice crystals will align with electric fields within a thunderstorm has been investigated throughout the last 50 years with Vonnegut (1965) first to note this occurrence.

- First polarimetric radar observations were obtained by Hendry and McCormick (1976) followed by others showing **strong indications of ice crystal orientation** in thunderstorms (e.g., Hendry and McCormick 1976, 1979; Hendry and Antar 1982; Krehbiel et al. 1991, 1992, 1996; Metcalf 1992, 1993, 1995; *Caylor and Chandrasekar 1996*; *Marshall et al. 2009)*.
- Various torques that influence ice particle orientation were calculated by Weinheimer and Few (1987). Krehbiel et al. (1996) noted that the particle orientation can determine whether the alignment is from electrical (vertical) or aerodynamic (horizontal) forces.

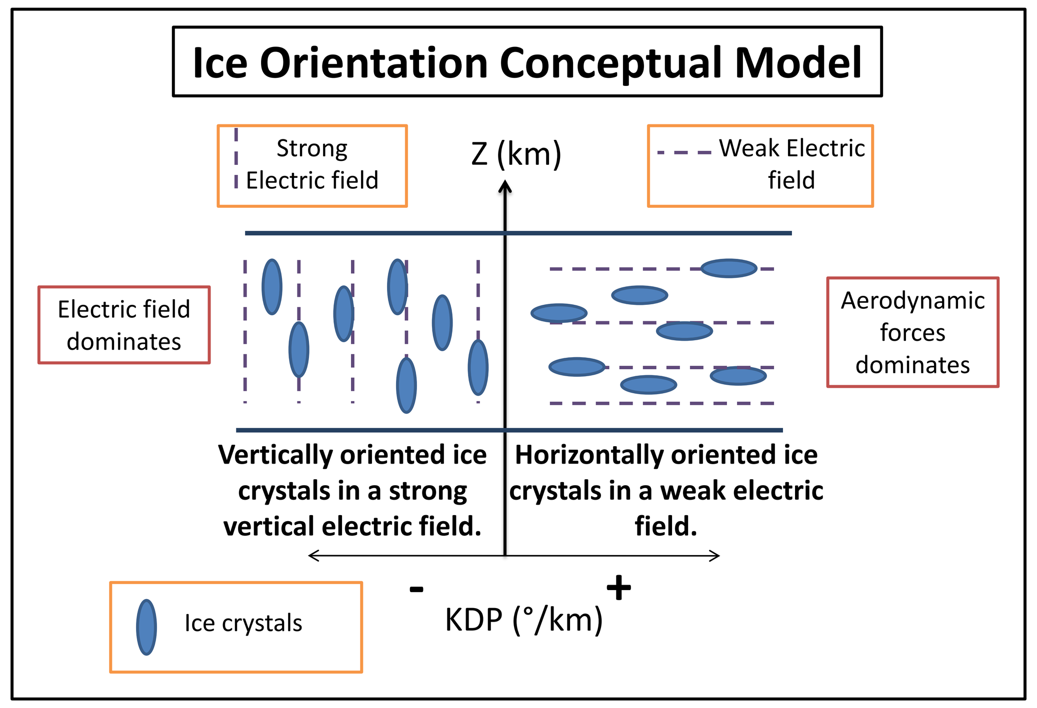


Figure 1. Conceptual model based on previous studies of ice orientation. A strong vertical electric field is inferred when ice particles are determined to be vertical using KDP. When ice crystals are horizontal, aerodynamic forces dominate the electric field.

Data

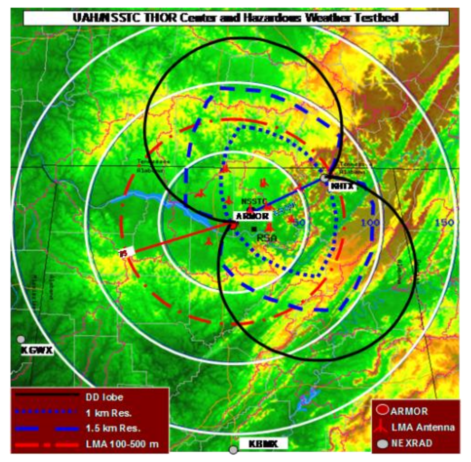


Figure 2. North Alabama instrumentation including ARMOR and NALMA.

- Advanced Radar for Meteorological and Operational Research (ARMOR) Dual-polarimetric C-band radar
- North Alabama Lightning Mapping Array (NALMA)
  - Three-dimensional lightning mapping
- Similar set up to the 45WS new dual-Polarimetric radar and KSC LDAR.

Review of Polarimetric Variables

Differential Propagation Phase (PHIDP) $\Phi_{DP} = \Phi_{HH} - \Phi_{VV}$

Phase difference between H and V. PHIDP depends on the intensity of precipitation, orientation of hydrometeors, path length through the hydrometeor, and distance from the radar (thus, we need KDP).

Specific Differential Phase (KDP) $[\Phi_{DP}(r_2) - \Phi_{DP}(r_1)] / 2(r_2 - r_1)$

KDP (°/km) is the range derivative of PHIDP. It is independent of receiver calibration, transmitter power, beam blockage. Negative values indicate hydrometeors have a larger vertical axis.

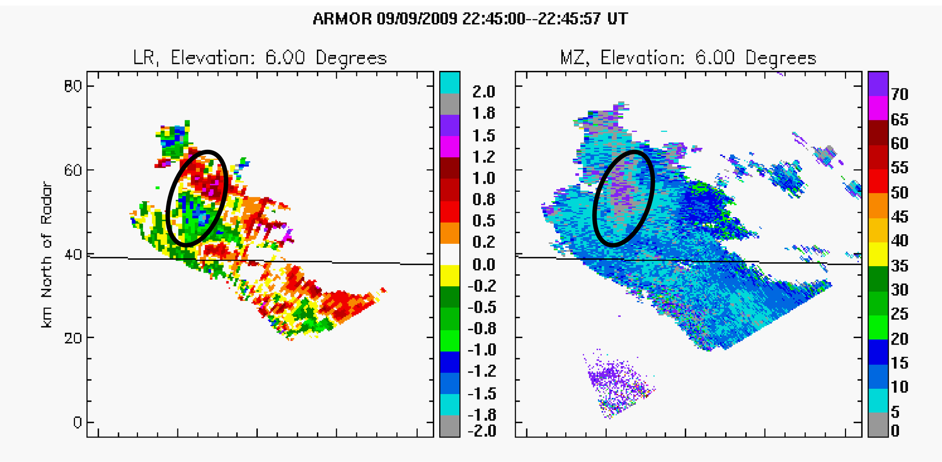
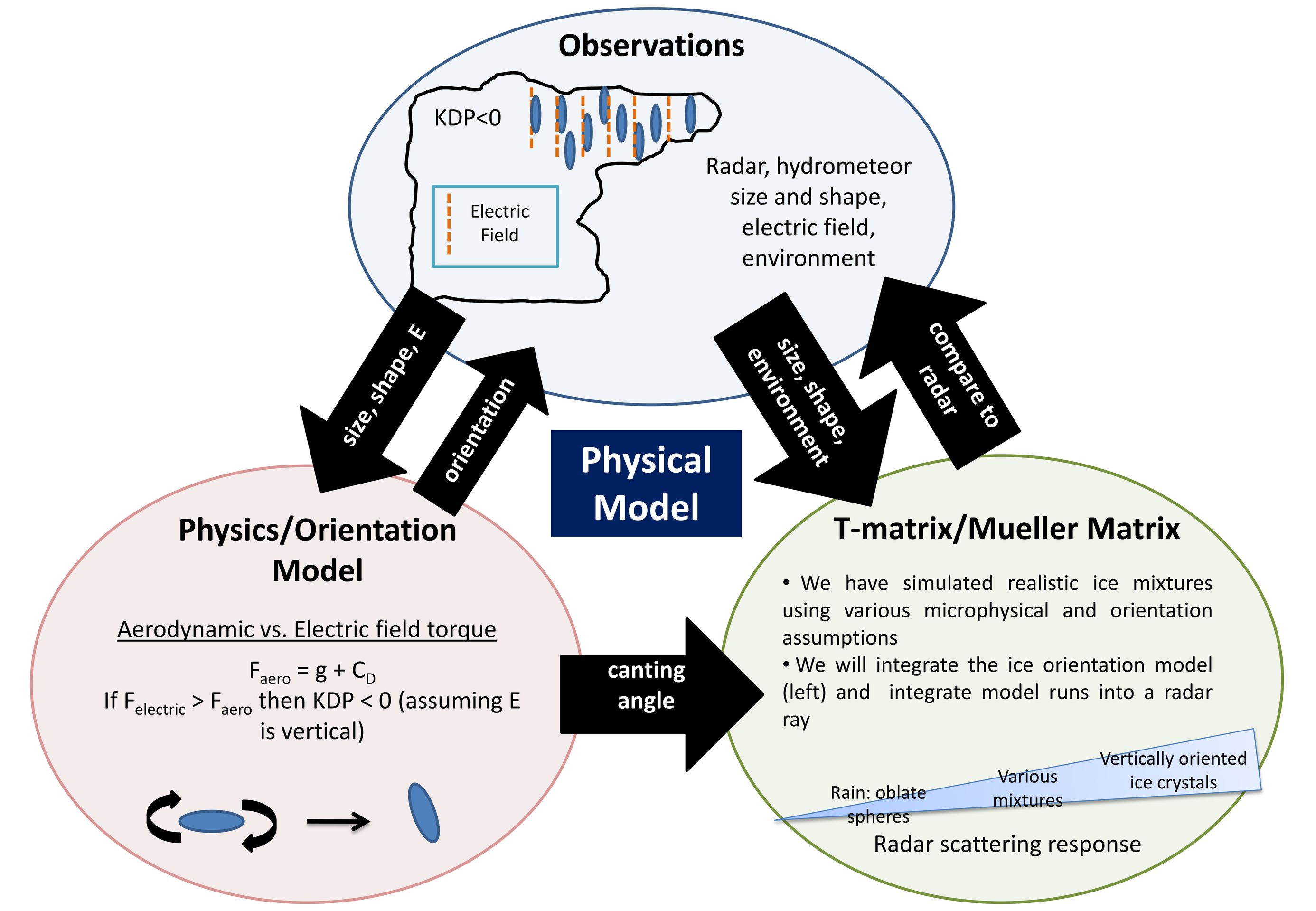


Figure 3. KDP (left) and PHIDP (right). Black oval indicates area of phase shift. KDP below 0 indicates vertically oriented hydrometeors.



Acknowledgments

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For references, see extended abstract.

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Methodology

- Continuously collecting events to determine temporal/spatial radar resolution that is needed to detect lightning cessation.
- Flash clustering algorithm for LMA data (McCaul et al., 2005)
- Subjective phase shift analysis of PHIDP relative to last flash
- NCAR Particle identification algorithm (PID)
- Apply various KDP calculations
- Compare results to VAHIRR

Preliminary Results

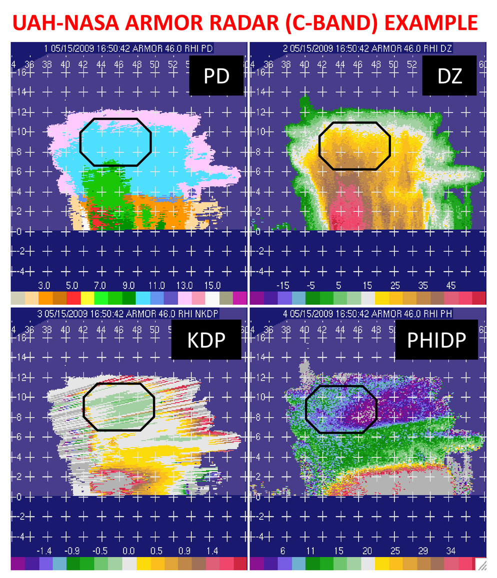

Figure 4. (left) This ARMOR vertical cross-section depicts a negative phase shift within a storm with particle type (PD), reflectivity (DZ), KDP, and PHIDP. The area in black represents the negative phase shift (seen in PHIDP and KDP). This area is collocated with dry snow according to the particle identification algorithm. It is known that the algorithm can have difficulties detecting mixtures of ice so there is likely ice crystals also in these areas as well as vertically oriented dry snow.

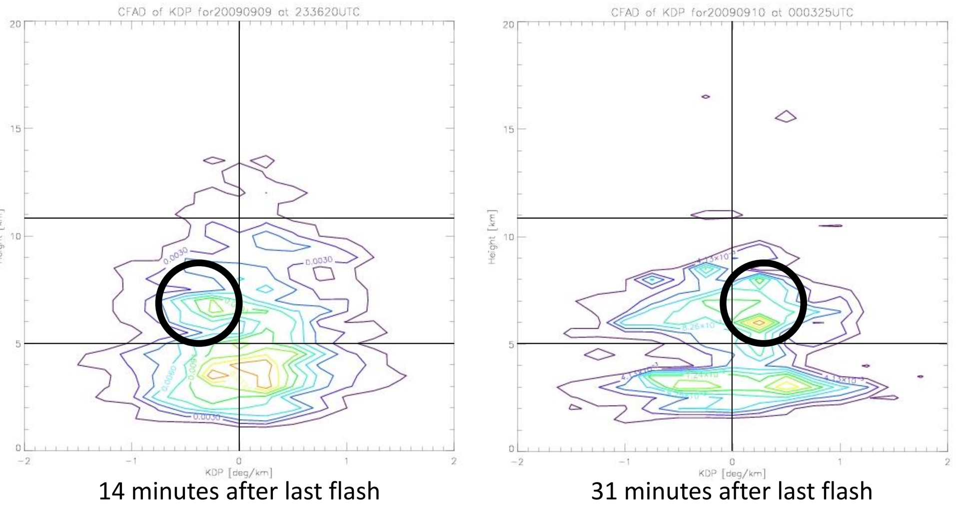

Figure 5. (below) Mean KDP time-series with height. The times selected represent a profile 3 minutes prior and 4, 20, and 37 minutes after the last flash. These profiles illustrate what is hypothesized based on previous research.

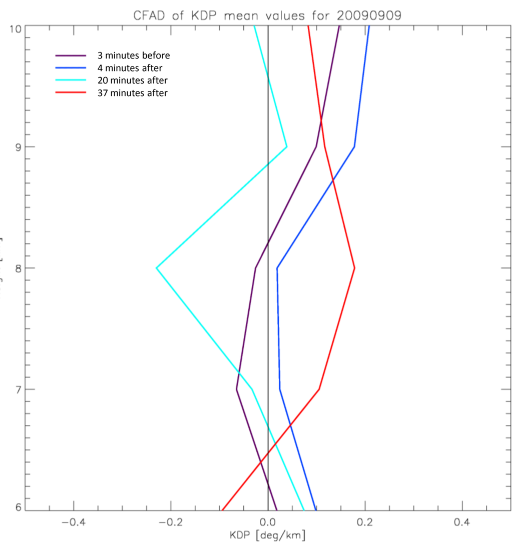

Figure 6. (above) KDP distribution with height. These CFADs show the distribution (%) of KDP 14 minutes (above, left) and about 30 minutes (above, right) after the last flash. The KDP infers that the electric field builds again after the flash (above, left image) but then the electric field diminishes without any additional lightning discharges (above, right).

Summary and Next Steps

- Current results support the conceptual model (Figure 1).
- Need to identify most efficient way to IDENTIFY the signature in additional cases
- Will compare to VAHIRR
  - Use just dual-polarimetric information, both, or just VAHIRR
- Consider null events
  - Near or greater 30 minutes between flashes within same storm cell

End Goal: Operation tool for lightning cessation prediction