The meteorology of storms that produce narrow bipolar events

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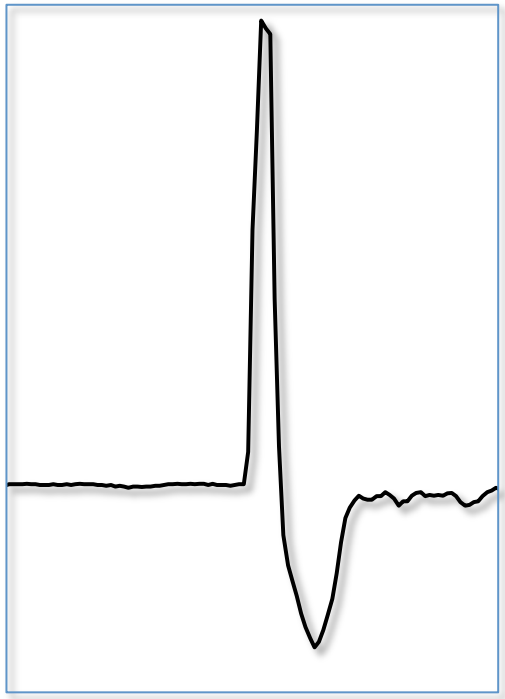


AGU FALL MEETING
San Francisco | 9–13 December 2013

DARPA

What is a narrow bipolar event (NBE)?

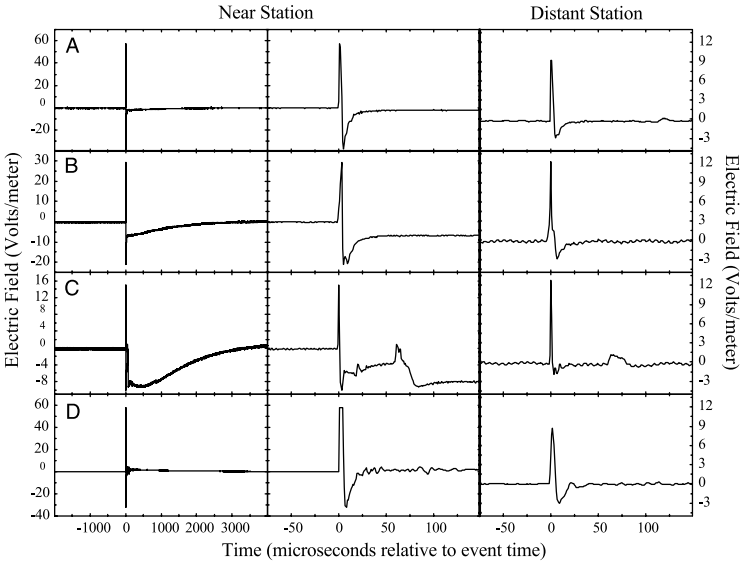
NBEs are compact (< 2 km), **powerful** (> 10 kW in VHF), **and impulsive** (~10 μs) **electrical discharges in thunderstorms**, also known as compact intracloud discharges (CIDs) [e.g., Smith et al. 1999].

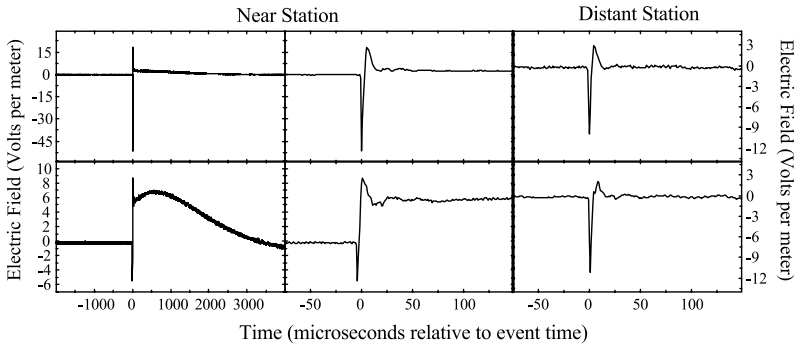
Can be either **positive or negative polarity** (Wu et al. 2012), and **have distinctive broadband waveform signatures** (Eack 2004) sometimes confused for +CGs in the past by NLDN and other networks (Tessendorf et al. 2007).

NBEs are related to lightning but are likely **optically "dark"** (Jacobson et al. 2013).

As revealed by VHF sensors (both satellite and ground):

- The **most powerful lightning-related VHF sources observed** (Jacobson et al. 2013)
- Tend to **occur at the beginning of intracloud discharges** (Rison et al. 1999)
- Difficult to estimate altitude properly due to receiver saturation (Thomas et al. 2001)





Positive and negative NBE examples from Eack (2004)

How do NBEs relate to thunderstorm structure and evolution?

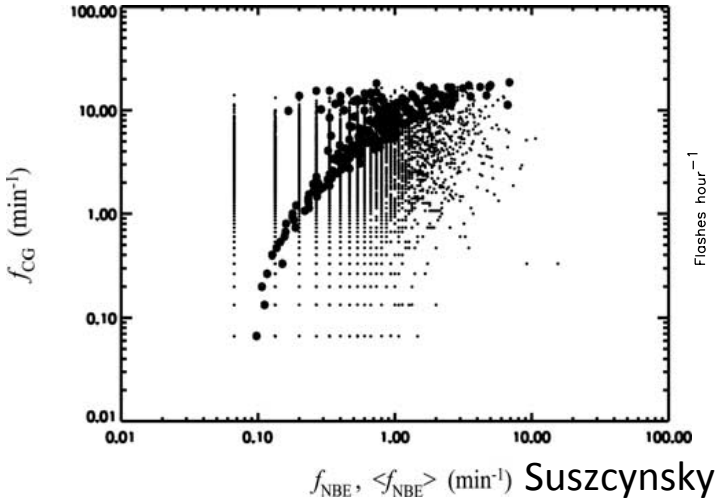
Good question! This is still open for exploration.

<u>What we know to date</u>

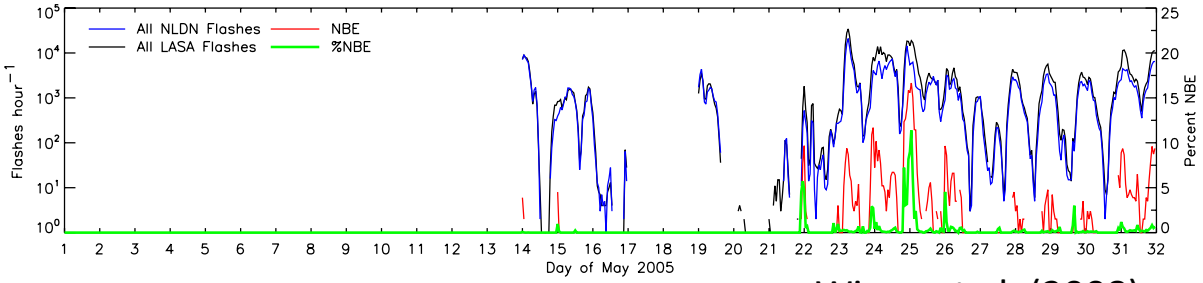
- Tend to occur near strong (~40-dBZ) cores (e.g., Smith et al. 1999)
- Tend to occur at high altitudes (> 8 km; Wu et al. 2012)
- Correlated to cloud-to-ground (CG) flash rate (Suszcynsky and Heavner 2003)
- Correlated to 30-dBZ heights (Wiens et al. 2008)
- Certain individual storms can produce very high NBE rates (Wiens et al. 2008)

<u>Outstanding issues</u>

- What is distinctively different about storms that produce many NBEs?
- Case studies needed of NBE occurrence related to total flash rate and storm evolution



Suszcynsky and Heavner (2003)



Wiens et al. (2008)

Data and Methodology

North Alabama Lightning Mapping Array (NALMA)
National Lightning Detection Network (NLDN)
National 3-D Radar Reflectivity Mosaics (NMQ)

McCaul LMA flash-counting methodology (McCaul et al. 2005)

No waveform data, so instead use concept of "NBE candidates"

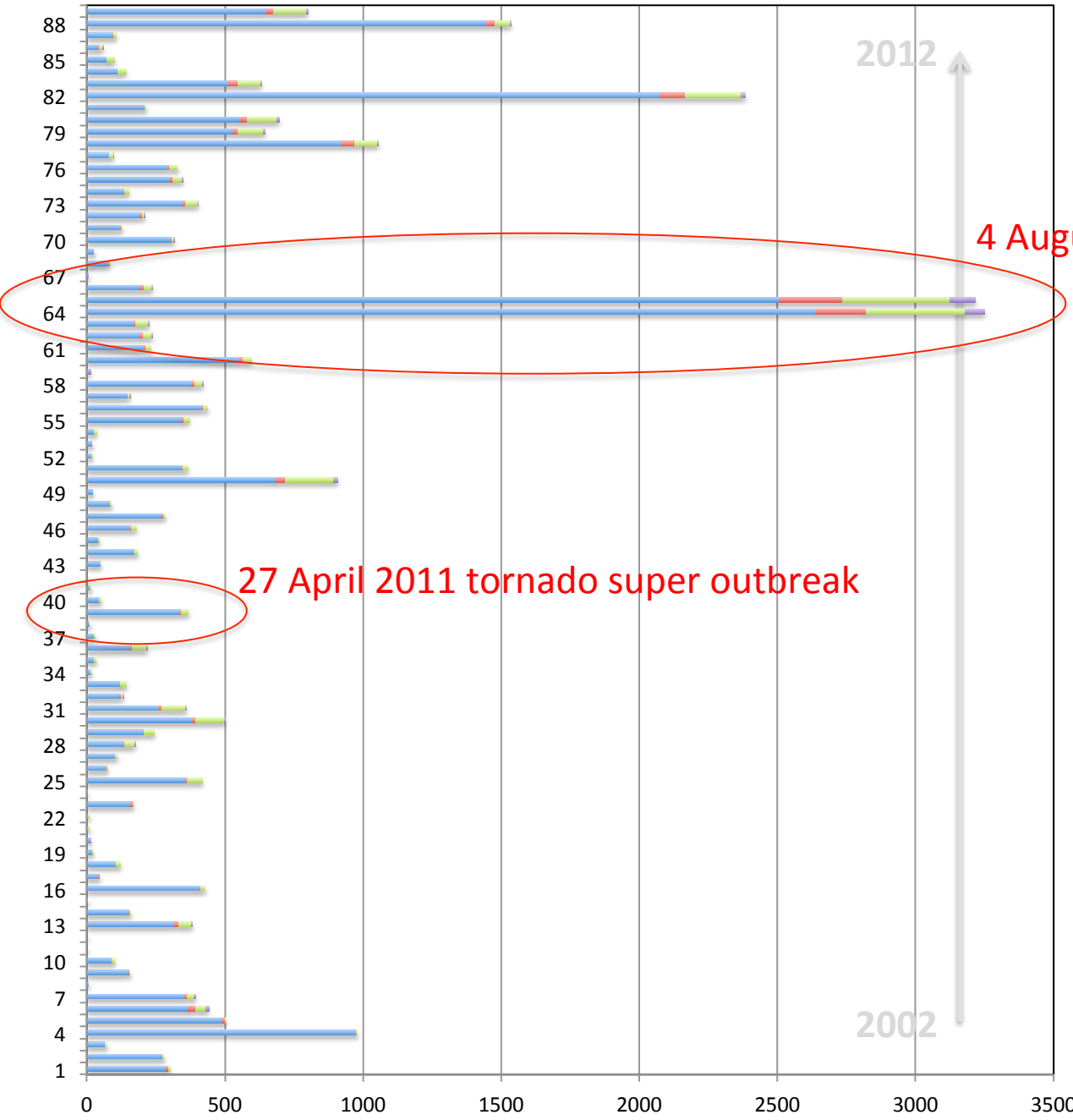
- NALMA flashes containing 40+ dBW source (**DB40**)
- Flashes containing 40+ dBW initial source (**NB40**)
- Flashes containing 50+ dBW source (**DB50**)
- Flashes containing 50+ dBW initial source (**NB50**)

Restrictiveness

DB40 is least-stringent category, NB50 the most stringent

Modest altitude criteria to filter out very poor solutions

Notable NALMA NBE candidate cases (2002-2012)

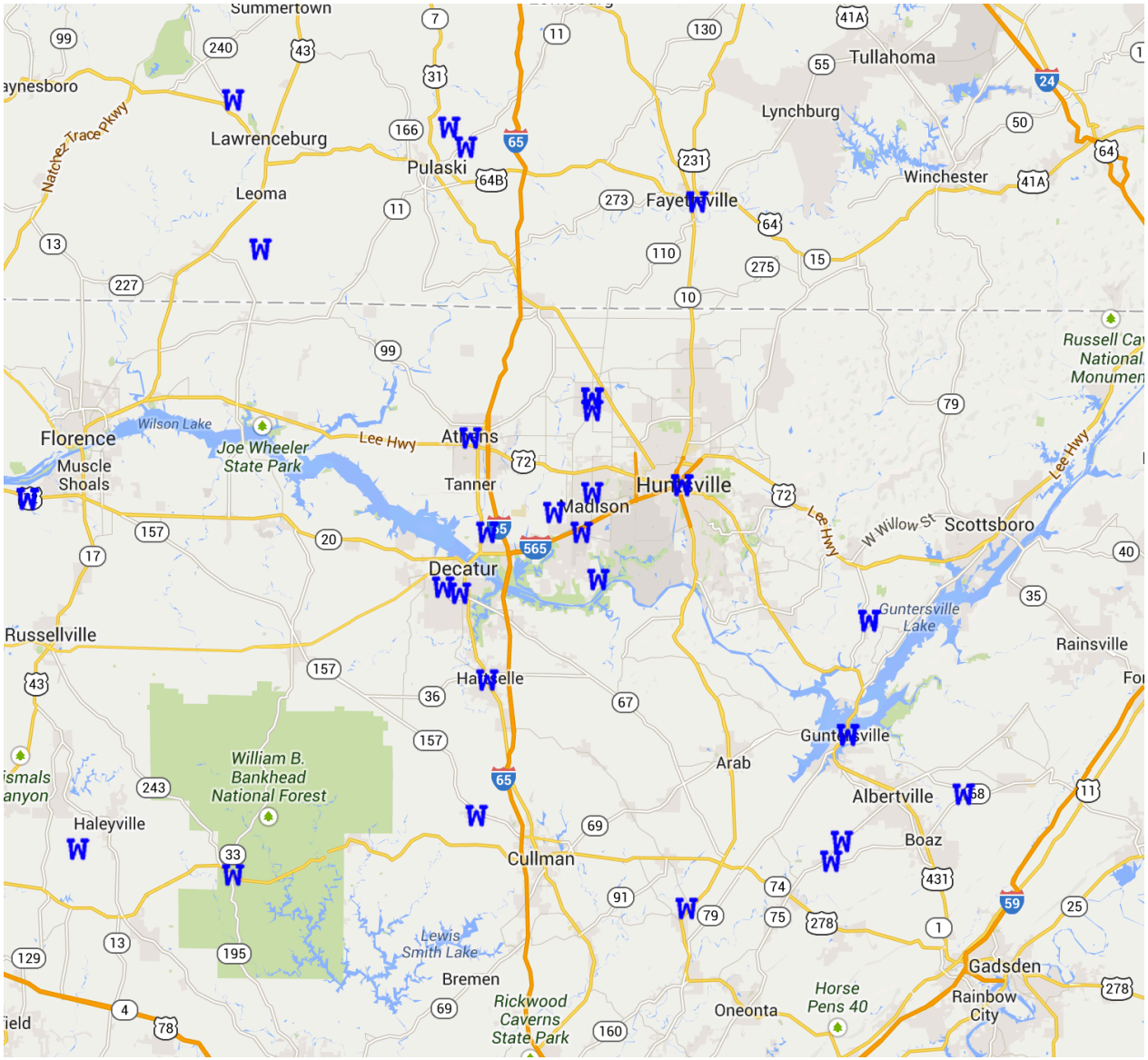


Data plotted as ~6-h cases

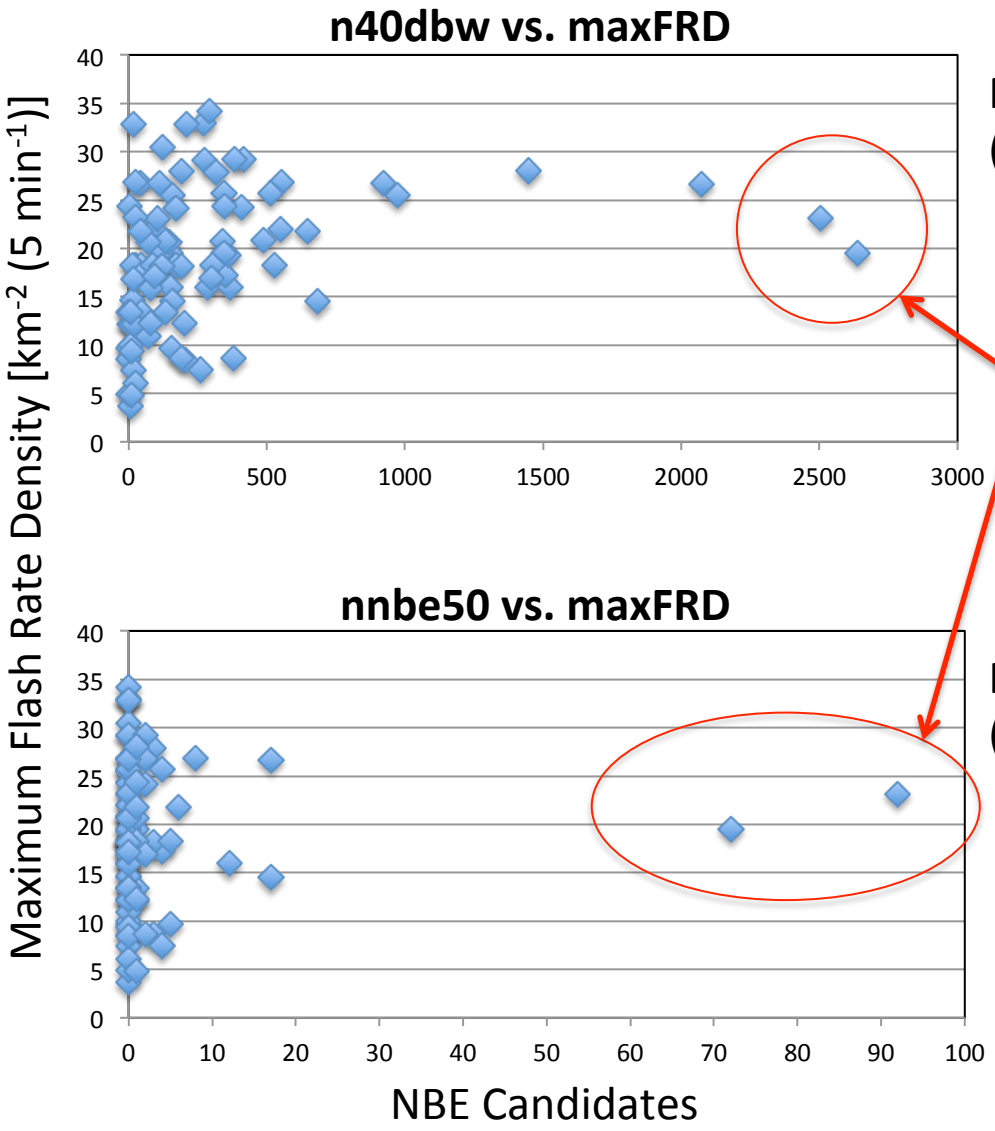
- DB40
- DB50
- NB40
- NB50

The two ~6-h periods on 4 August 2011 are by far the biggest NBE candidate producers, by any metric

4 August 2011 Svr Wx Reports (thru 12 UTC)



NALMA NBE Candidates vs. Max Flash Rate Densities (2002-2012)

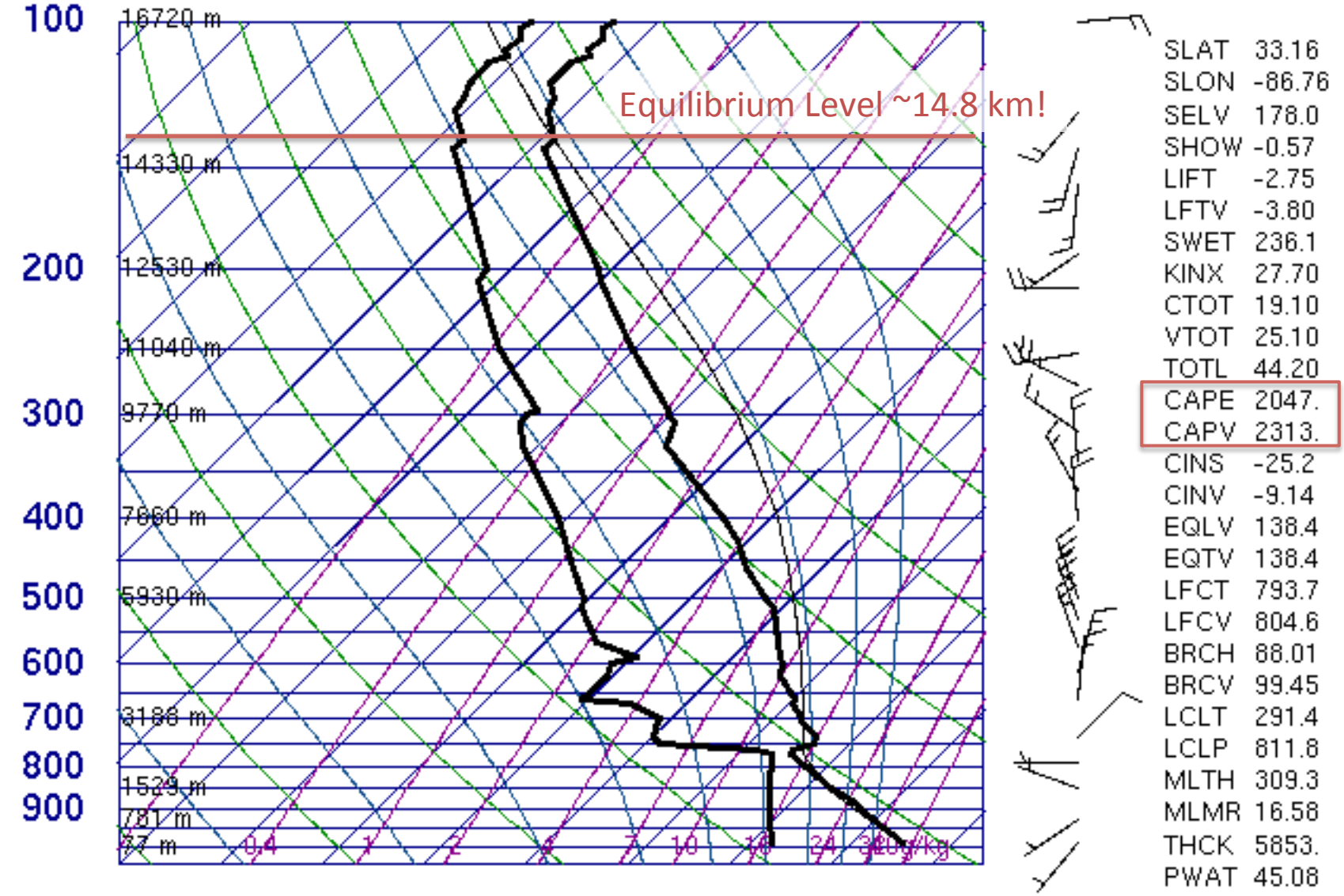


Flash contains 40 dBW source anywhere (DB40)

Two ~6-h periods on 4 August 2011

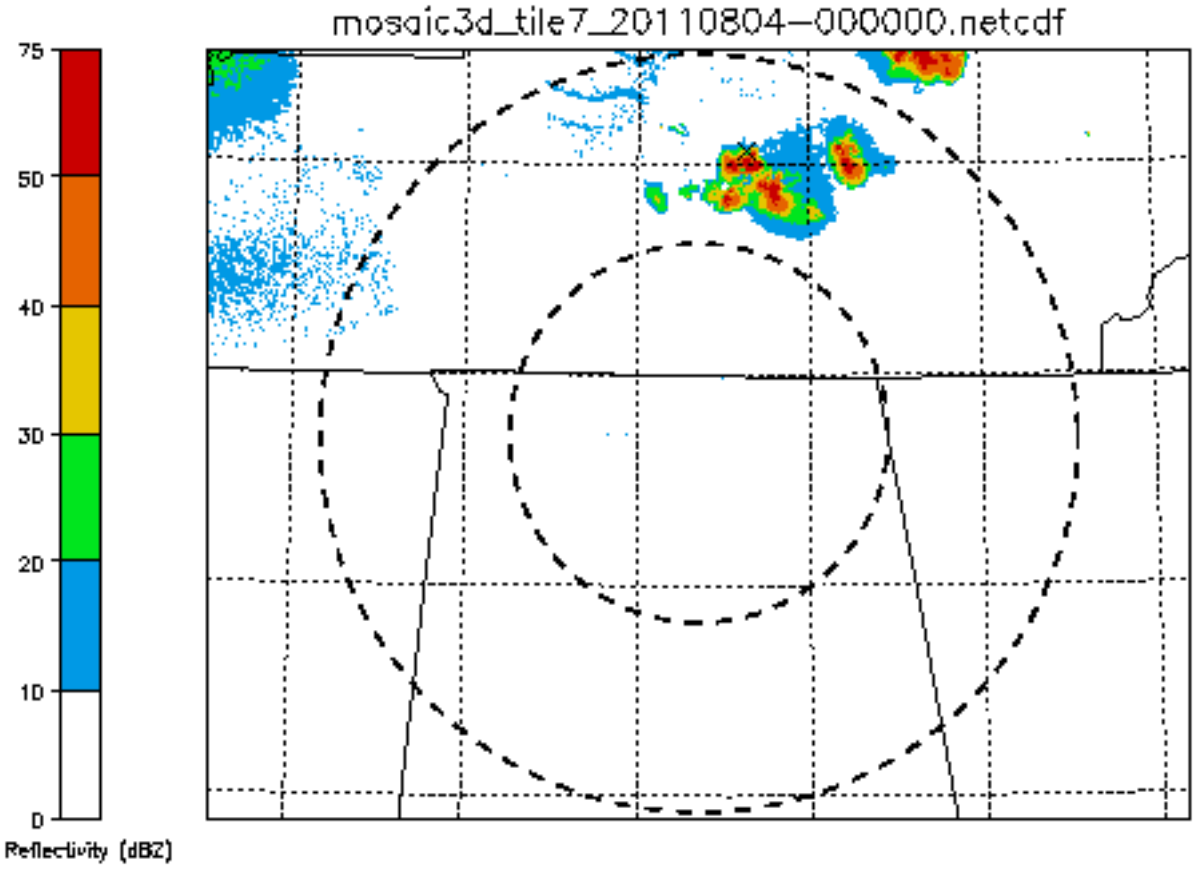
Flash contains 50 dBW as initial source (NB50)

Standout NBE candidate cases are middle of the road in terms of max flash rates

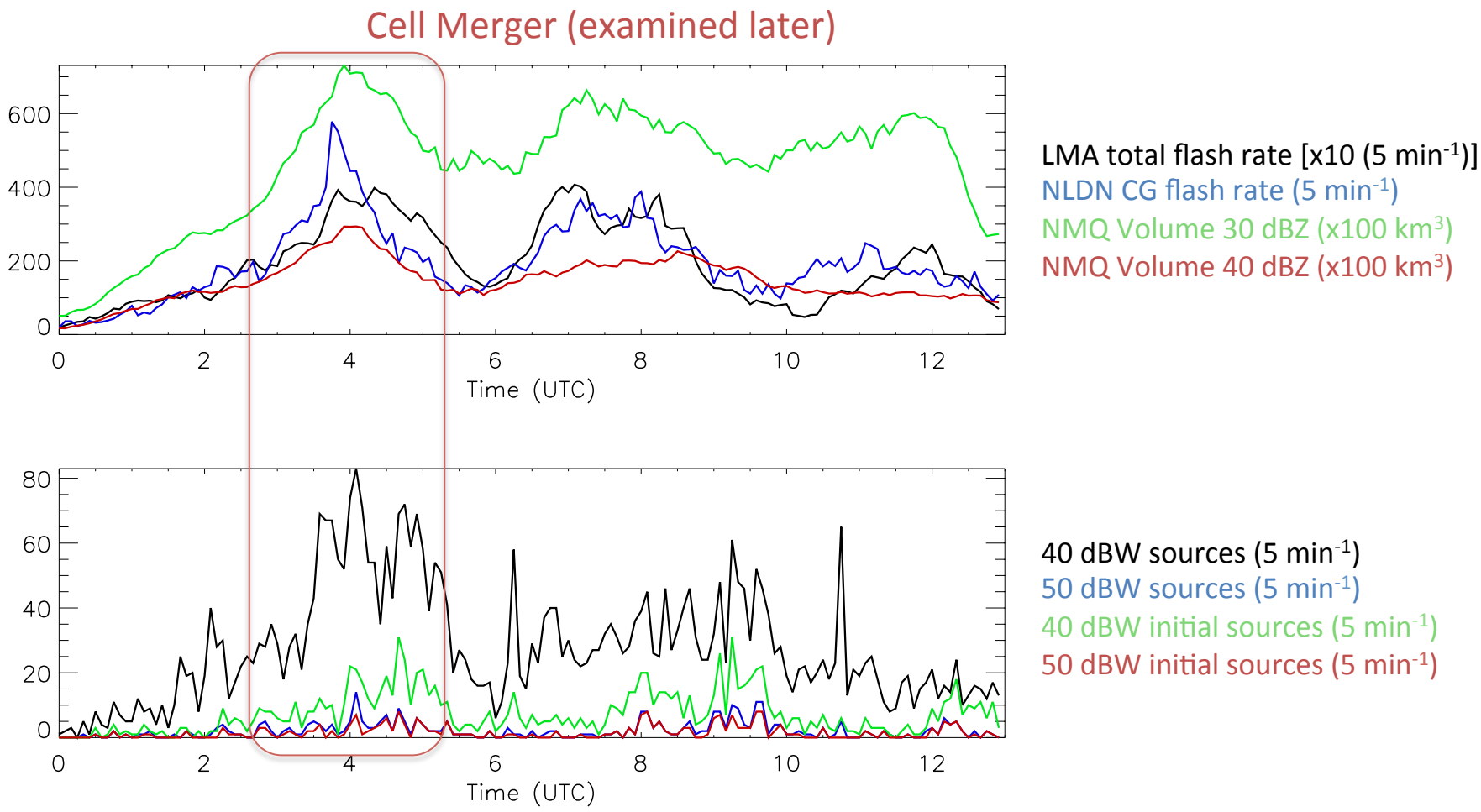

72230 BMX Shelby County Airport
Equilibrium Level ~14.8 km!
100
200
300
400
500
600
700
800
900
16720 m
14330 m
12530 m
11040 m
9770 m
7660 m
5930 m
3186 m
1529 m
781 m
-40 -30 -20 -10 0 10 20 30 40
SLAT 33.16
SLON -86.76
SELV 178.0
SHOW -0.57
LIFT -2.75
LFTV -3.80
SWET 236.1
KINX 27.70
CTOT 19.10
VTOT 25.10
TOTL 44.20
CAPE 2047.
CAPV 2313.
CINS -25.2
CINV -9.14
EQLV 138.4
EQTV 138.4
LFCT 793.7
LFCV 804.6
BRCH 88.01
BRCV 99.45
LCLT 291.4
LCLP 811.8
MLTH 309.3
MLMR 16.58
THCK 5853.
PWAT 45.08
00Z 04 Aug 2011
University of Wyoming

4 August 2011 NMQ composite reflectivity (contours) and 40 dBW flashes (X)

100-km and 200-km NALMA Range Rings (dashed circles)



Cell mergers appear to be associated with enhanced NBE candidate activity



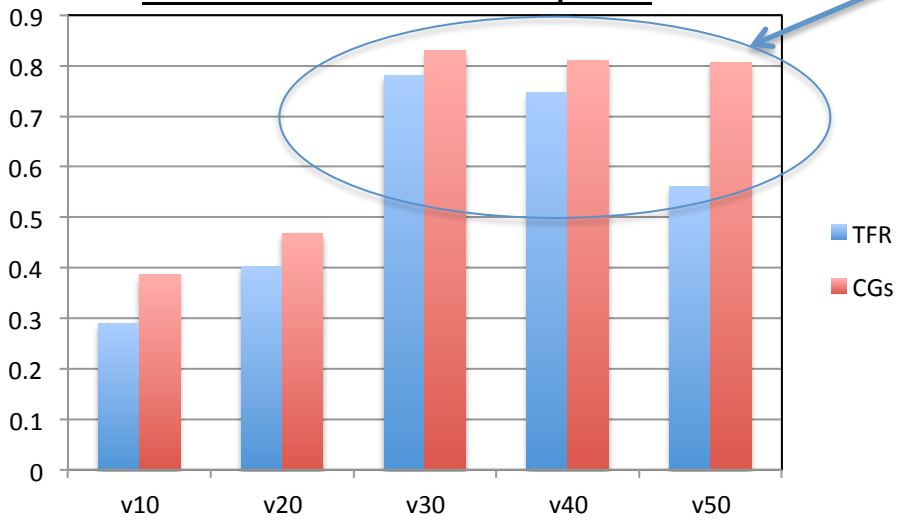
Bulk Regional Time Series

- Includes all observations within 200 km range of NALMA center
- Superficial comparison suggests good correlations among 30/40 dBZ volumes and various flash parameters, including NBEs

Bulk Spearman's Rank Correlations

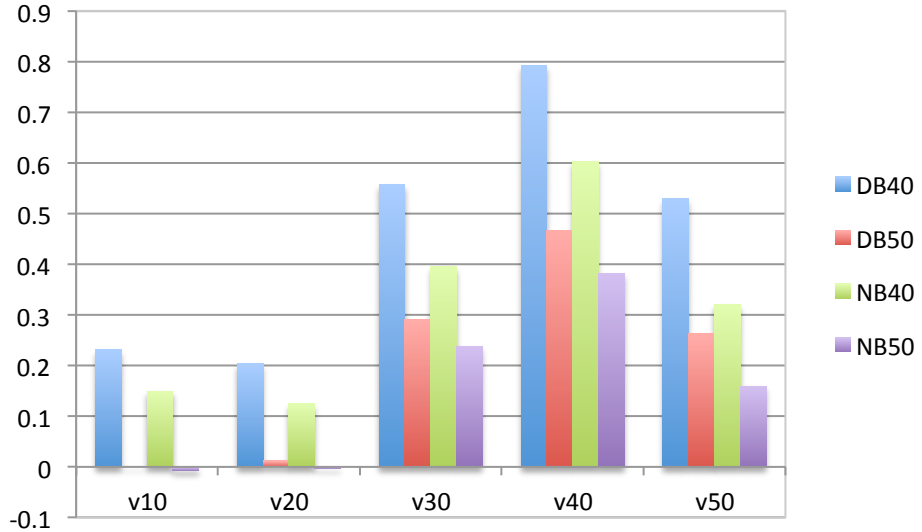
NALMA Range/DE effects

Echo volumes vs. TFR/CGs

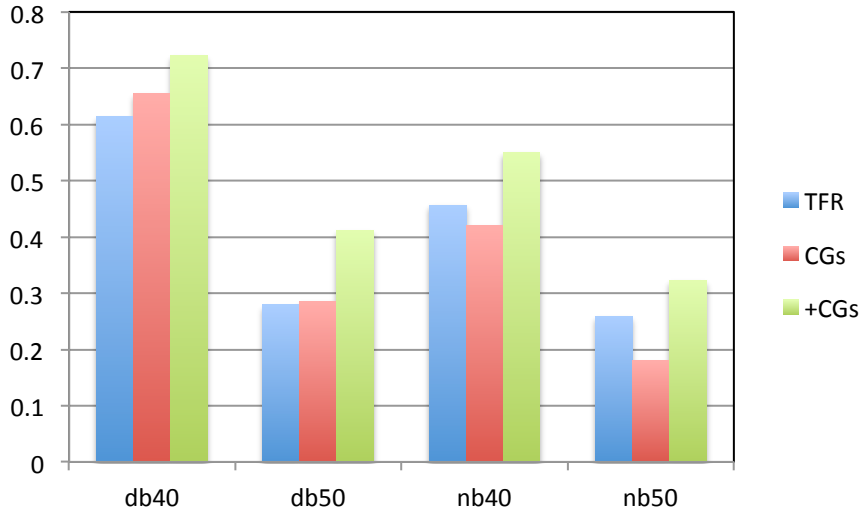


- NBE candidates best correlated to 40-dBZ echo volumes.
- DB40 category highest correlations
- Higher NBE correlations to +CGs interesting (Tessendorf et al. 2007)

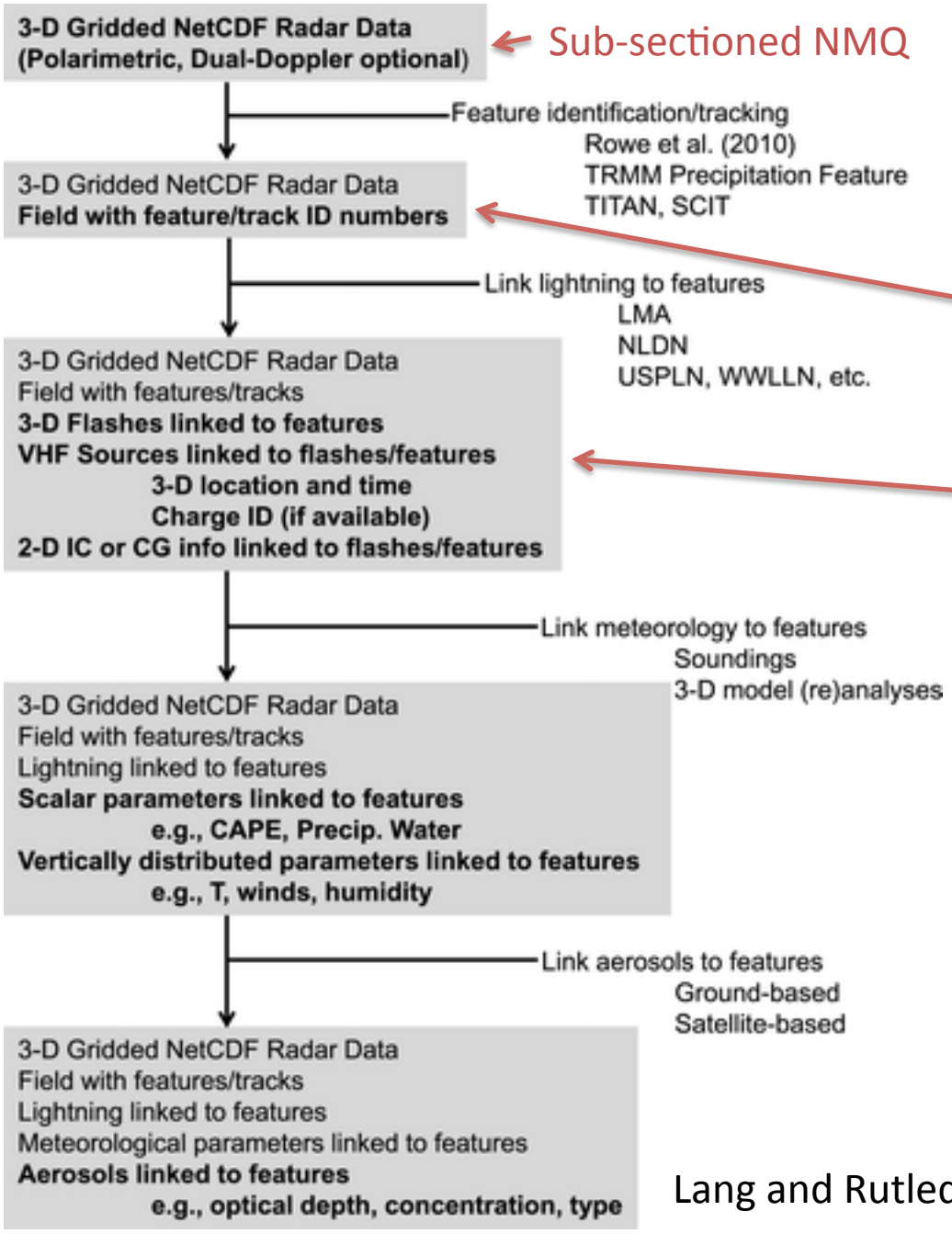
Echo volumes vs. NBE candidates



NBE candidates vs. TFR/CGs



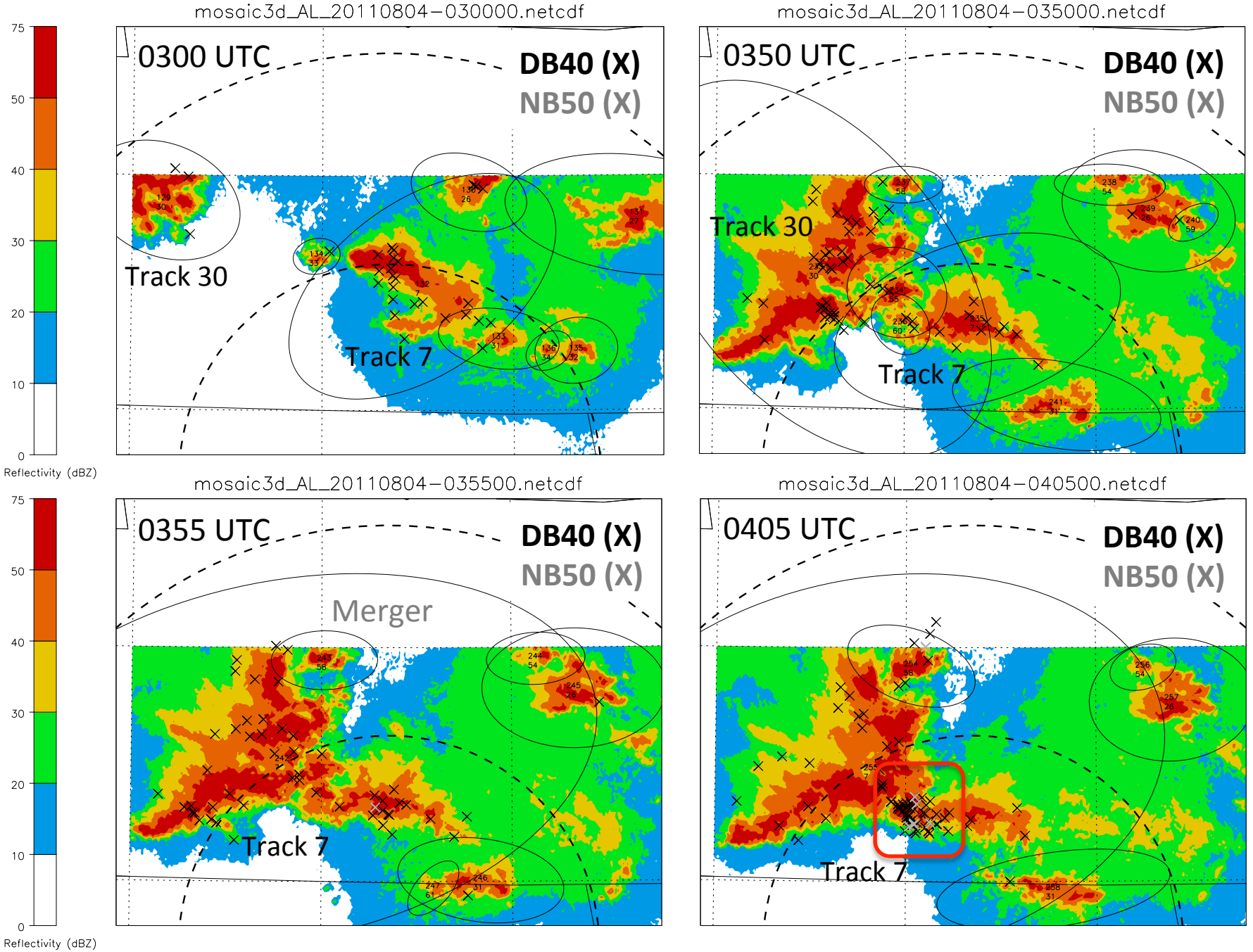
DB40/NB50 correlation = 0.52



CSU Lightning, Environment, Aerosols, and Radar (CLEAR) statistical framework

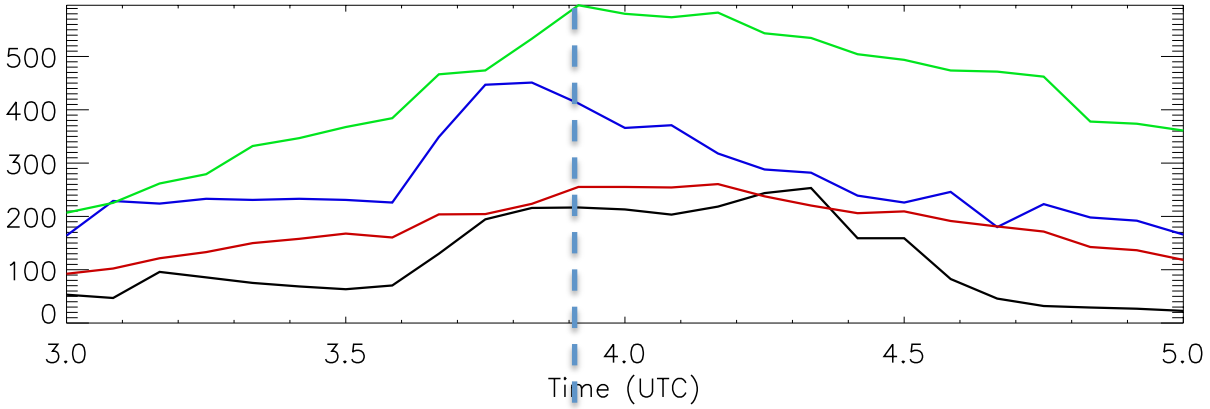
Basic idea – Identify and track features in radar data, link lightning and other observations to those features using simple temporal/spatial criteria for later statistical or case study analysis

Lang and Rutledge (2011)


mosaic3d_AL_20110804−030000.netcdf
0300 UTC
DB40 (X)
NB50 (X)
Track 30
Track 7
mosaic3d_AL_20110804−035000.netcdf
0350 UTC
DB40 (X)
NB50 (X)
Track 30
Track 7
mosaic3d_AL_20110804−035500.netcdf
0355 UTC
DB40 (X)
NB50 (X)
Merger
Track 7
mosaic3d_AL_20110804−040500.netcdf
0405 UTC
DB40 (X)
NB50 (X)
Track 7
75
50
40
30
20
10
0
Reflectivity (dBZ)

Examination of Merger

Tracks 7 & 30

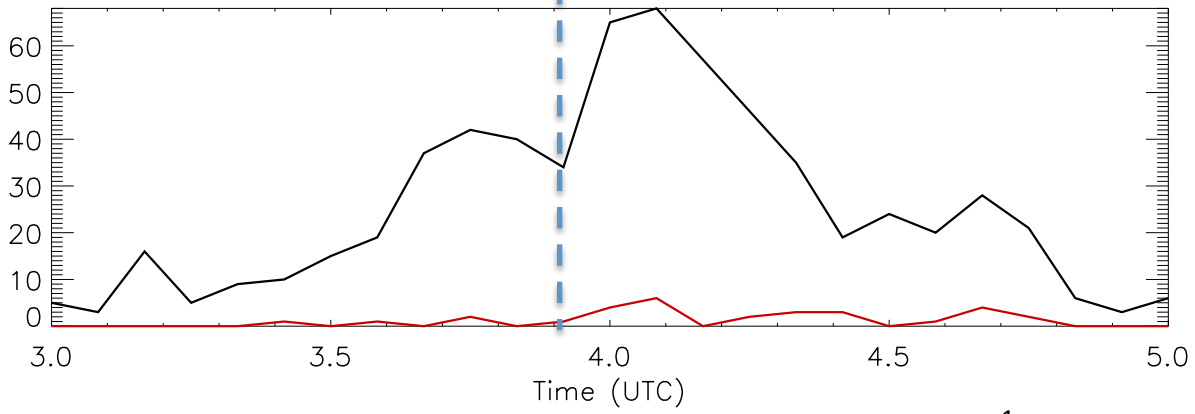


LMA total flash rate [x10 (5 min^{-1})]

NLDN CG flash rate (5 min^{-1})

NMQ Volume 30 dBZ (x100 km^3)

NMQ Volume 40 dBZ (x100 km^3)

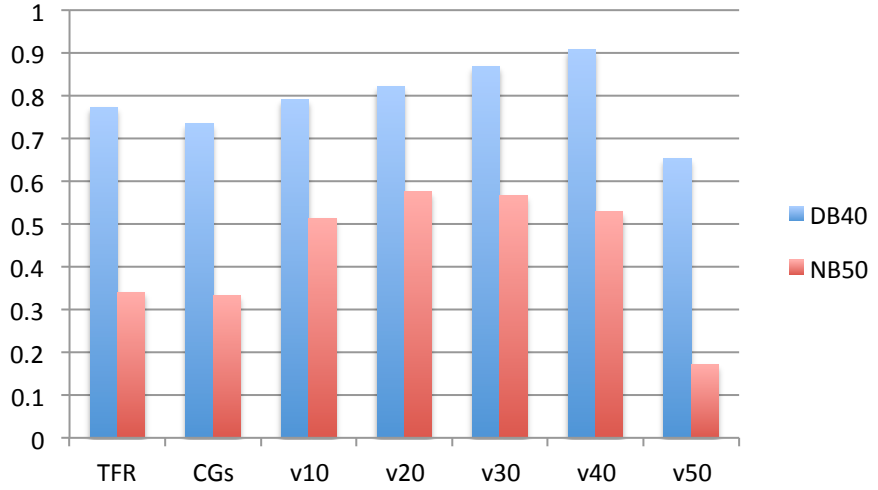


40 dBW sources (5 min^{-1})

50 dBW initial sources (5 min^{-1})

DB40 well correlated to storm metrics during two-hour analysis window

NB50 somewhat correlated to reflectivities, no statistically significant correlation with TFR, CGs



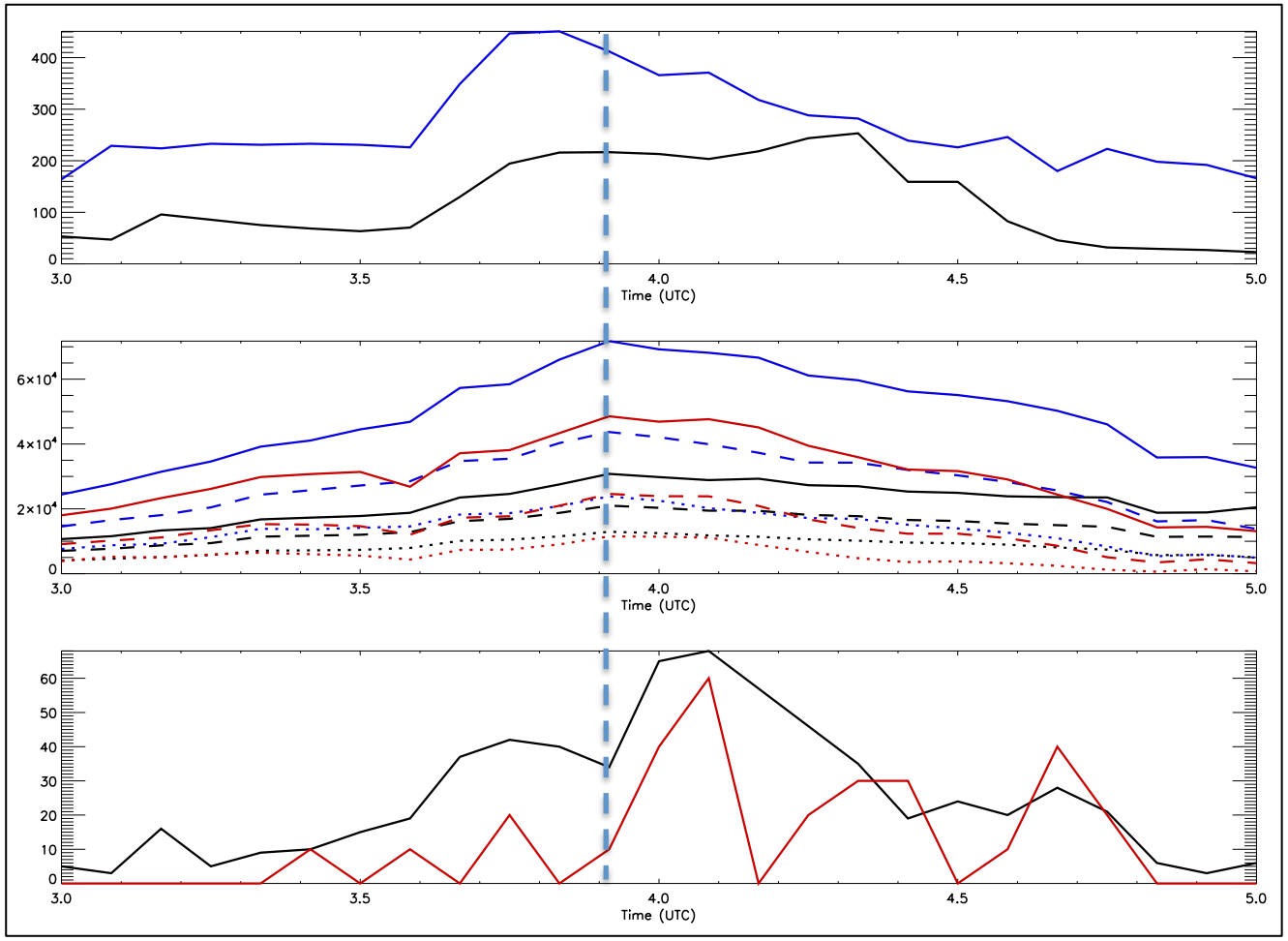
Vertical analysis

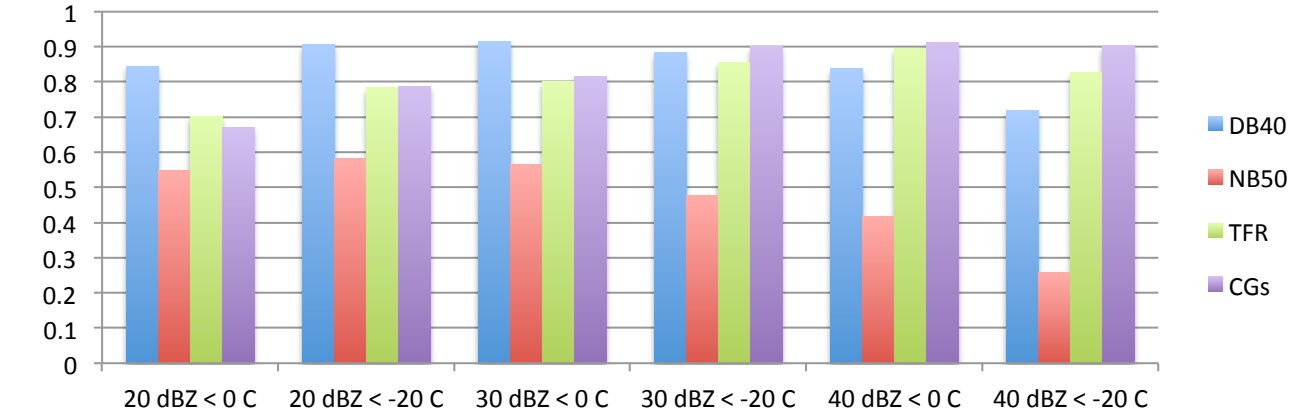
Tracks 7 & 30

LMA total flash rate [x10 (5 min^{-1})]
NLDN CG flash rate (5 min^{-1})

NMQ Volume 20 dBZ (km^3)
NMQ Volume 30 dBZ (÷2 km^3)
NMQ Volume 40 dBZ (÷4 km^3)
Solid: T < 0 C
Dash: T < -20 C
Dot: T < -40 C

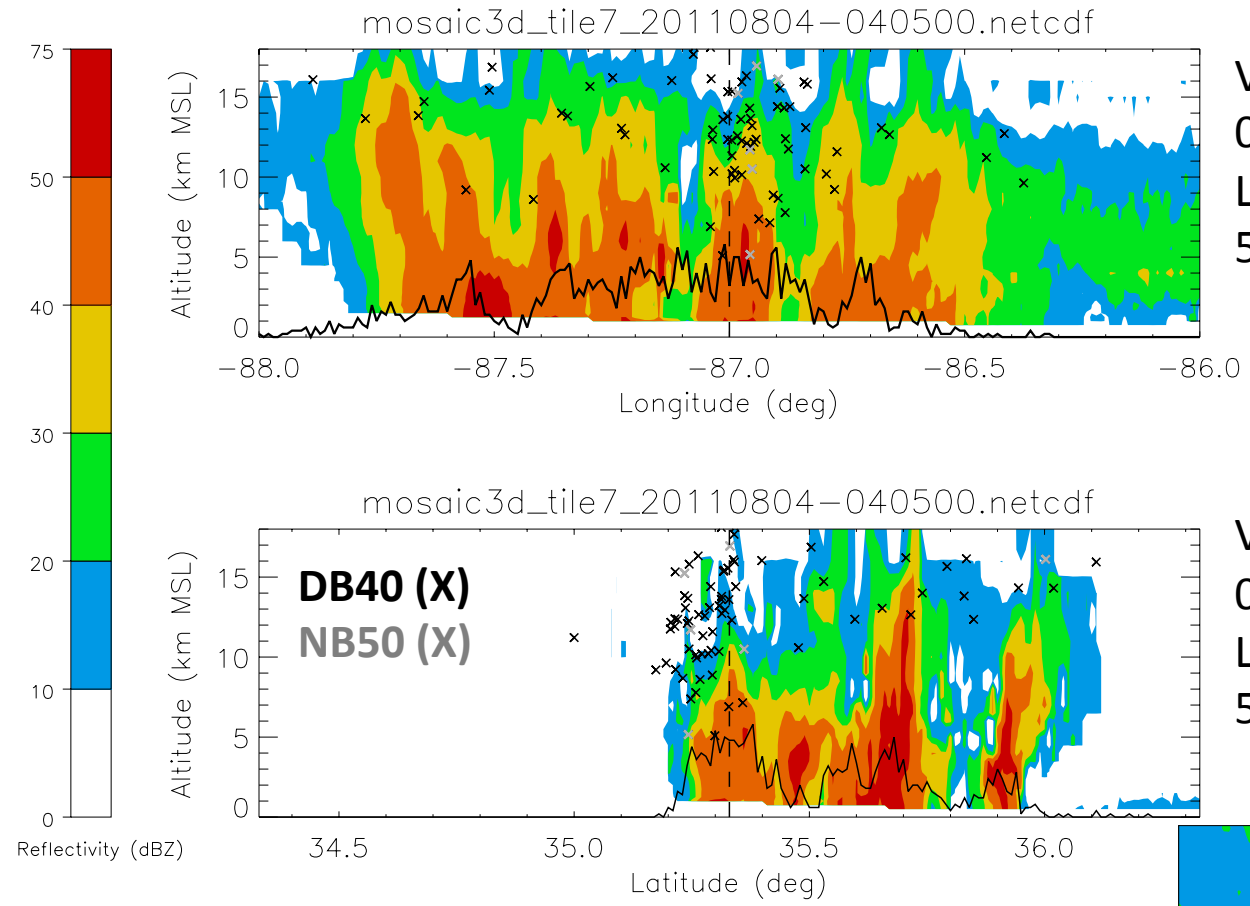
40 dBW sources (5 min^{-1})
50 dBW init. sources [÷10 (5 min^{-1})]





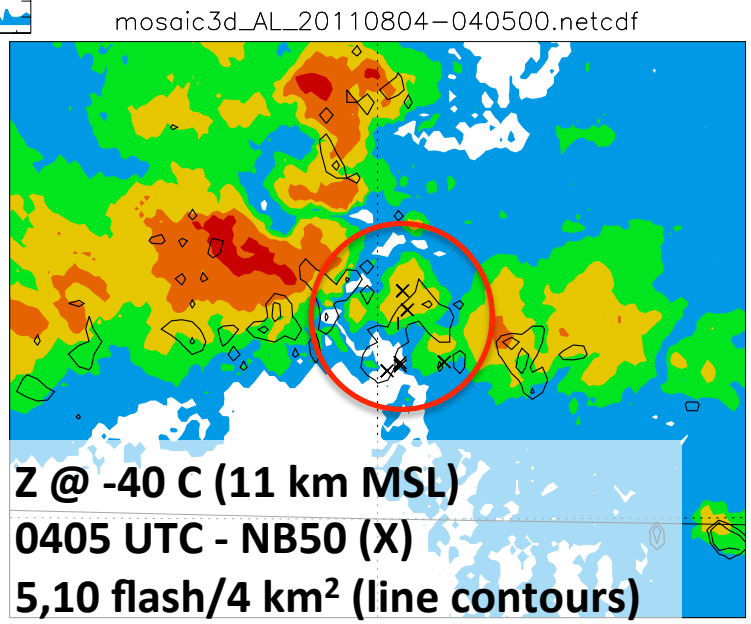
DB40, TFR, and CGs highly correlated to vertical intensity

NB50 loosely correlated at best



Vertical cross-section
0405 UTC
Latitude = 35.33 N
5-min LMA flash histogram (x5)

Vertical cross-section
0405 UTC
Longitude = 87.00 W
5-min LMA flash histogram (x5)



NBE candidate burst cell

- Ground zero for merger of larger storms
- Mid-strength reflectivity structure
- Comparable in terms of total flash production

Conclusions and Future Work

NBE candidates occurred within strong convection

- But not always the strongest!
- DB40 best correlation to storm metrics (influence of TFR?)
- NB50 worst correlation (Sampling issues?)
  - Low to no correlation with other lightning
  - Some statistically significant correlation to radar metrics
- NBE candidate burst associated with cell merger

Intense convection a necessary, but not sufficient, condition for NBE production?

- Results consistent with NBEs requiring an additional trigger
- Effect of solar proton storm on 4 August 2011?

To Do

- Further analysis of this case – additional time periods
- Examine other cases (e.g., 2nd most NBEs - 7/31/2012)
- Statistics for NBE/No-NBE storms