Microphysical, Kinematic, and Lightning Properties of Deep Moist Convection across Northern Alabama during the Deep Convective Clouds and Chemistry Experiment

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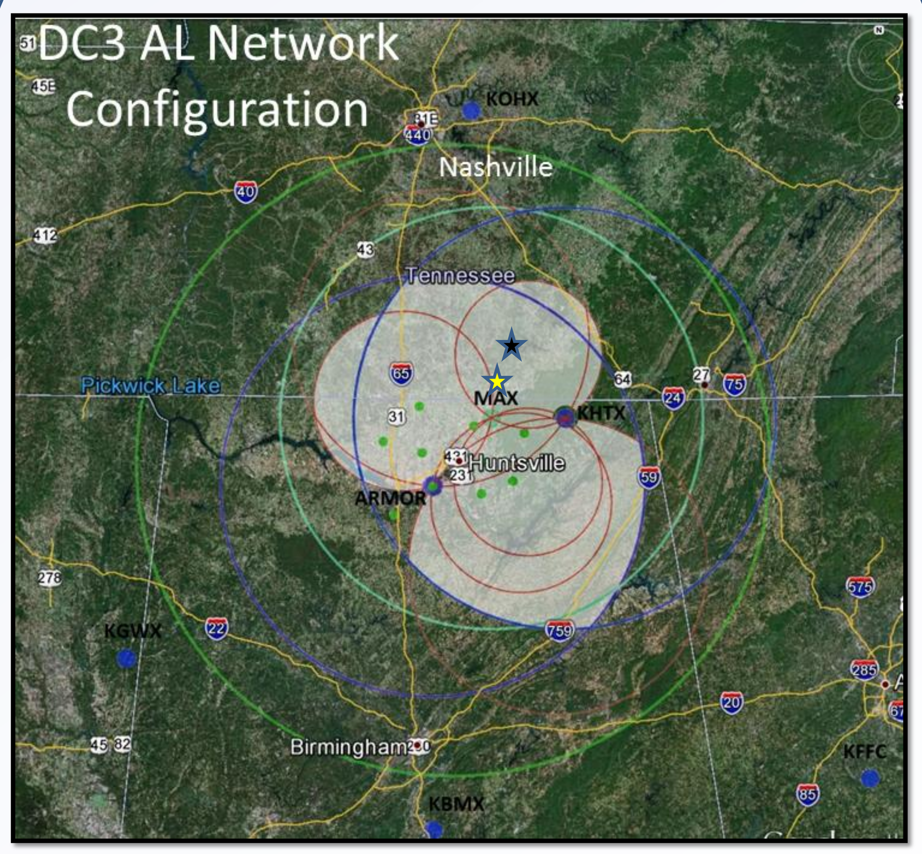
Primary Objectives

- Examine the two case days (21 May & 11 June 2012) in which air- and ground based platforms sampled ordinary to multicellular convection across the Alabama Region
- Document detailed microphysical and kinematic controls on the lightning properties of deep moist convection (DMC) via polarimetric, multi-Doppler network and Very High Frequency (VHF) Lightning Mapping Array (LMA)
- Explore implications on NO_x production via lightning generation

DC3 Alabama Network Configuration



Radars

- Triple-Doppler (30° beam crossing angles)
- Advanced Radar for Meteorological Operational and Research (ARMOR) C-Band Polarimetric Radar: 100 km range
- Mobile Alabama X-Band (MAX) Polarimetric Radar: 100 km range
- Weather Surveillance Radar 1988D at Hytop, AL (KHTX) S-Band Polarimetric Radar: 100 km range

North Alabama Lightning Mapping Array

- NA-LMA sensors with 150 km range rings

☆ Denotes approximate location of convection on 1st aircraft day (05/21/2012)

★ Denotes approximate location of convection on 2nd aircraft day (06/11/2012)

Brief Literature

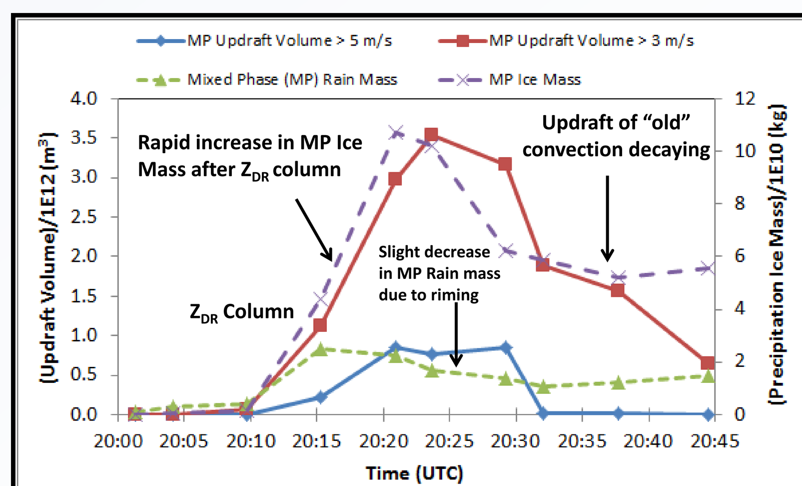
- *Takahashi (1978)* suggested that the rate of charge due to riming graupel is directly related to particle motion and updraft speed via the following expression:

$$\frac{dQ}{dt} = \pi R^2 n(V - vi)qE$$

- Q is the charge, R is the radius of the graupel particle, V (v_i) is the graupel (ice crystal) vertical motion (which includes updraft-fall speed), E is the collision efficiency and q is the charge separated per collision
- *Zipser (1994)* also theorizes that a sufficient updraft speed must exist to loft precipitation sized drops necessary for the growth of graupel
- *Deierling and Petersen (2008)* illustrated that an increase in upward vertical velocities was well correlated with mean total lightning
- *Carey and Rutledge (1996)* showed that the descent of ice graupel below the melting layer can contribute to an increase in the CG lightning rate

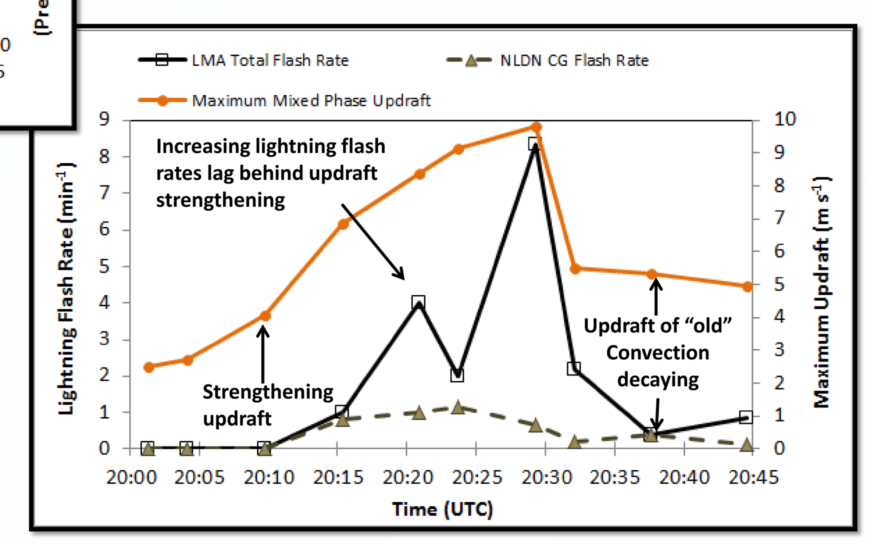
21 May 2012 Aircraft Case #1

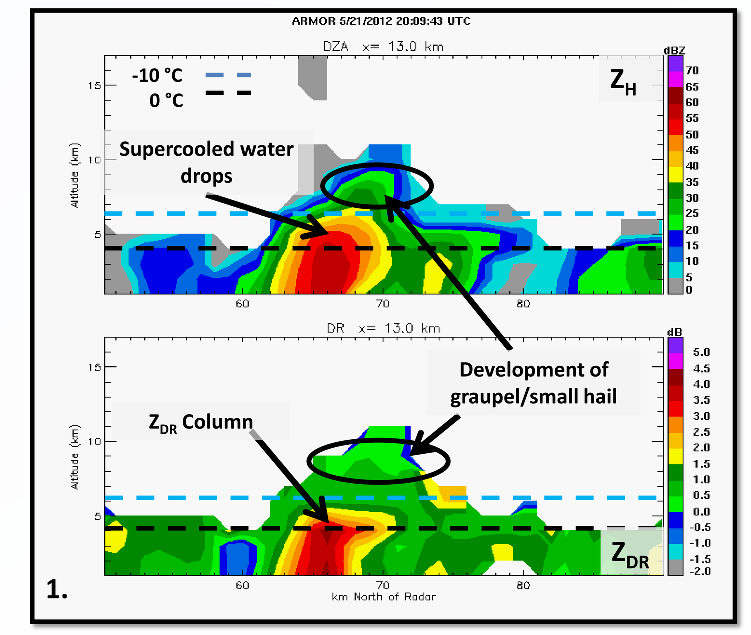
1. The Z_{DR} column signature indicates a flux of supercooled water drops into the mixed phase (MP) region and corroborates with an increase in the Mixed Phase (MP) region rain mass (see time series below). Low values of Z_{DR} ~0 dB around 10 km suggests the growth of graupel/small hail via the riming of supercooled drops .
2. The expansion of the w>3, 5 m/s updraft volume , the height of the 30 dBZ contour and the increase of ice mass within the MP region trend well with total lightning activity from the NA LMA (Dierling et al. (2008). The slight decrease in the MP Rain Mass could be explained due to the growth of graupel/small hail at the expense of droplets. The low level updraft is likely quite effective at lofting drops into the MP region where they will then freeze.
3. NA LMA VHF sources increase and expand through anvil as the "old" updraft enters the maturity. The volume of w > 3, 5 m/s as well as ice mass peak, decay rapidly at first, but then decline at a slower rate due in part to the "new" updraft. The descent of ice/graupel below the melting layer (Goodman 1988; Carey and Rutledge 1996) may contributed to the CG lightning flash.
4. "New "convection along leading edge outflow develops , but is initially electrically inactive. In the "old" convection, the height of the 55 dBZ echo has descended to below 2 km. Z_{DR} values ~ 2 dB. The rate of decrease of the MP rain mass slows as new drops are injected into the complex via the Z_{DR} column signature.



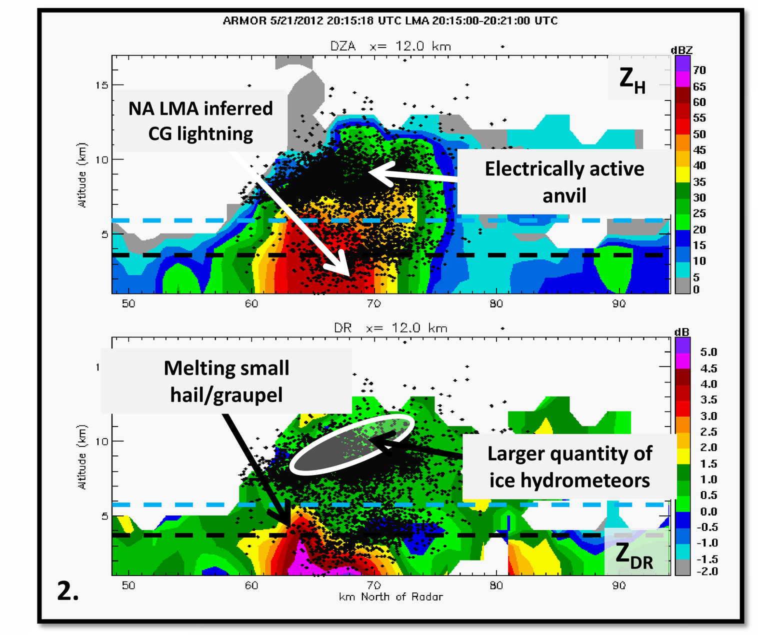
Left Image: Calculations of MP Updraft Volume of W > 3 m/s and W > 5 m/s from dual-Doppler wind synthesis. Mixed Phase Rain and Ice masses computed from ARMOR C-Band polarimetric radar measurements.

Right Image: Maximum Mixed Phase Updraft velocity computed from dual-Doppler wind synthesis with total flash rate from the NA LMA and CG flashes from National Lightning Detection Network.

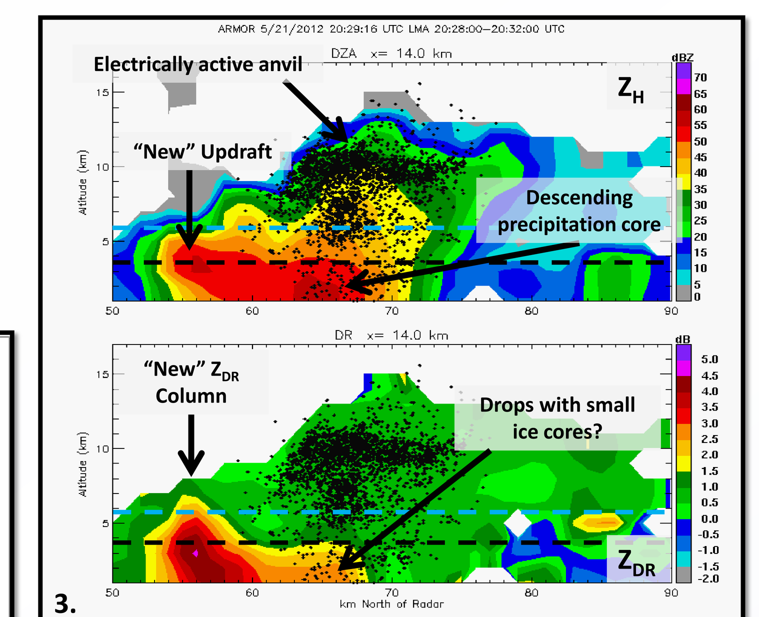




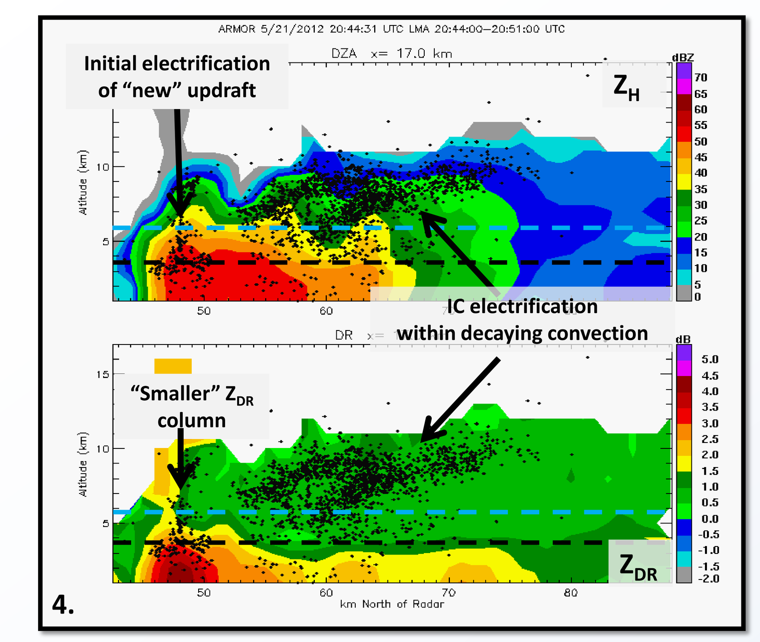
ARMOR[A] (20:09 UTC)



ARMOR (20:15 UTC) NA LMA[B] (20:15-20:21 UTC)



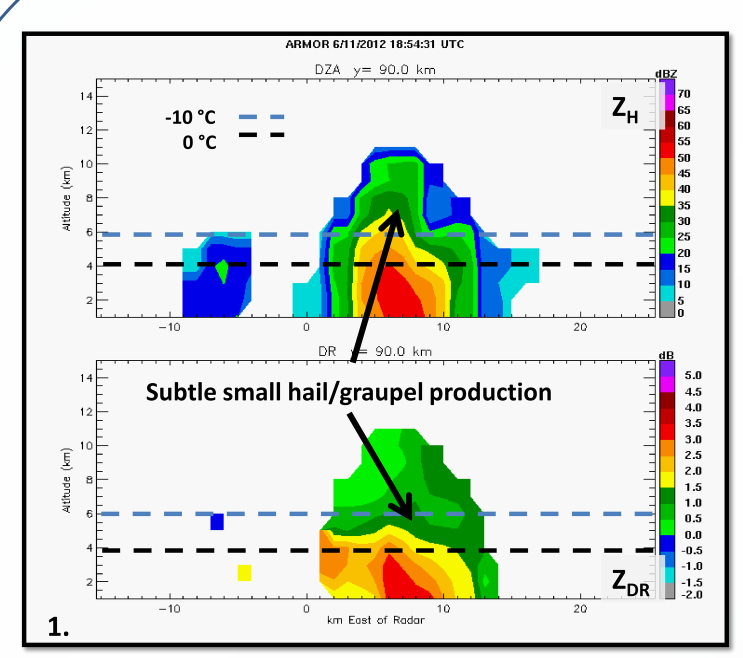
ARMOR (20:29 UTC) NA LMA (20:28-20:32 UTC)



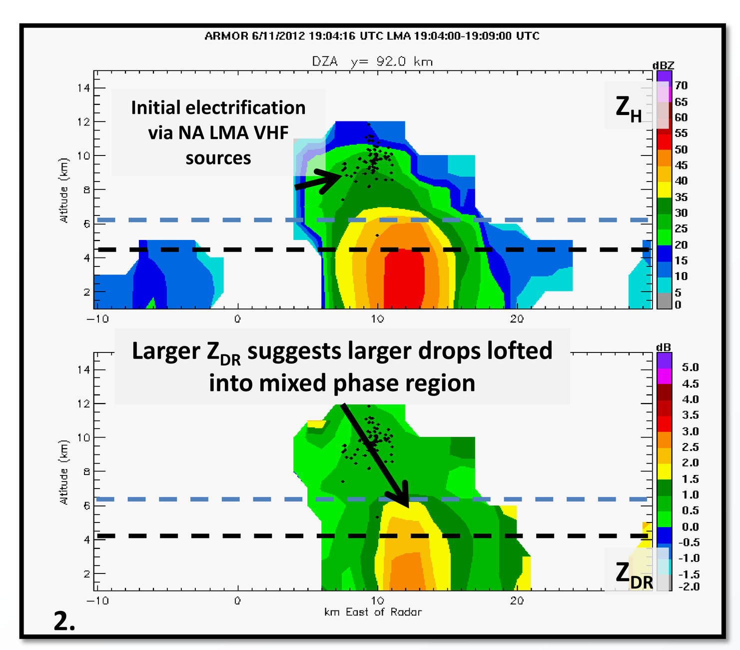
ARMOR (20:44 UTC) NA LMA (20:44-20:51 UTC)

A- ARMOR or Advanced Radar for Meteorological and Operational Research is a C-Band Polarimetric Radar.
B- NA LMA or Northern Alabama Lightning Mapping Array is comprised of 14 stations across northern AL. Dots in images denote VHF radiation sources.

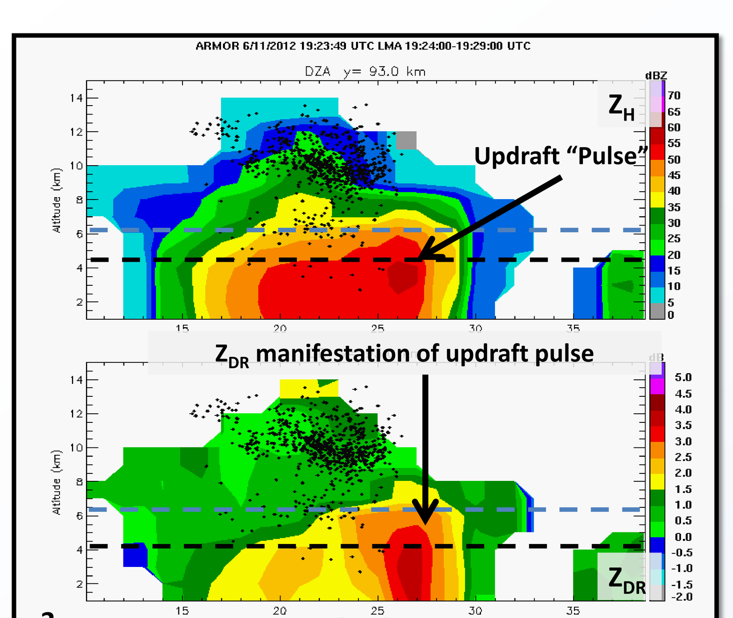
11 June 2012 Aircraft Case #2



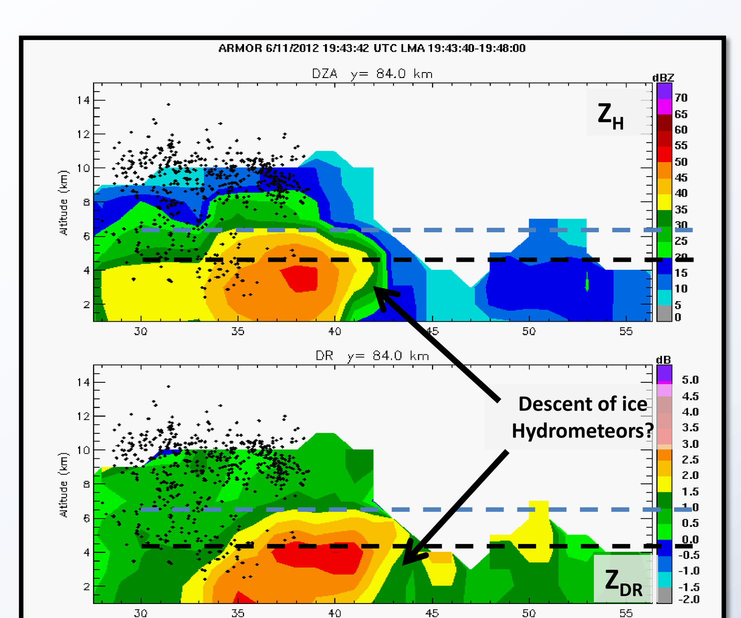
ARMOR (18:54 UTC)



ARMOR (19:04 UTC) NA LMA (19:04-19:09 UTC)



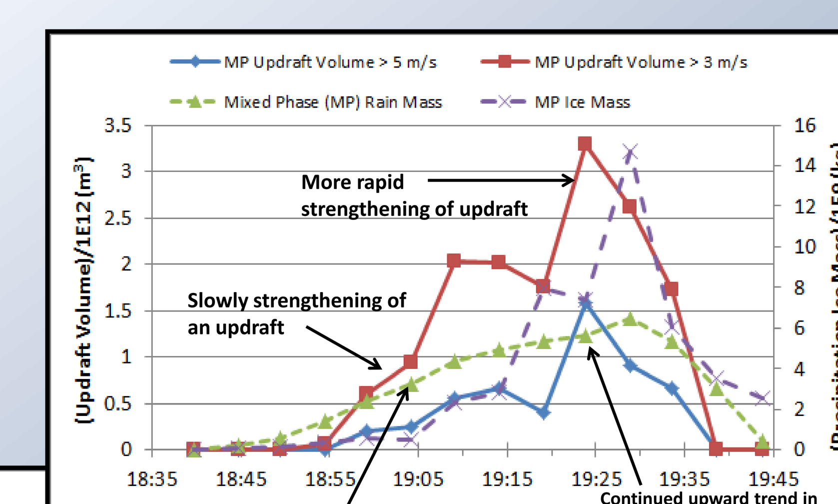
ARMOR (19:23 UTC) NA LMA (19:24-19:29 UTC)

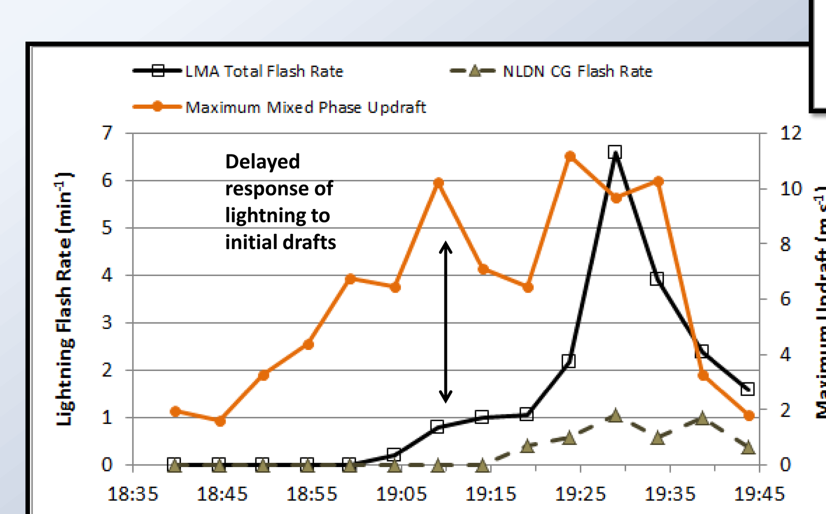


ARMOR (19:43 UTC) NA LMA (19:43-19:48 UTC)

1. Polarimetric observations suggested the continued strengthening updraft via the developing Z_{DR} column during this phase of the convective cell's lifecycle. The slow growth of the updraft results in little to no electrification in the storms early life.
2. Initial Electrification- The slow expansion of the 30 dBZ echo in the mixed phase region (MPR) in concert with a slow increase in updraft volume and within the MPR resulted in initial storm electrification. Additional/larger condensates within MPR is manifest by an increase in warm cloud layer Z_{DR}.
3. Mature Electrification- A vigorous updraft pulse lofts fresh condensates into the MP region. Per the expression derived by *Takahasi (1978)*, the time rate of change of charge increases and the resultant electrification of the cloud ensues. The kinematic proxies for the updrafts both increase with a response in the MP Ice and Rain masses as well.
4. The decrease in the updraft mirrors the decrease in lightning activity, as well as the Ice and Rain masses. The rapid depletion of the ice may stem from the fact that a large quantity of the ice is melted. As the updraft collapses, the total lightning flash rate decreases. However, VHF radiation sources from the NA LMA continue to descend closer to the ground suggesting that perhaps a contribution of the CG lightning produce was due to the fallout of graupel/ice hydrometeors below the melting level.

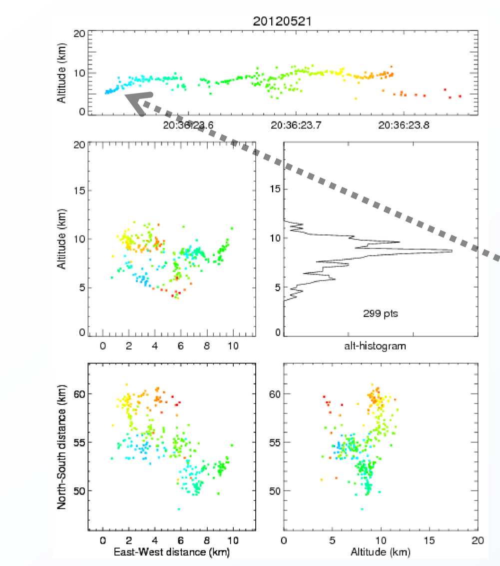
Right Image: Mixed Phase Updraft of greater than 3 and/or 5 m/s computed from dual-Doppler wind synthesis, as well as MP Rain and Ice masses.





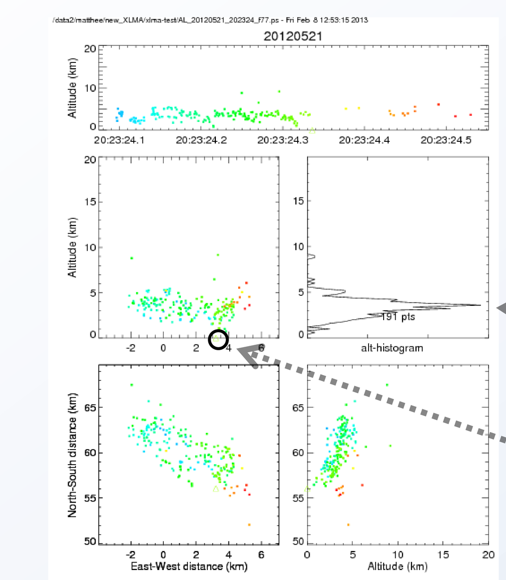
Left Image: Maximum Mixed Phase Updraft velocity computed from dual-Doppler wind synthesis with total flash rate from the NA LMA and CG flashes from National Lightning Detection Network.

Lightning Type



Typical Normal Polarity Intra-cloud (IC) Flash 21 May 2012 (Case #1)

Initial upward movement of bi-level flash into upper positive charge



Typical Negative Cloud-to-ground (CG) Flash 21 May 2012 (Case #1)

Low-level peak LMA sources

NLDN -CG

- Preliminary analysis of NA-LMA and NLDN lightning data suggest that DC3 Alabama storms were *ordinary polarity*
- Both analyzed cells on aircraft days had *100% negative* CG polarity according to NLDN.
- Consistent with weak shear, modest instability and updrafts

Environmental Summary

- Both days low shear and low-to-moderate CAPE/instability
  - Consistent with ordinary isolated to multicell convection, normal polarity lightning and overwhelming –CG polarity
- June 11 moister, deeper warm cloud depth and weaker low level lapse rates
  - Consistent with increased MP rain mass and delayed ice and lightning

Date	*5/21/2012*	*6/11/2012*
850-700 mb lapse rates [C/km]	-7.0	-5.0
Precipitable Water mm [inches]	29.464 (1.16)	43.434 (1.71)
Wet-Bulb Zero Height (AGL) km [hPa]	2.97 (695)	3.96 (615)
0 C Level (AGL) [km]	3.46	4.43
Warm Cloud Depth [km]	1.8	3.6
Surface Based CAPE (J/kg) (T_v Correction)	789	958
Downdraft CAPE (using Coldest Wetbulb)	704	744
0-6 km shear bulk shear [knots]	12	12
Lifted Index	-2	-3

Future Work

- Examine flash extent as it relates to environmental as well as storm microphysics and kinematics
- Utilize NCAR Hydrometeor Identification based off of C-band update of *Straka et al. (2000)* fuzzy logic scheme
- Refine kinematic quantities and examine any correlation with microphysical and lightning properties
- Analyze more convective cells on each aircraft day

Special Thanks

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