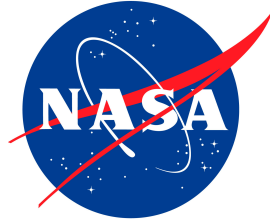


The meteorology of storms that produce narrow bipolar events

Timothy Lang
NASA MSFC



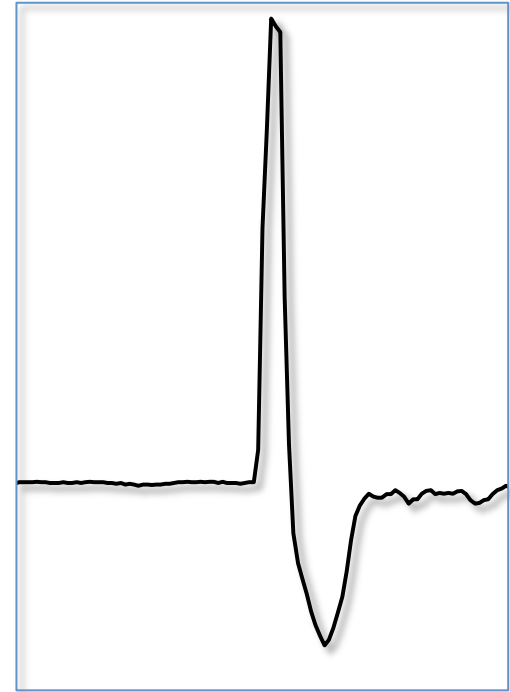
Bill McCaul
USRA



Brody Fuchs
CSU Atmos. Science



Steve Cummer
Duke EE



 **AGU FALL MEETING**
San Francisco | 9–13 December 2013



What is a narrow bipolar event (NBE)?

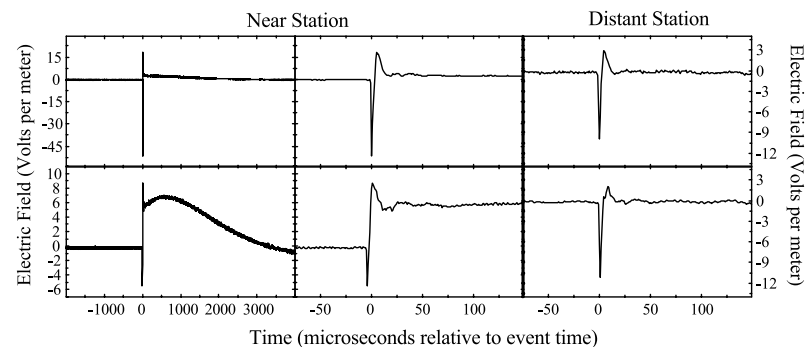
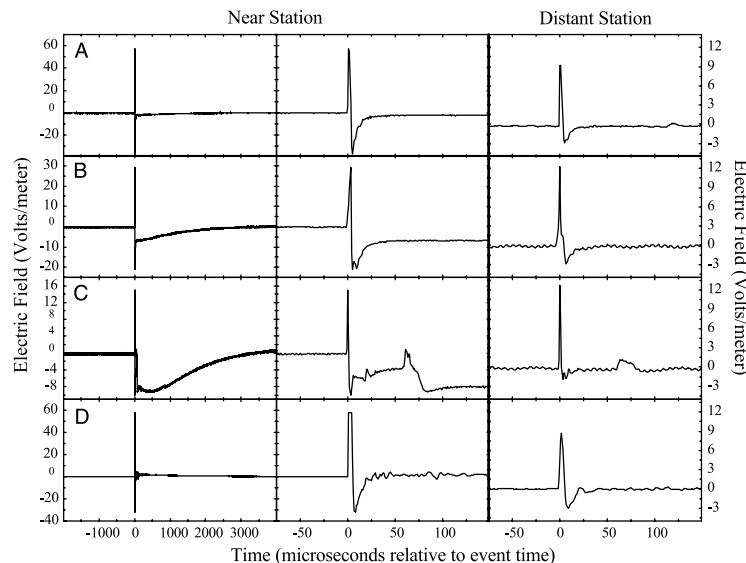
NBEs are compact (< 2 km), **powerful** (> 10 kW in VHF), and **impulsive** ($\sim 10 \mu\text{s}$) **electrical discharges in thunderstorms**, also known as compact intracloud discharges (CIDs) [e.g., Smith et al. 1999].

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?

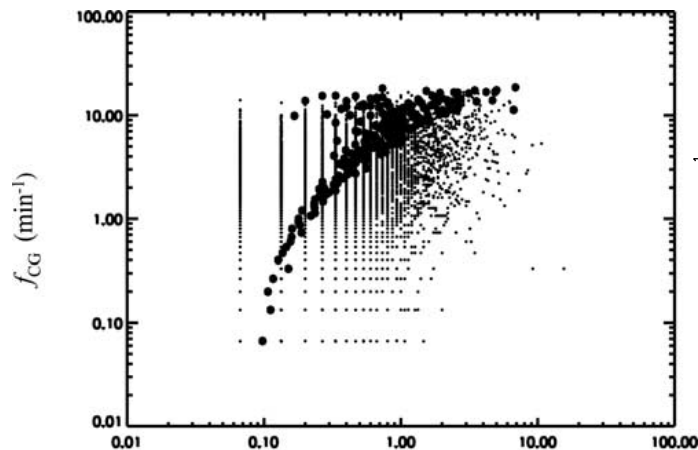
Good question! This is still open for exploration.

What we know to date

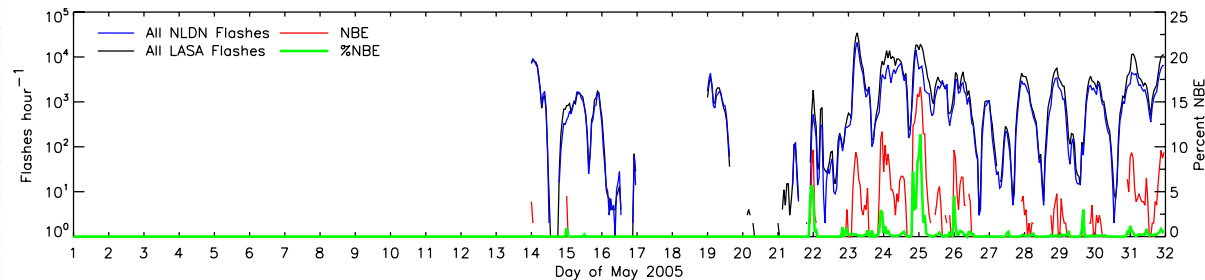
- Tend to occur near strong (~ 40 -dBZ) cores (e.g., Smith et al. 1999)
- Tend to occur at high altitudes (> 8 km; Wu et al. 2012)
- Correlated to cloud-to-ground (CG) flash rate (Suszcynsky and Heavner 2003)
- Correlated to 30-dBZ heights (Wiens et al. 2008)
- Certain individual storms can produce very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

Outstanding issues

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



$f_{NBE}, \langle f_{NBE} \rangle$ (min^{-1}) 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**”

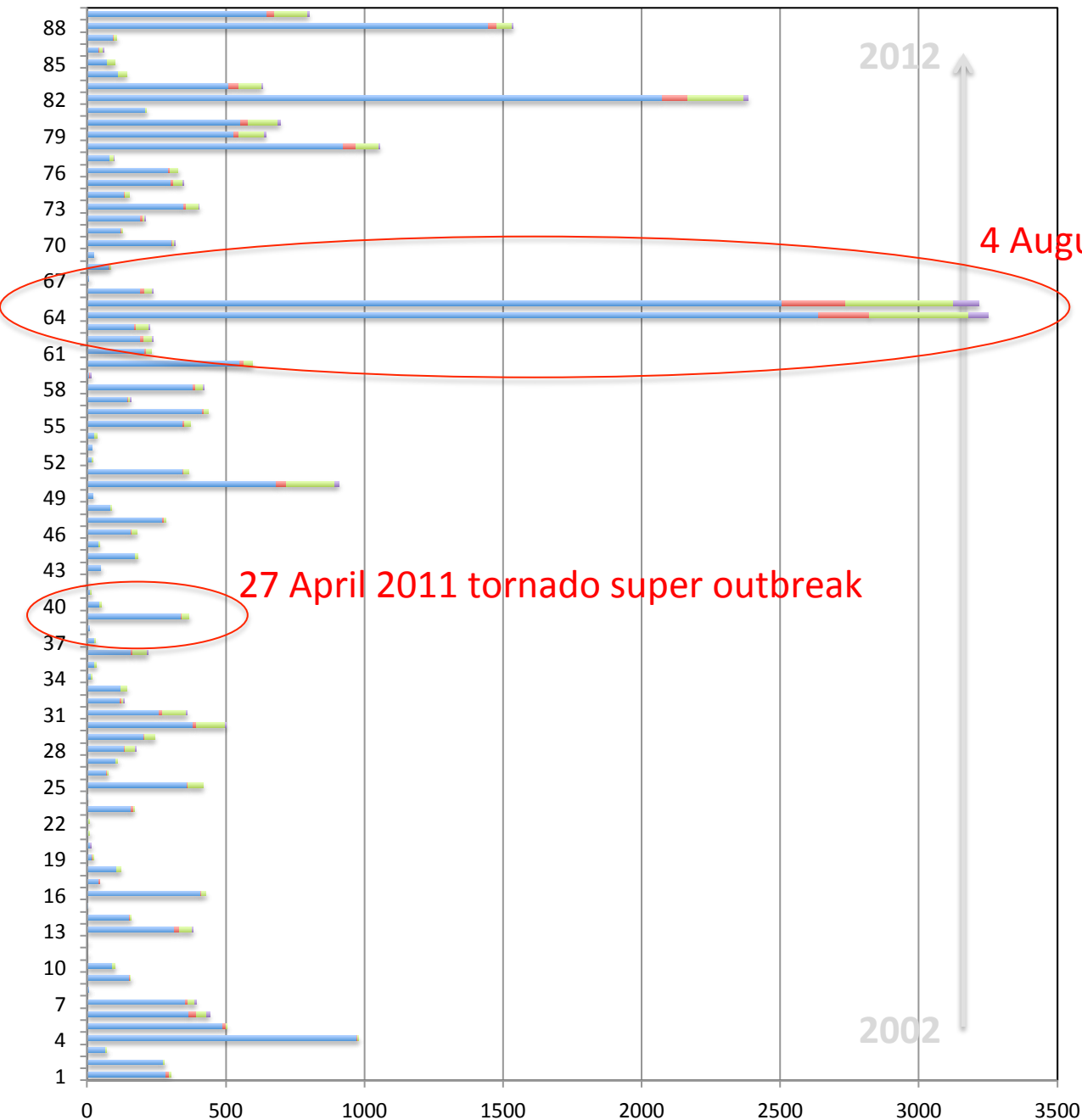
- NALMA flashes containing 40+ dBW source (**DB40**)
- Flashes containing 40+ dBW initial source (**NB40**)
- Flashes containing 50+ dBW source (**DB50**)
- Flashes containing 50+ dBW initial source (**NB50**)

↓
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)



4 August 2011

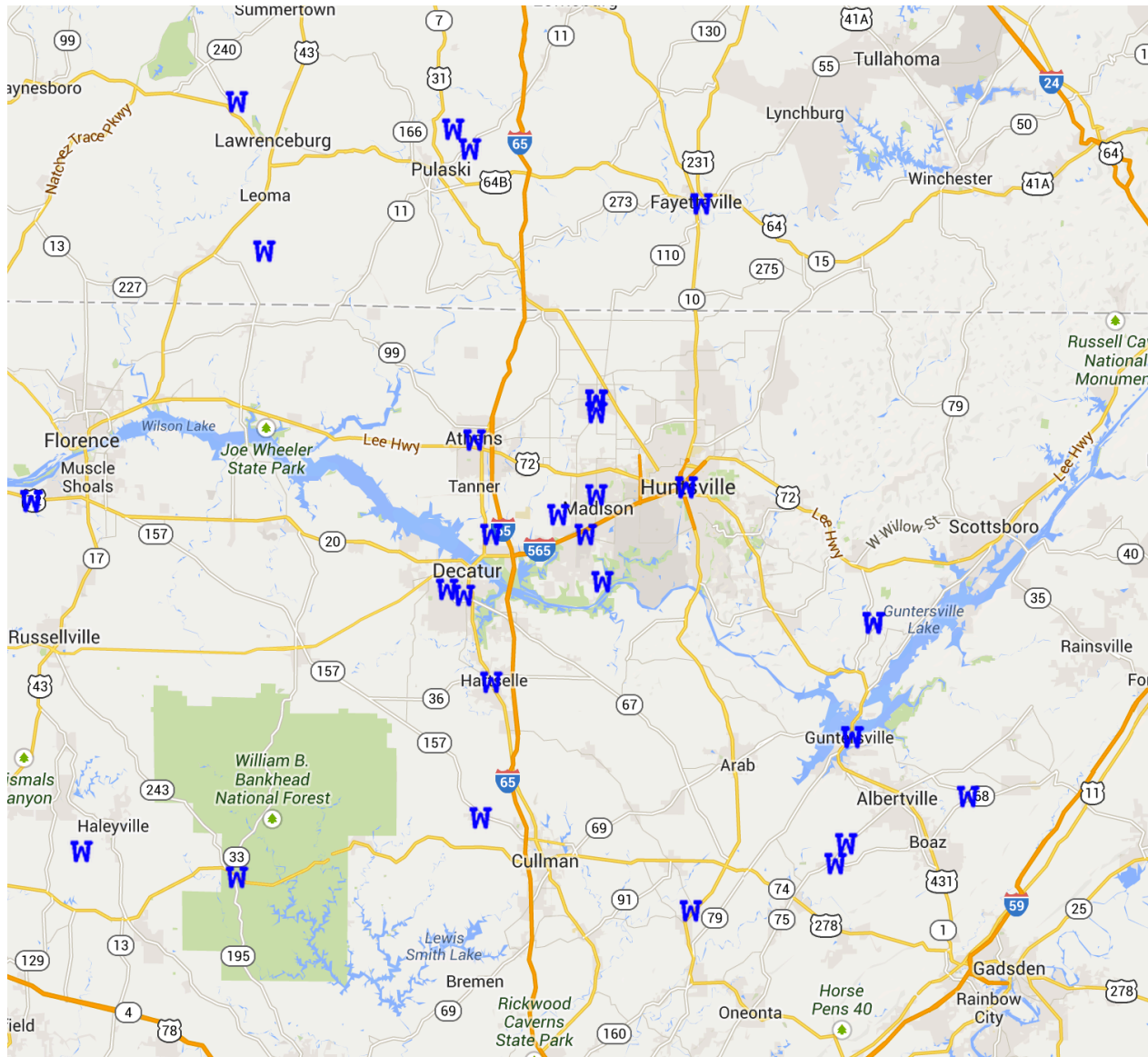
Data plotted as ~6-h cases

- DB40
- DB50
- NB40
- NB50

27 April 2011 tornado super outbreak

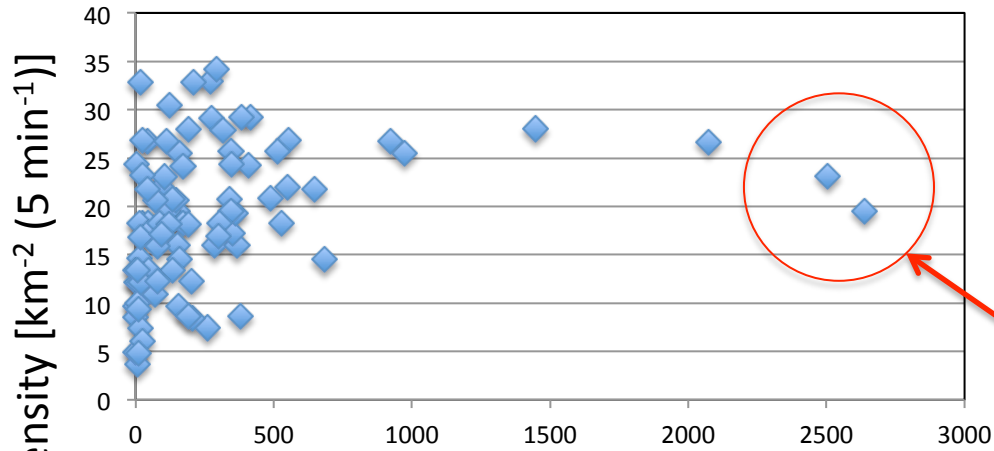
The two ~6-h periods on 4 August 2011 are by far the biggest NBE candidate producers, by any metric

4 August 2011 Svr Wx Reports (thru 12 UTC)



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

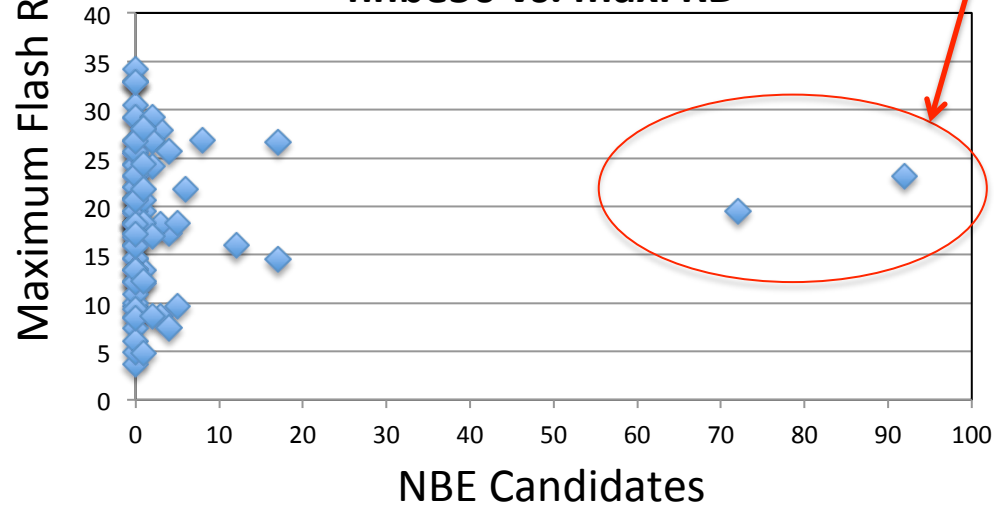
n40dbw vs. maxFRD



Flash contains 40 dBW source anywhere
(DB40)

Two ~6-h periods on 4 August 2011

nnbe50 vs. maxFRD



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

100

200

300

400

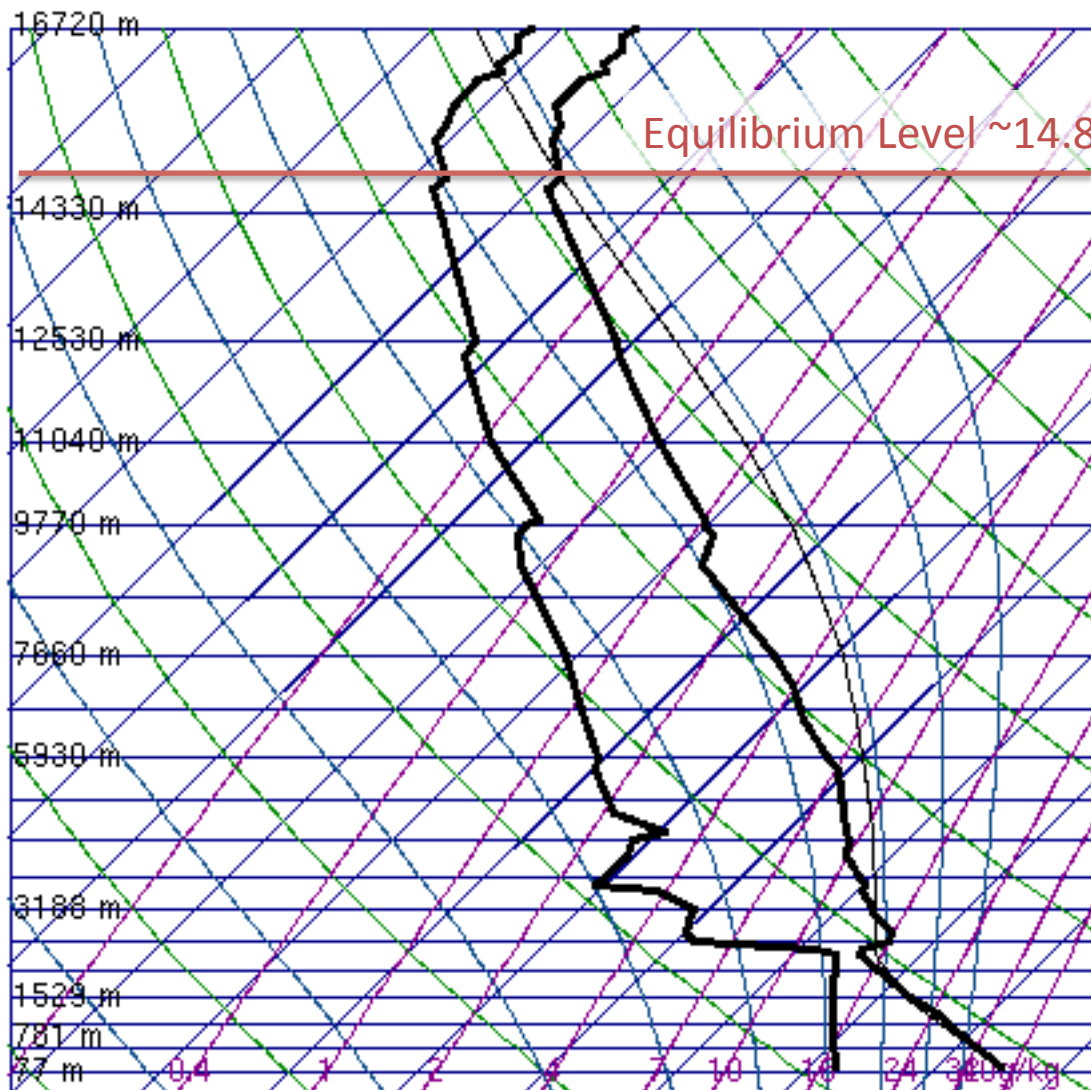
500

600

700

800

900

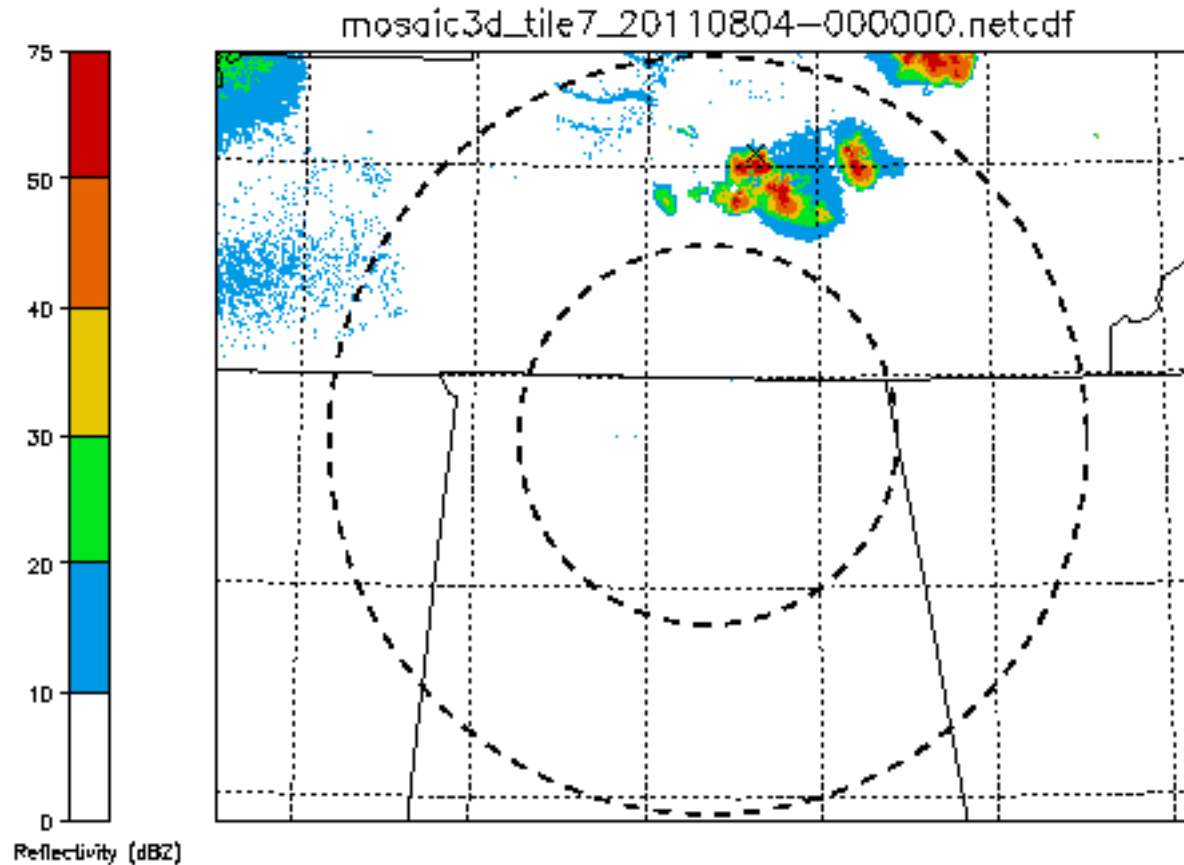


SLAT	33.16
SLON	-86.76
SELV	178.0
SHOW	-0.57
LIFT	-2.75
LFTV	-3.80
SWET	236.1
KINX	27.70
CTOT	19.10
VTOT	25.10
TOTL	44.20
CAPE	2047.
CAPV	2313.
CINS	-25.2
CINV	-9.14
EQLV	138.4
EQTV	138.4
LFCT	793.7
LFCV	804.6
BRCH	88.01
BRCV	99.45
LCLT	291.4
LCLP	811.8
MLTH	309.3
MLMR	16.58
THCK	5853.
PWAT	45.08

00Z 04 Aug 2011

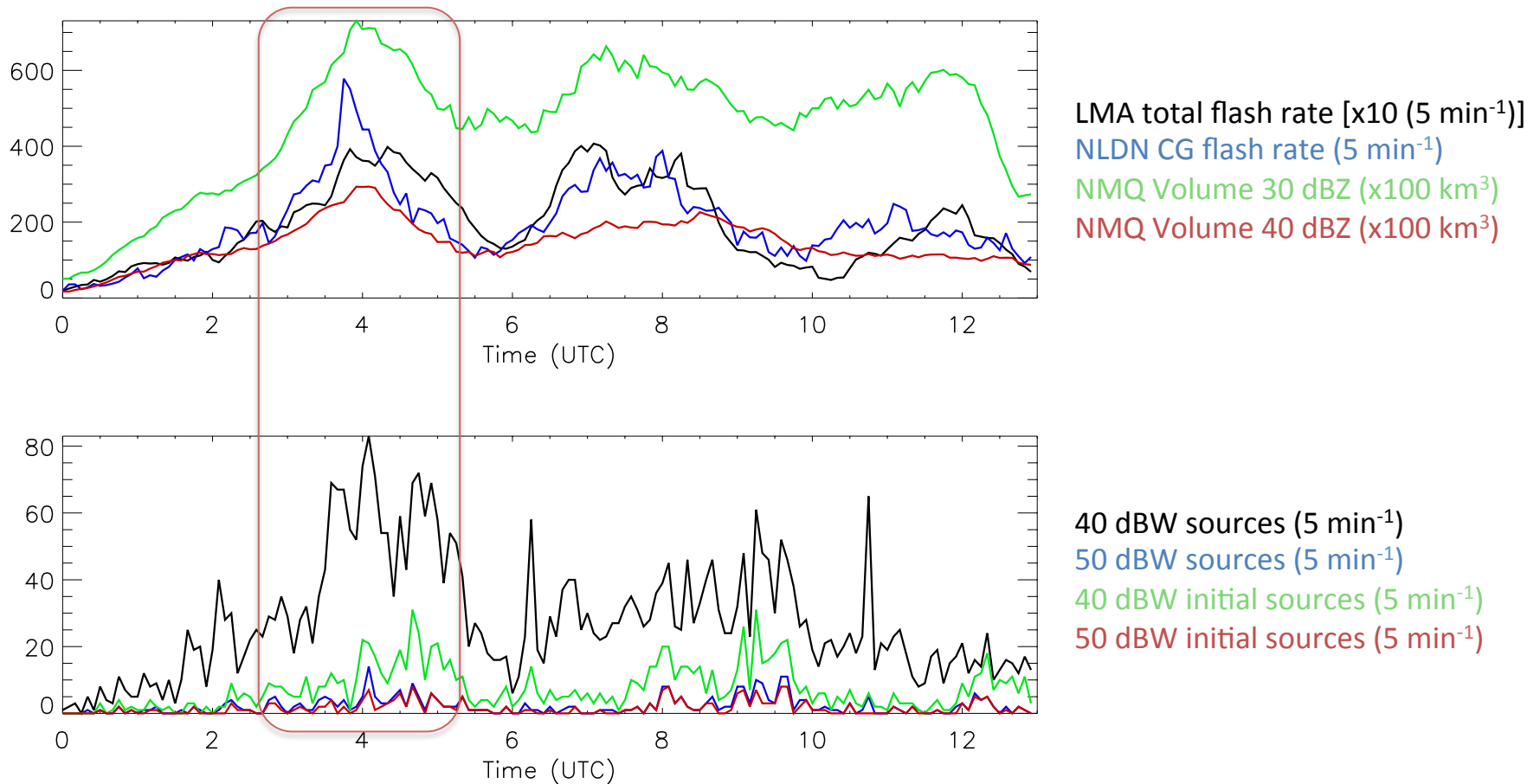
University of Wyoming

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

Cell Merger (examined later)

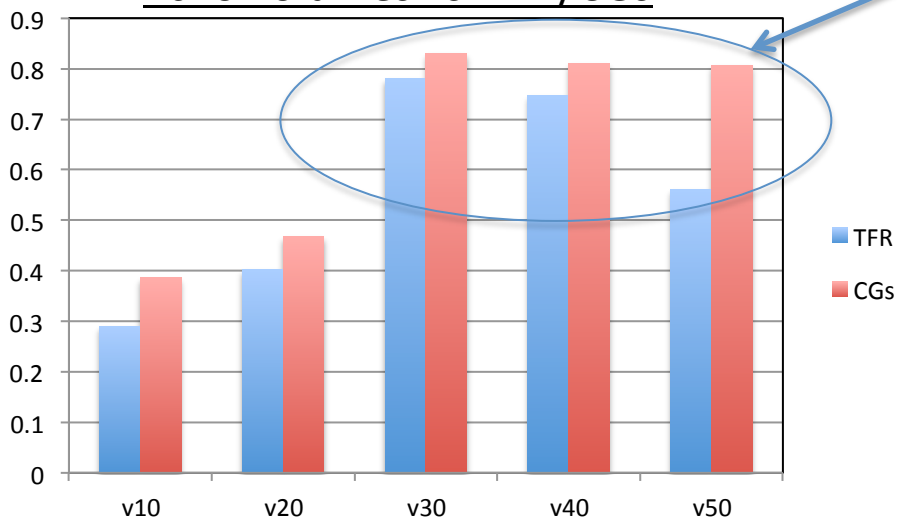


Bulk Regional Time Series

- 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

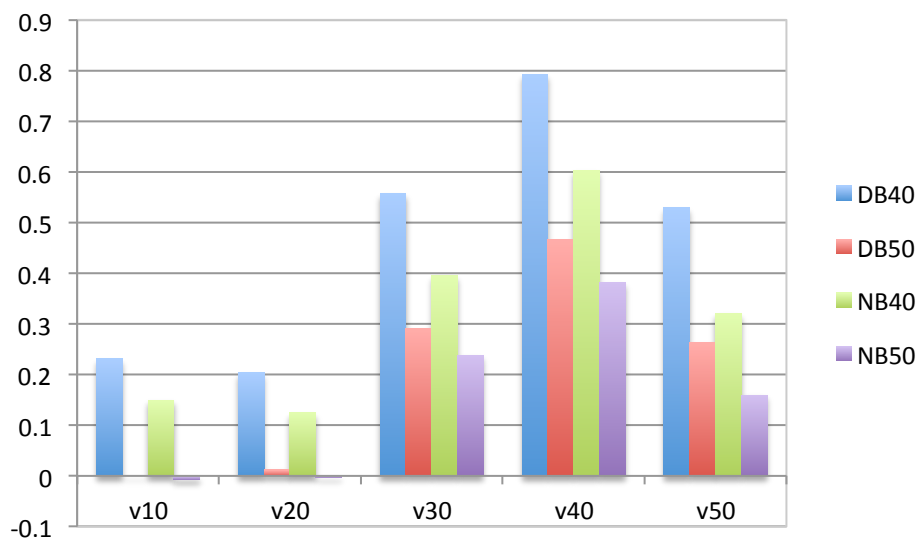
Bulk Spearman's Rank Correlations

Echo volumes vs. TFR/CGs

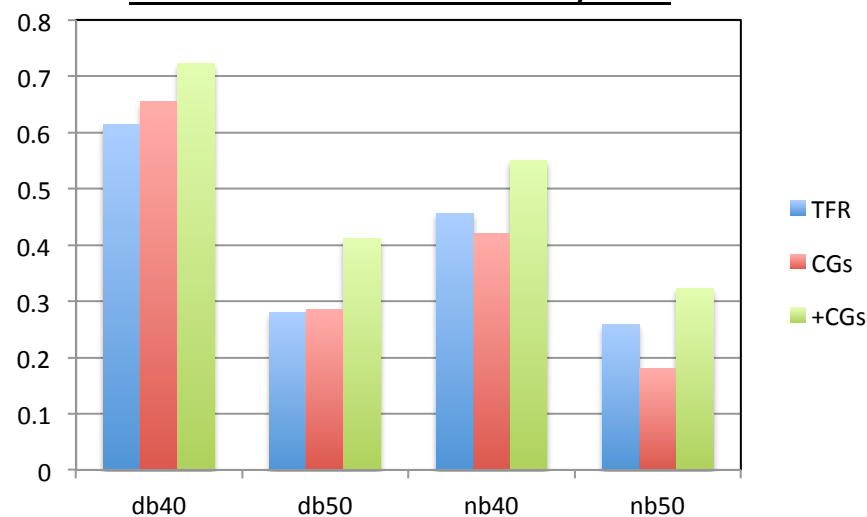


- NBE candidates best correlated to 40-dBZ echo volumes.
- DB40 category highest correlations
- Higher NBE correlations to +CGs interesting (Tessendorf et al. 2007)

Echo volumes vs. NBE candidates



NBE candidates vs. TFR/CGs



DB40/NB50 correlation = 0.52

3-D Gridded NetCDF Radar Data
(Polarimetric, Dual-Doppler optional)

← Sub-sectioned NMQ

Feature identification/tracking
Rowe et al. (2010)
TRMM Precipitation Feature
TITAN, SCIT

3-D Gridded NetCDF Radar Data
Field with feature/track ID numbers

Link lightning to features
LMA
NLDN
USPLN, WWLLN, etc.

3-D Gridded NetCDF Radar Data
Field with features/tracks
3-D Flashes linked to features
VHF Sources linked to flashes/features
3-D location and time
Charge ID (if available)
2-D IC or CG info linked to flashes/features

Link meteorology to features
Soundings
3-D model (re)analyses

3-D Gridded NetCDF Radar Data
Field with features/tracks
Lightning linked to features
Scalar parameters linked to features
e.g., CAPE, Precip. Water
Vertically distributed parameters linked to features
e.g., T, winds, humidity

Link aerosols to features
Ground-based
Satellite-based

3-D Gridded NetCDF Radar Data
Field with features/tracks
Lightning linked to features
Meteorological parameters linked to features
Aerosols linked to features
e.g., optical depth, concentration, type

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

Fuchs et al. (2013) tracking
Twin thresholds - 30 & 40 dBZ
2-D median filter (4-km)

NALMA flashes/sources
NLDN Flashes
NBE Candidates

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)

Examination of Merger

Tracks 7 & 30

LMA total flash rate [$\times 10$ (5 min^{-1})]

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

NMQ Volume 30 dBZ ($\times 100 \text{ km}^3$)

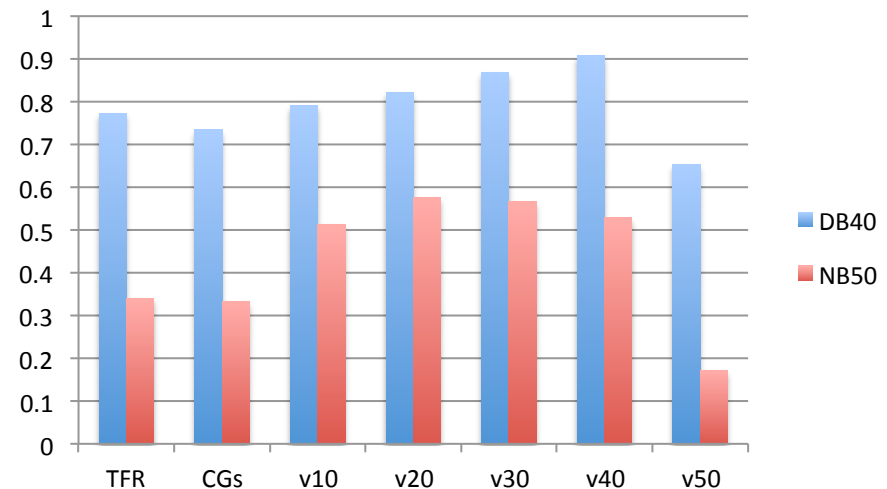
NMQ Volume 40 dBZ ($\times 100 \text{ km}^3$)

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 [$\times 10$ (5 min^{-1})]

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

NMQ Volume 20 dBZ (km^3)

NMQ Volume 30 dBZ ($\div 2 \text{ km}^3$)

NMQ Volume 40 dBZ ($\div 4 \text{ km}^3$)

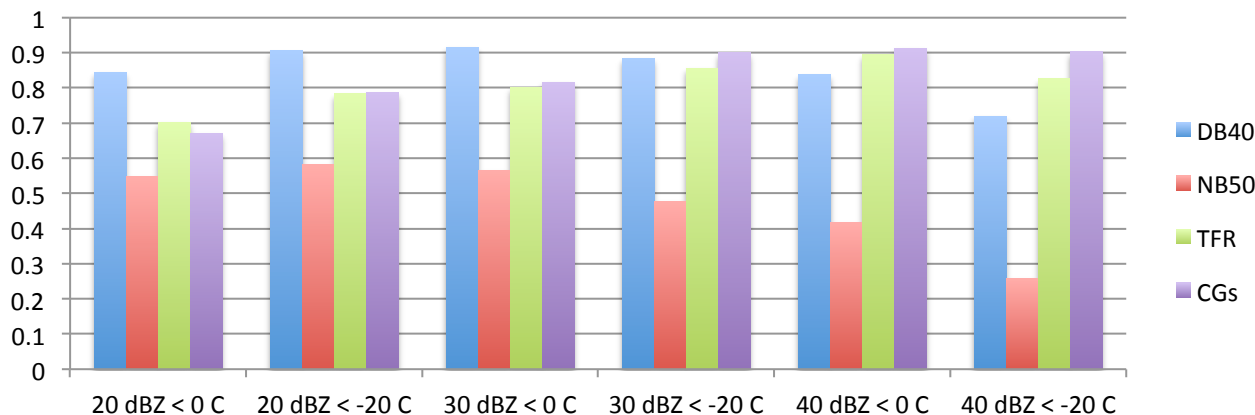
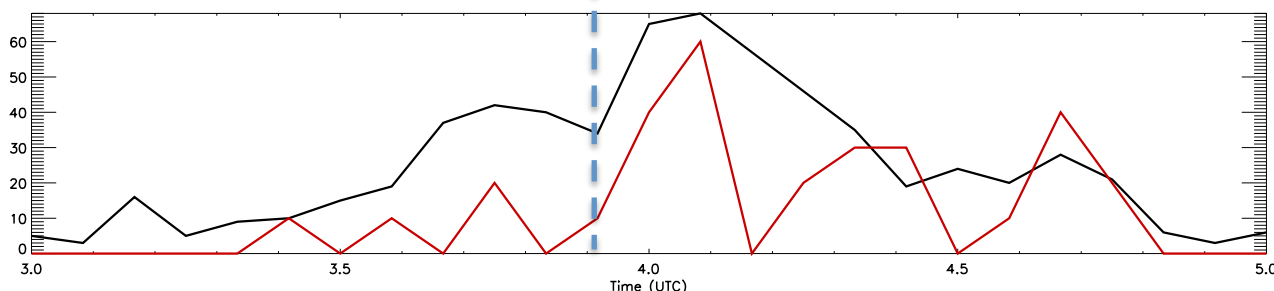
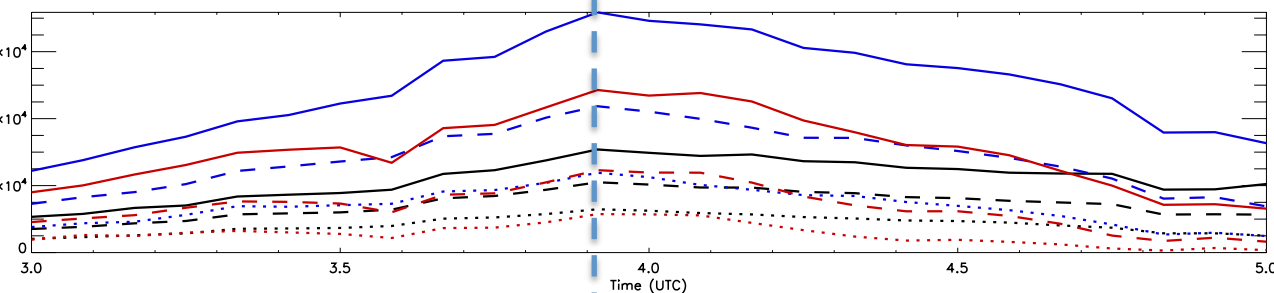
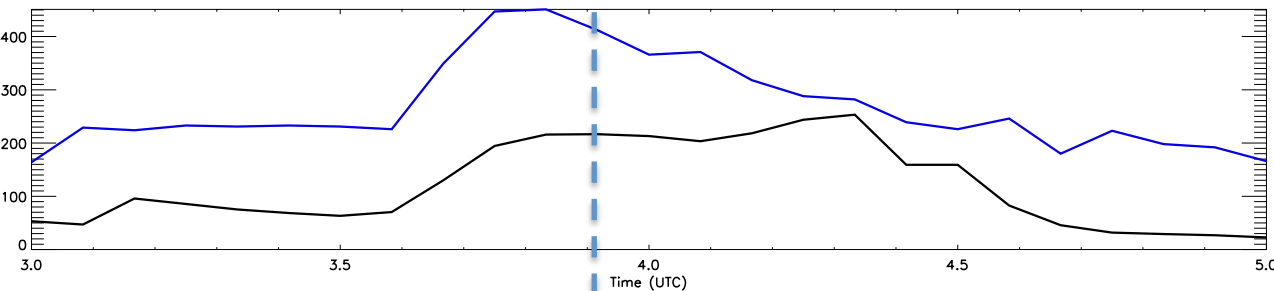
Solid: $T < 0 \text{ C}$

Dash: $T < -20 \text{ C}$

Dot: $T < -40 \text{ C}$

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

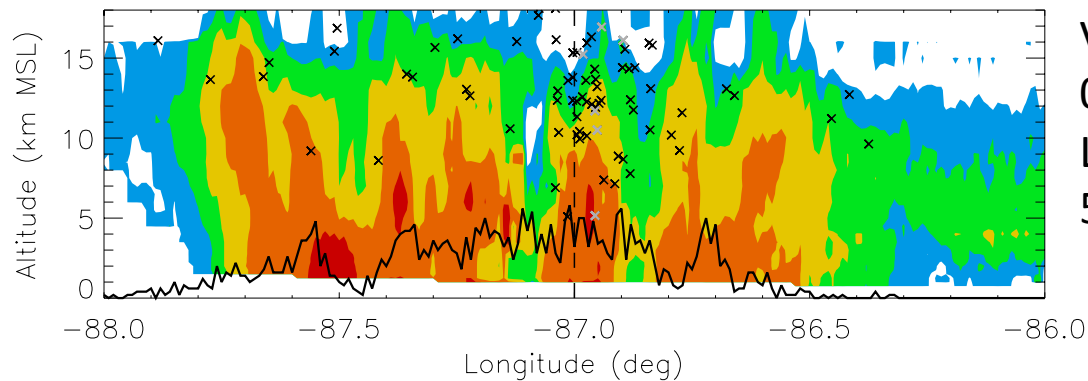
50 dBW init. sources [$\div 10$ (5 min^{-1})]



DB40, TFR, and CGs
highly correlated to
vertical intensity

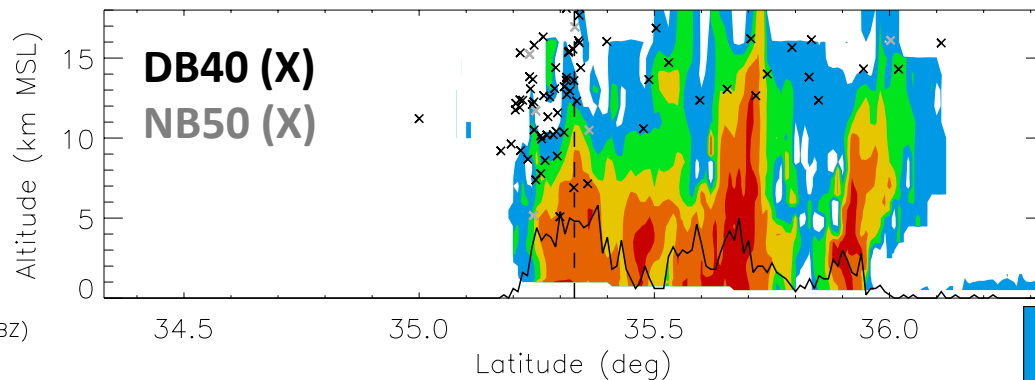
NB50 loosely
correlated at best

mosaic3d_tile7_20110804-040500.netcdf



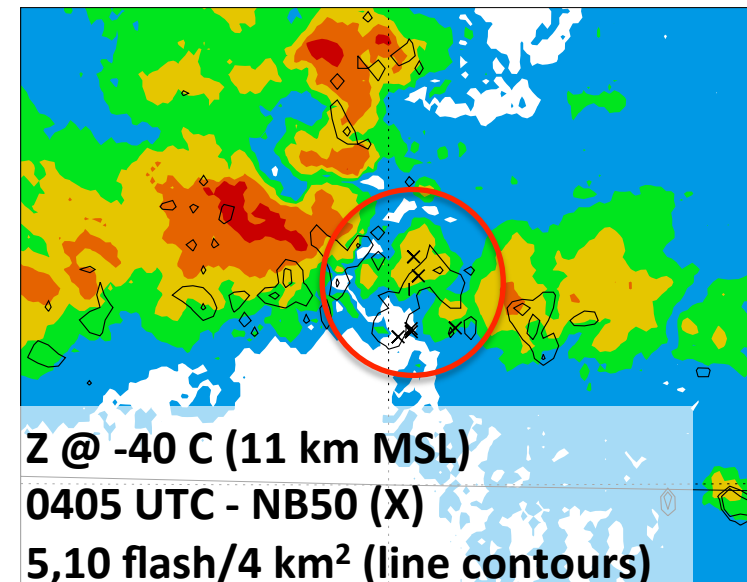
Vertical cross-section
0405 UTC
Latitude = 35.33 N
5-min LMA flash histogram (x5)

mosaic3d_tile7_20110804-040500.netcdf



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

mosaic3d_AL_20110804-040500.netcdf



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