TEXAS TECH UNIVERSITY

2017 AMS Annual Meeting

An analysis of small changes in environment which resulted in diverse charge structures on 4 June 2012 in West Texas

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Big Acknowledgements: Ted Mansell, Chris Weiss, Matt Brothers

Deep Convective Clouds and Chemistry - Motivation

The environmental controls on electrification & vertical distribution of lightning channels

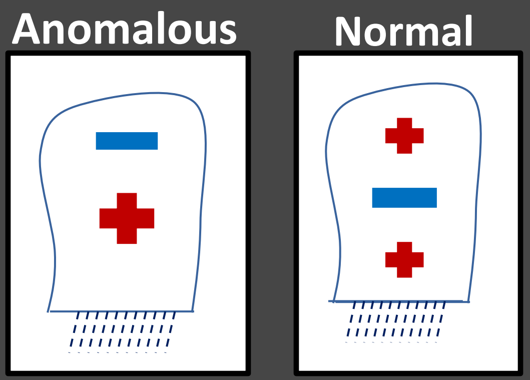
Hypothesis: Storms with

- Upper level -IC [intra-cloud] flashes
- +CG [cloud-to-ground] flashes

Are associated with a mixed phase region that contains a "large fraction of the adiabatic liquid water profile" (Scientific Program Overview)

Anomalous storms:

- Drier at low and mid-levels
- Larger θ_e gradients (west of θ_e ridge)
- Often LP storms
- More CCN



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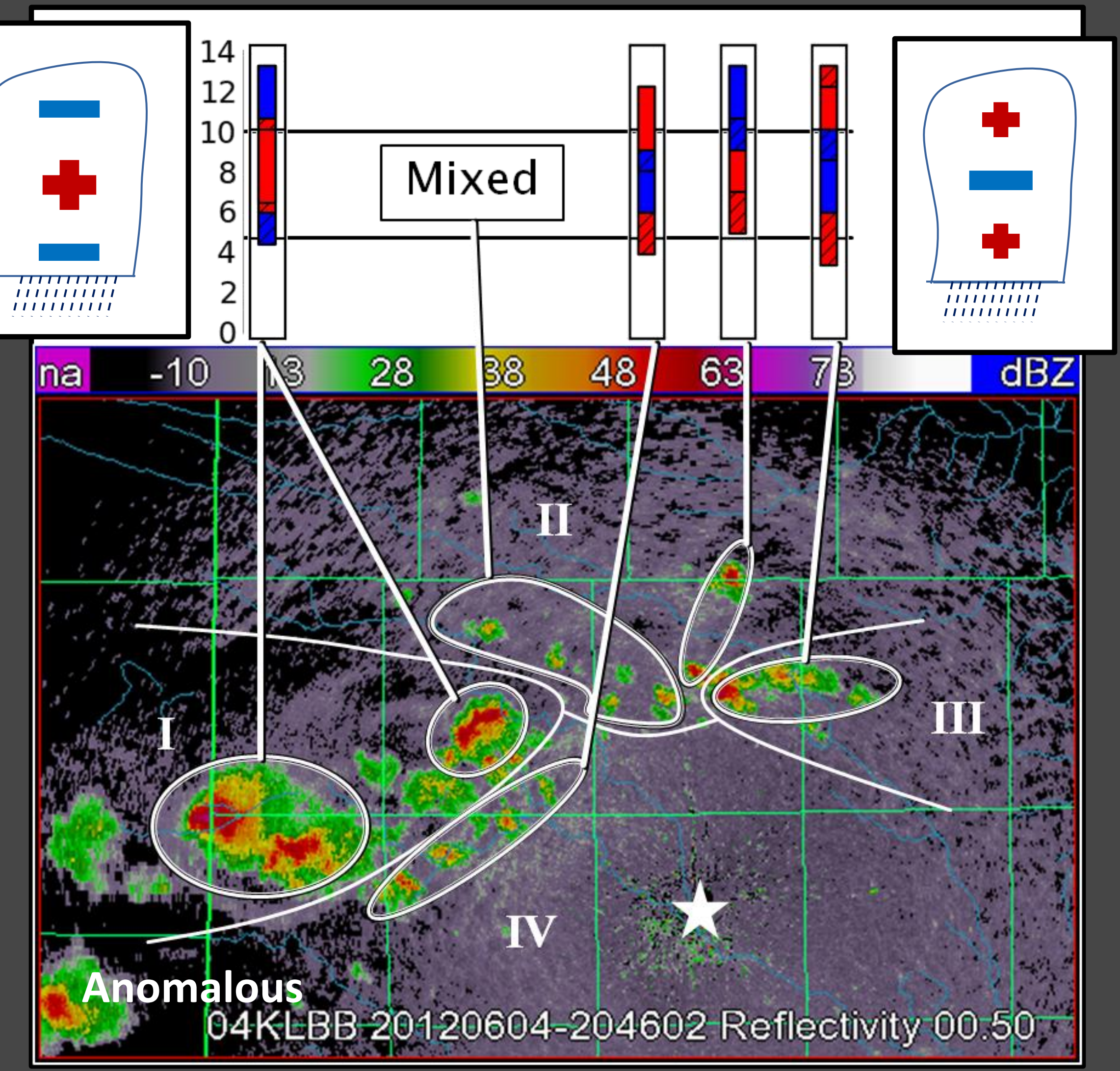


LMA-based Charge Assignment:

Region I

- Mid-level **positive** charge
- Infrequent +CG

Region II

- Mixed charge structures in short-lived storms
- Mid-level **positive** in longer-lived storms
- Low flash rates, few CG

Region III

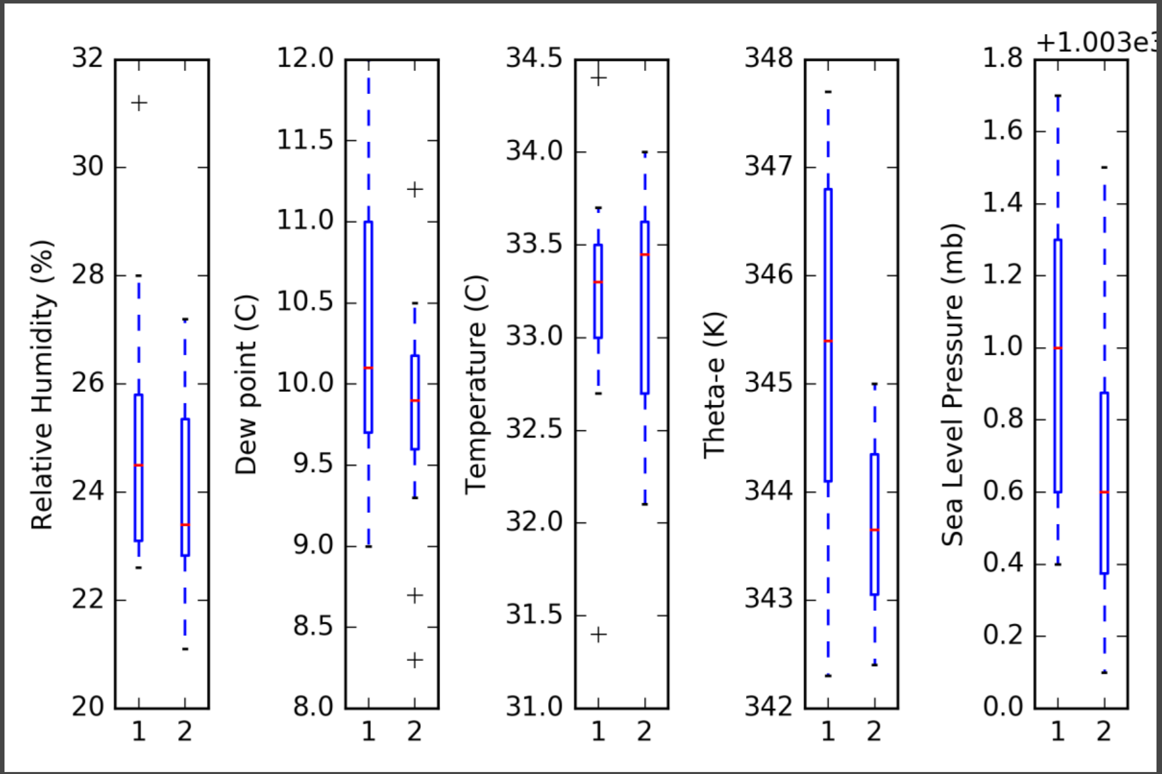
- Mid-level **negative**
- Active lower charge region
- Frequent –CG
- Faster storm growth

Region IV

- Outflow-driven
- Mid-level **negative** charge
- -CG on leading edge, mixed in stratiform region

Surface – 15 minutes before first LMA flash

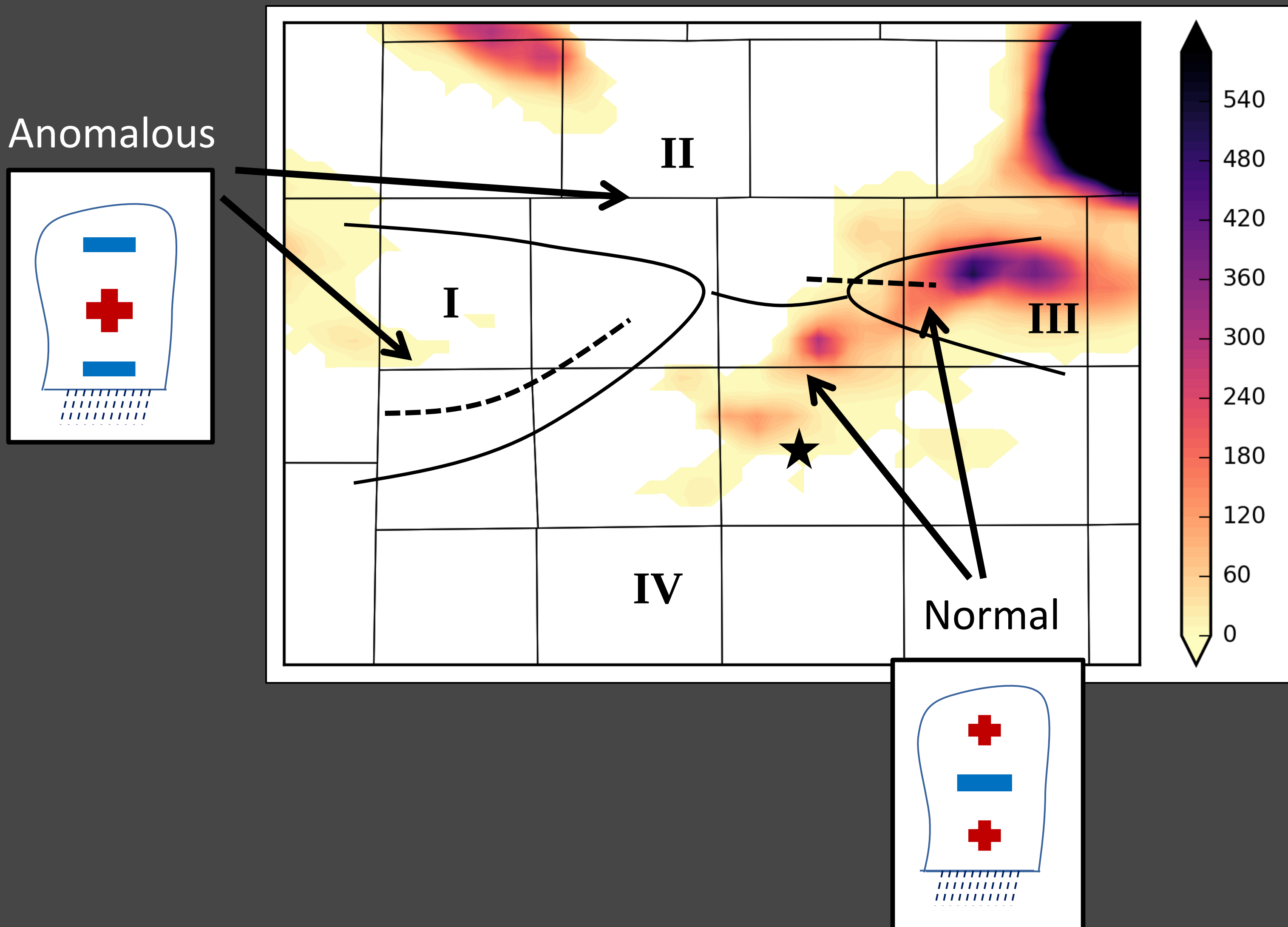
- **Statistical difference in θ_e**
- **No difference in dew point depression**
- **No variable could be used deterministically to discriminate between environments producing anomalous or normal storms**



1: Anomalous storms, n=18

2: Normal storms, n=12

Total flashes in 24 hour period prior to initiation

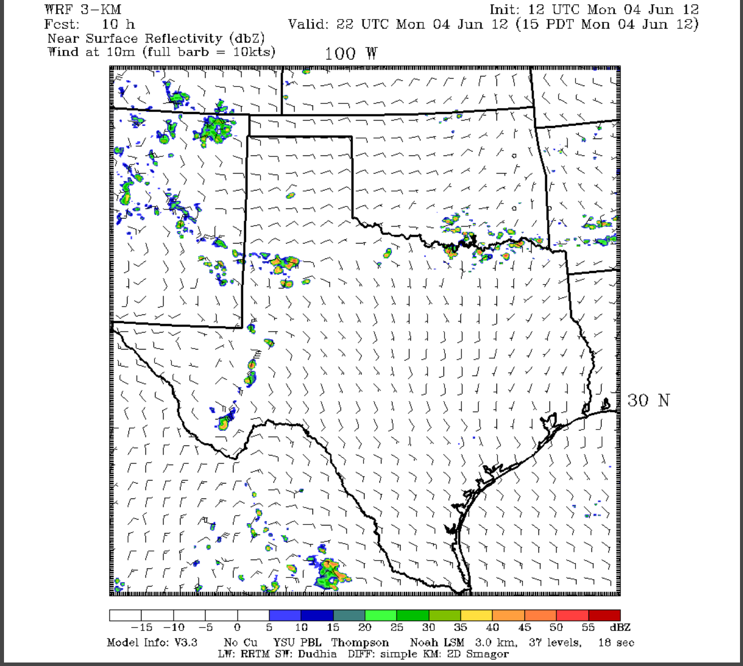


Above Surface – Modeled environment

No soundings in the area

Reanalysis fields too coarse

Analyzed a 50-member ensemble based on TTU WRF with nested 4 km grid-spacing



Only analyzed locations where model spread covered observed surface temperature and moisture

Things which did not vary significantly between locations with and without previous convection:

- CAPE
- NCAPE
- Warm Cloud Depth

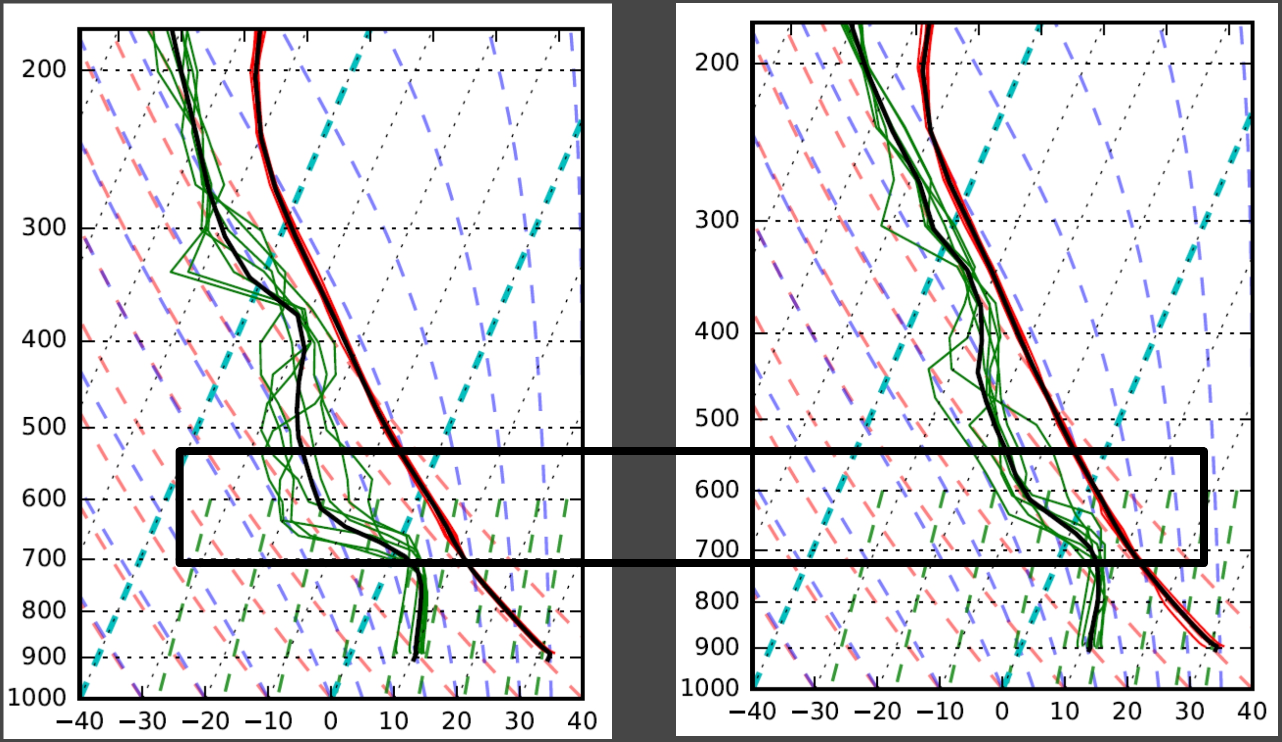
Things which did vary:

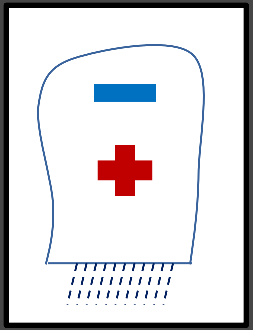
- Mid-level moisture

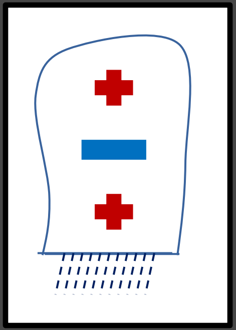
Above Surface – Modeled environment

No Previous Convection
Anomalous Polarity

Previous Convection
Normal Polarity







Above Surface – Effect of Entrainment

- Insights from meteorological studies
  - Larger impact on storm morphology than aerosols
  - Increased entrainment at base of cloud
    - Smaller droplets in warm cloud depths and updraft regions
    - Reduced warm rain processes
    - More CCN activation at higher altitudes – bimodal spectra, favored on storm periphery
- Enhanced depth of positive charging?

Devenish, B. J., P. Bartello, J. Brenguier, L. R. Collins, W. W. Grabowski, R. H. A. Ijzermans, S. P. Malinowski, M. W. Reeks, J. C. Vassilicos, L. P. Wang, and Z. Warhaft, 2012: Droplet growth in warm turbulent clouds, QJ RMS, 138, 1401--1429
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Gilmore, M. S. and L. J. Wicker, 1998: The Influence of Midtropospheric Dryness on Supercell Morphology and Evolution. MWR, 126 (4), 943--958.
Lu, C., S. Niu, Y. Liu, and A. M. Vogelmann, 2013: Empirical relationship between entrainment rate and microphysics in cumulus clouds. GRL, 40 (10), 2333--2338.

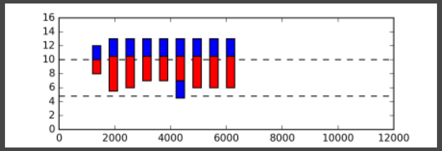
Idealized Model – Effect of Entrainment?

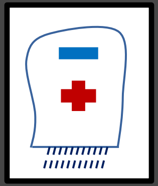
- Used 6 representative ensemble sounding with modified mixed layer to match observations
- NCOMMAS
- Model grid
  - 125 m grid spacing horizontal
  - Average 170 m grid spacing vertical
- Warm bubble + flux forcing for initiation
- Important parameterizations
  - 2-moment 3-ice Ziegler 1985 scheme with variable graupel density
  - Various non-inductive charging and inductive charging included
- Results shown: Flash channel density by altitude and time to compare to observations

Idealized Model – Brooks et al.
Charge layers based on flash locations

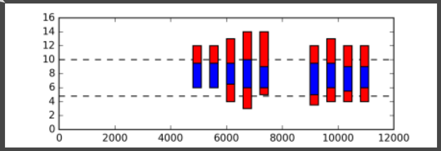
Observed

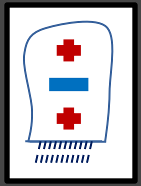
No previous convection
Dry mid-levels





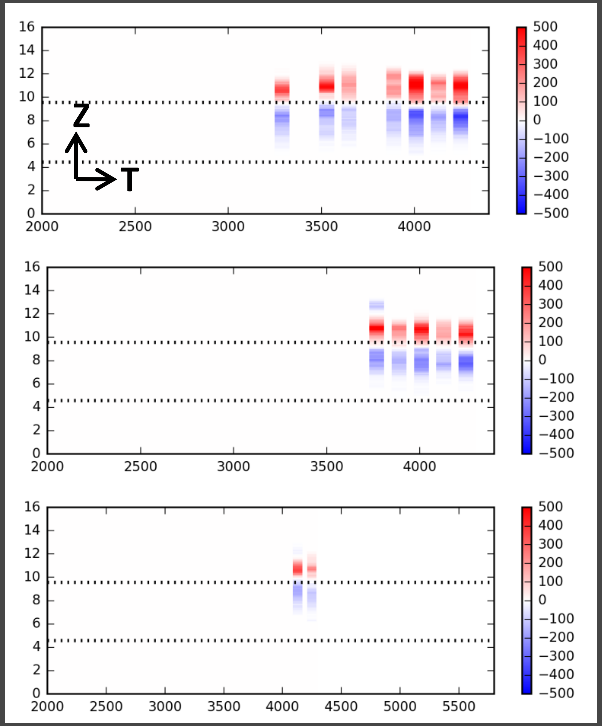
Previous convection
Moist mid-levels

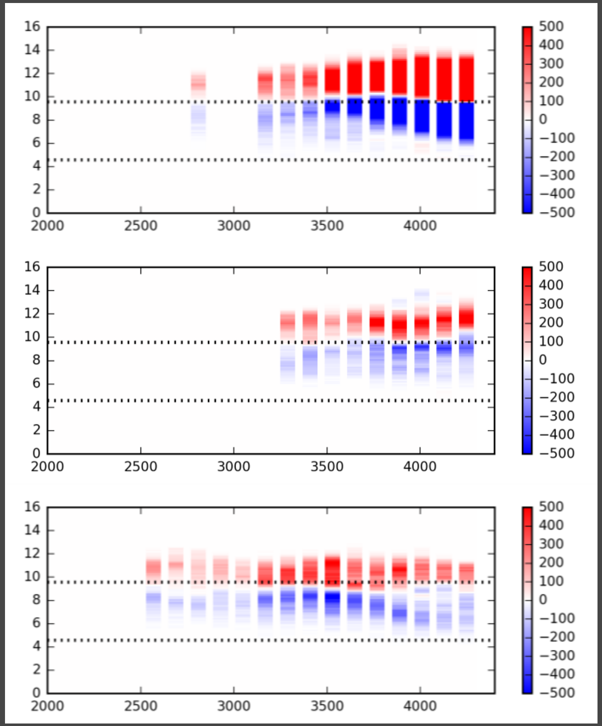




Simulated

Most mid-tropospheric moisture





Idealized Model – Brooks et al.
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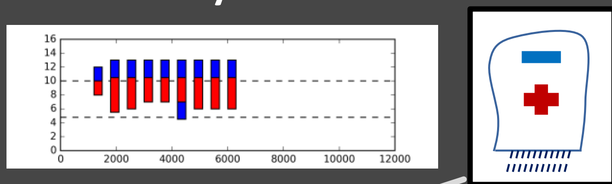

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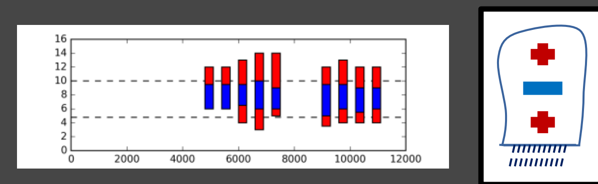

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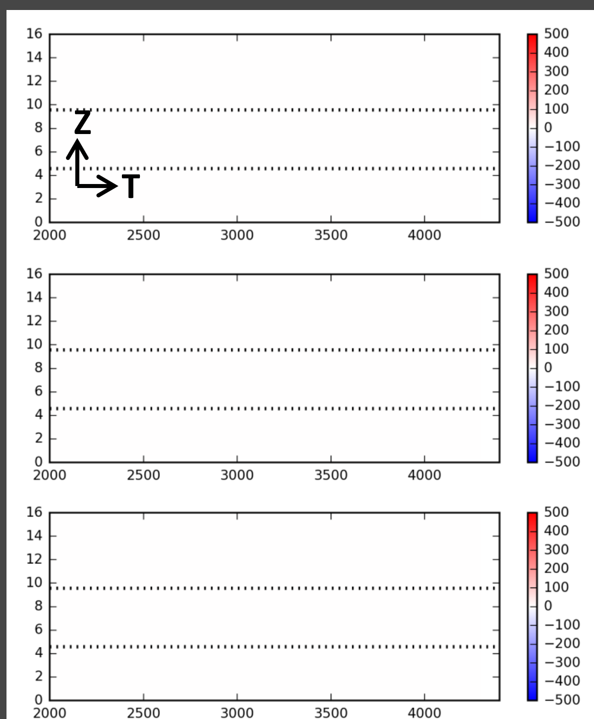
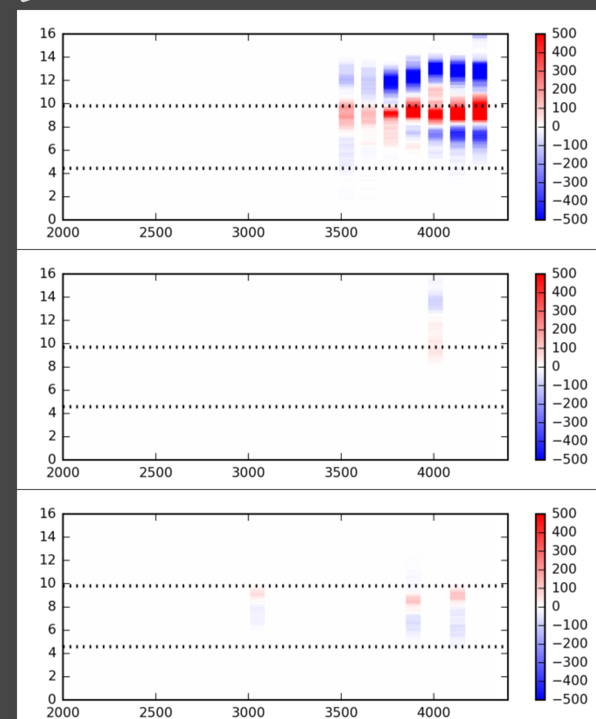
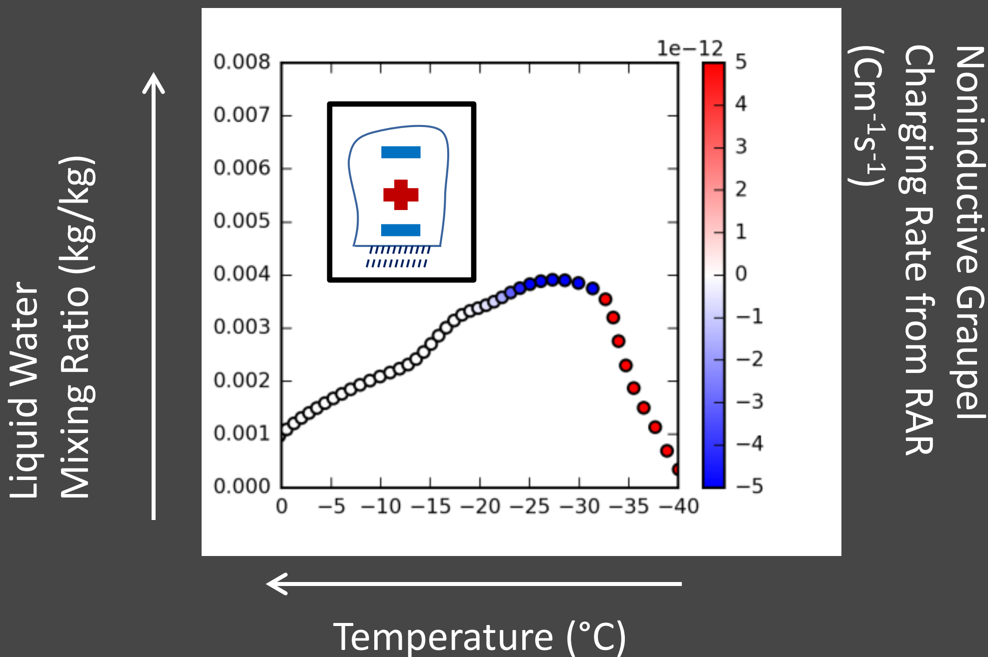




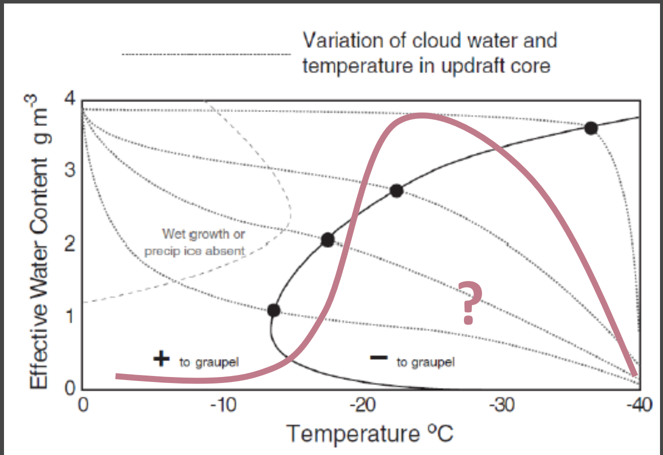
What is Happening?

5 km x 5 km average
T = 1920 s



Still converting water vapor into liquid well into the mixed-phase region

Huge amount of variability in time and around the updraft



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Current Results and Questions

Meteorologically - “Normal” regions had faster storm growth and more CG’s

Modeled drier air at mid-levels with a lack of previous thunderstorms in regions with anomalous charge structures

Different mid-level moisture has large impacts on resolved flash rates and storm morphology, but not in charge polarity

Different charging parameterizations can give realistic charge structures for one region or the other but no one parameterization gives realistic results in both

Within the simulation water vapor can make it well into the mixed phase before conversion to liquid

Next step: Examine the variability of water content associated with entrainment. Can that be used to determine which charge reversal results would be most representative in similar environments?

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