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

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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 $\theta_e$ gradients (west of $\theta_e$ ridge)
- Often LP storms
- More CCN

Using 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 $\theta_e$

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

Anomalous storms
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 do 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
    • Reduced warm rain processes
    • More CCN activation at higher altitudes – bimodal spectra

• Enhanced depth of positive charging?

Grant, L. D and S. C. van den Heever, 2015: Cold Pool and Precipitation Responses to Aerosol Loading: Modulation by Dry Layers, JAS, 72, 1398–1408
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 – Takahashi-based parameterization

Charge layers based on flash locations

Most mid-tropospheric moisture

Observed

No previous convection

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

Observed

Most mid-tropospheric moisture

No previous convection

Previous convection

Most mid-tropospheric moisture
Idealized Model – Saunders and Peck

Charge layers based on flash locations

Observed

Most mid-tropospheric moisture

No previous convection

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

Huge amount of variability in time and around the updraft

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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