Investigation of the Electrification of Pyrocumulus Clouds

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Outline of Talk

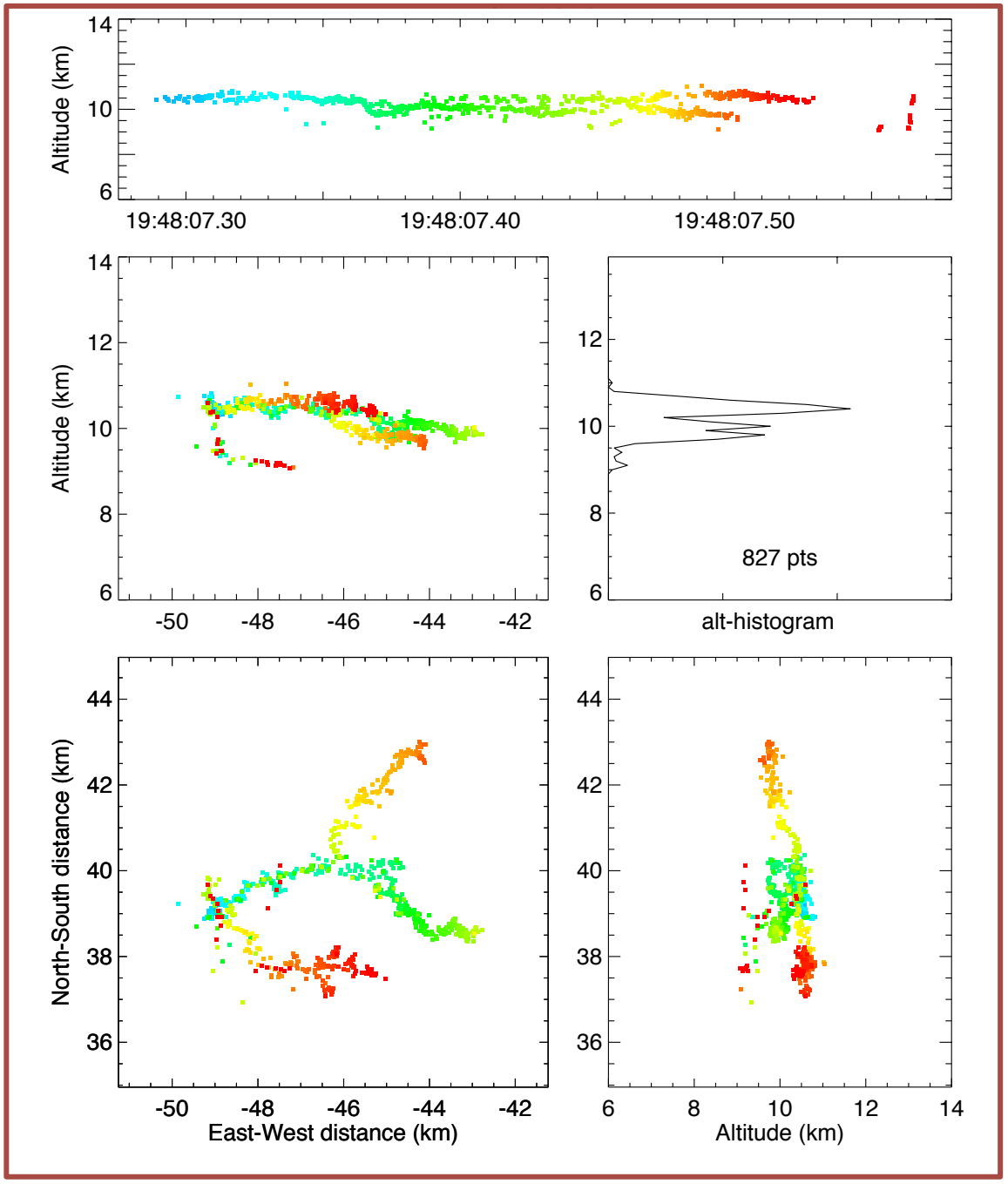
1. Background and Motivation
2. 2013 Pyrocumulus Lightning Cases
3. Geostationary Lightning Mapper (GLM) Proxy Data
4. Summary and Conclusions

Background

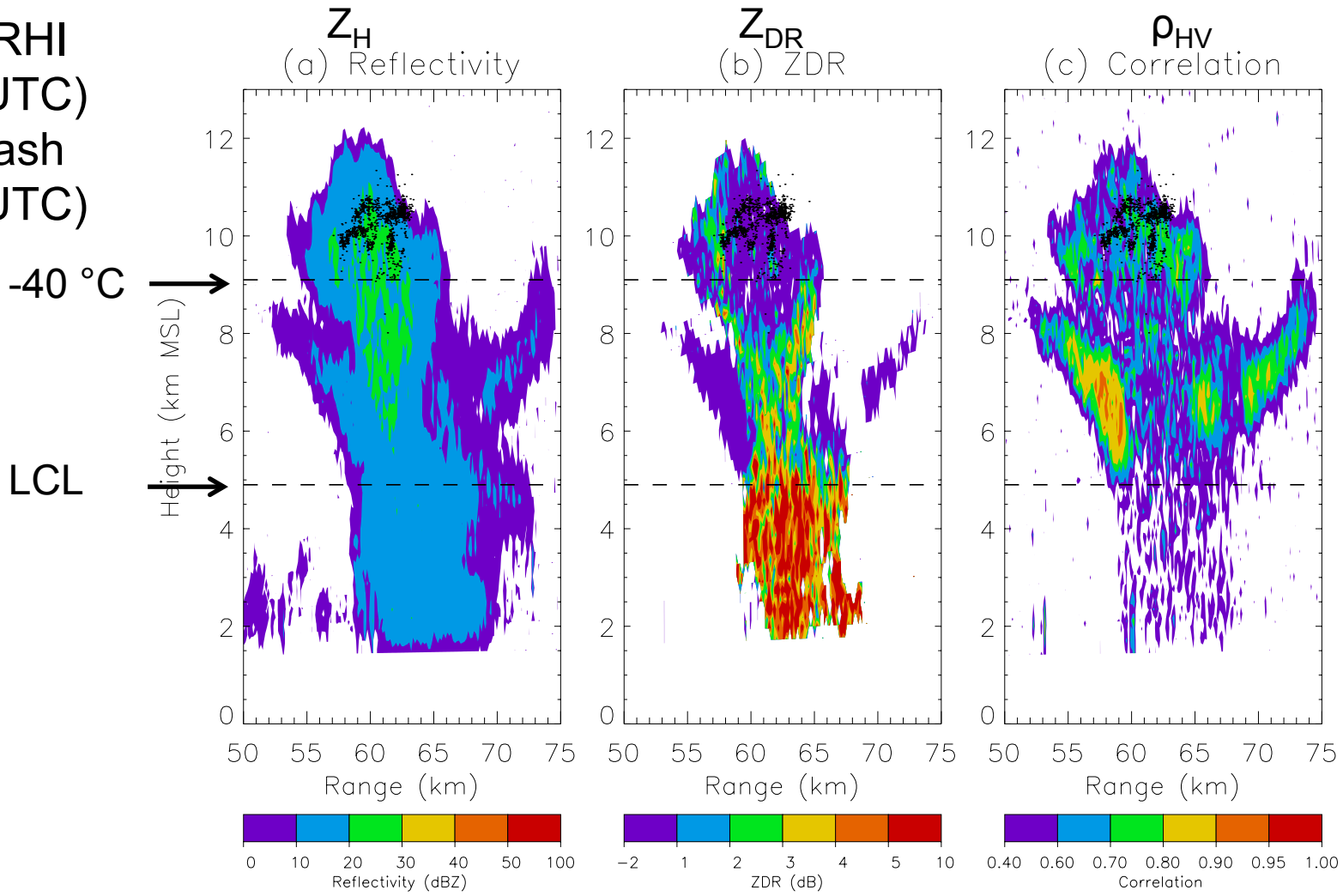
Typical Pyrocumulus Lightning Flash
(Lang et al. 2014)

Hewlett Fire flash detected by Colorado Lightning Mapping Array (COLMA)

- Intracloud (not CG)
- High-altitude (~10 km MSL)
- Shallow (~2 km deep)
- Duration << 1 s
- Small! *L* ~ 5-7 km
- Positive charge overlaying negative (“normal” polarity)
- Numerous precursor VHF sources starting ~30 s prior to flash

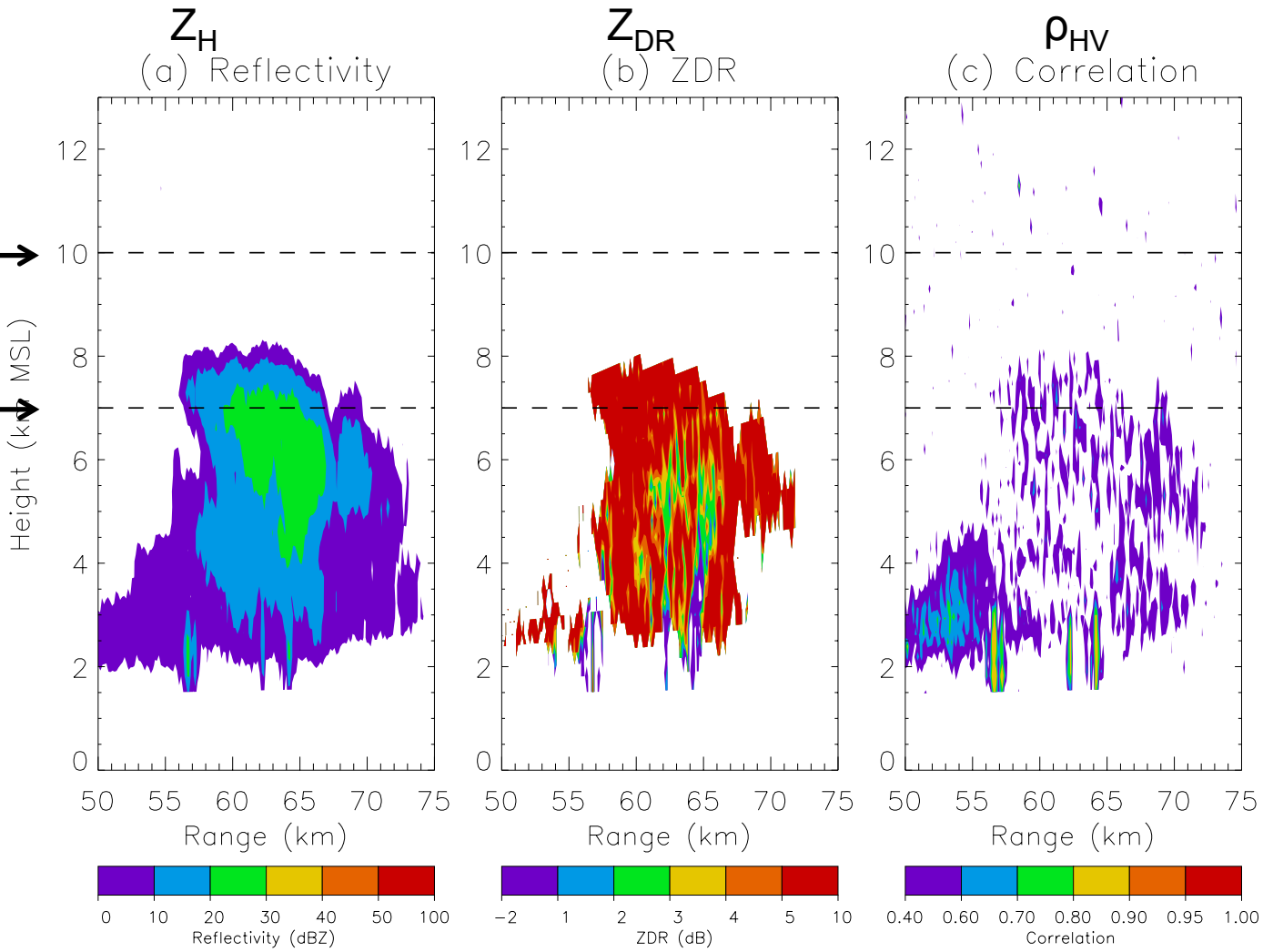


CHILL RHI
(1949 UTC)
LMA Flash
(1948 UTC)



- Below LCL – High Z_{DR}/low ρ_{HV} indicating mostly smoke
- Above LCL – increasing ρ_{HV} and decreasing Z_{DR} – condensation/freezing?
- Mid-level cloud bookending plume – Low Z_{DR}/high ρ_{HV} relatively clean
- Near and above -40 °C altitude – ZDR -1 to +1 dB, ρ_{HV} ~0.6 or more
- Lightning occurred in this inferred ice/ash mixture

Null Case
High Park Fire
22 June 2012
CHILL RHI
(1956 UTC)



- What about non-lightning-producing plumes?
- Many examples during DC3!
- Only smoke signature evident in polarimetric data
- No growth above -40 °C

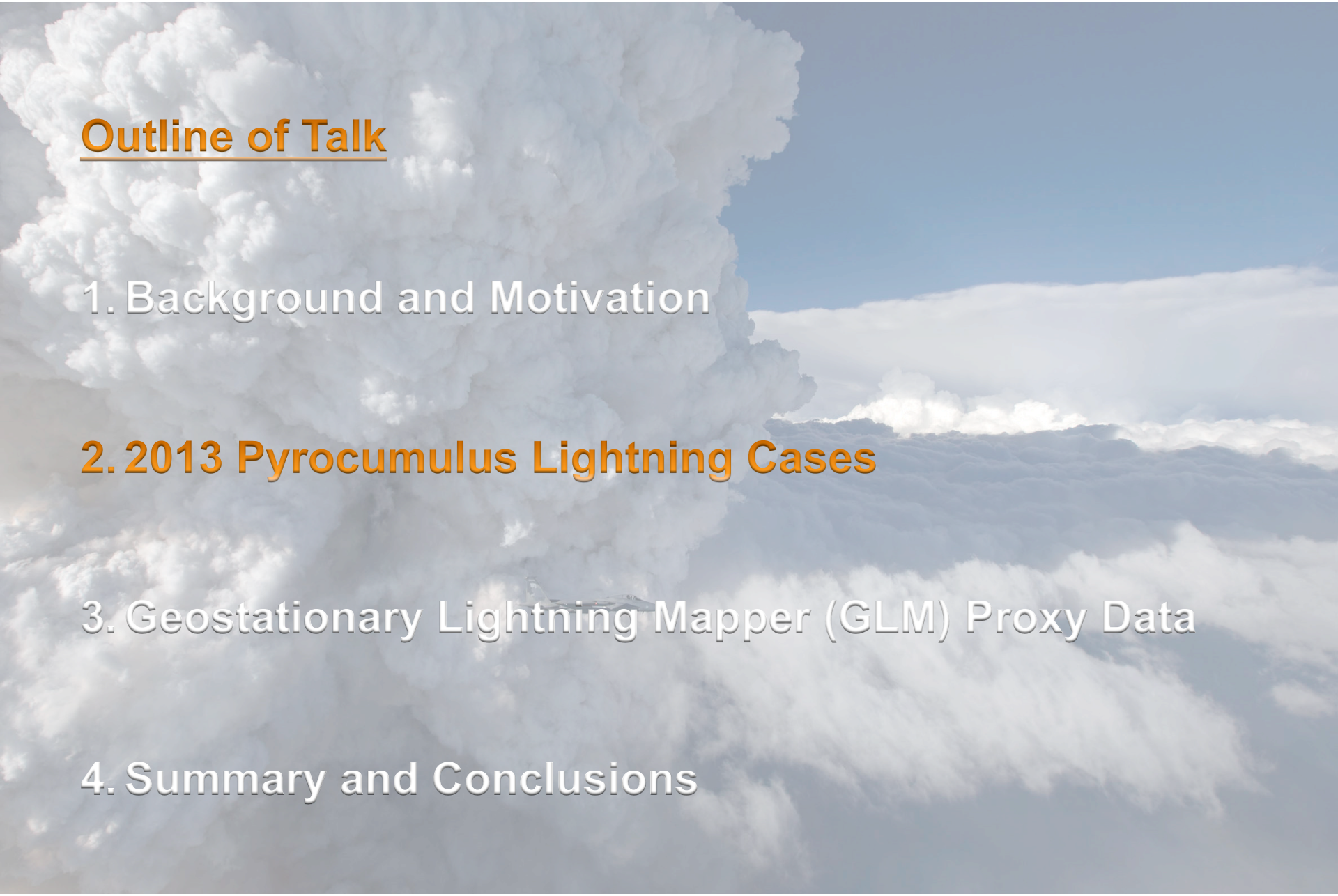
Motivation

- The lightning and microphysical structures observed in Colorado during 2012 are very unusual for thunderstorms. Are these observations seen in PyroCu elsewhere?

- The NEXRAD radar network was recently upgraded to dual-pol. Can we document the internal microphysical structures of PyroCu elsewhere?

- The 2012 PyroCu produced no NLDN-detected flashes. The NLDN was upgraded after 2012; can it now observe at least some PyroCu lightning?

- GOES-R will be launched soon and will feature the Geostationary Lightning Mapper (GLM) instrument. Can we expect GLM to provide useful information about PyroCu lightning?



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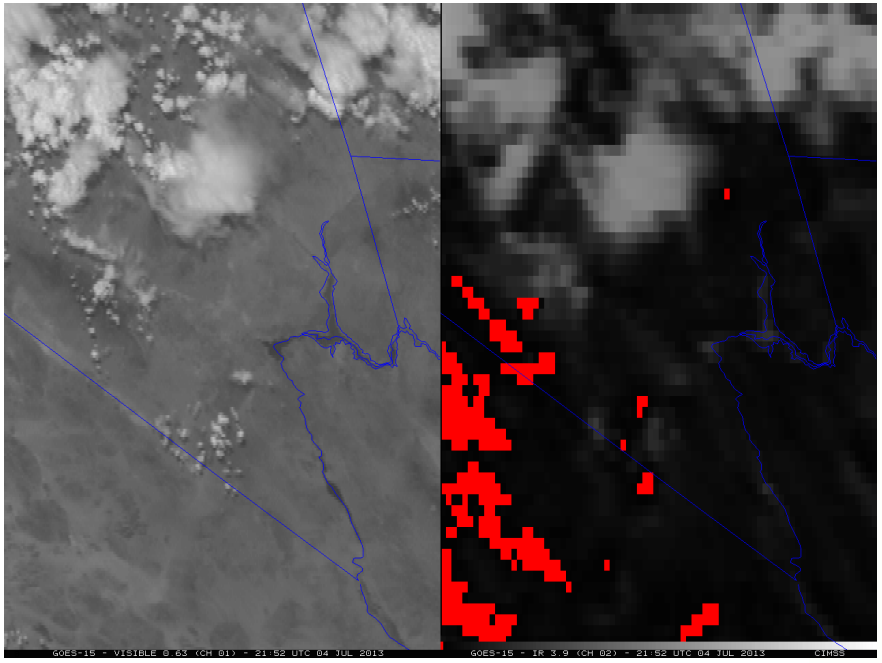
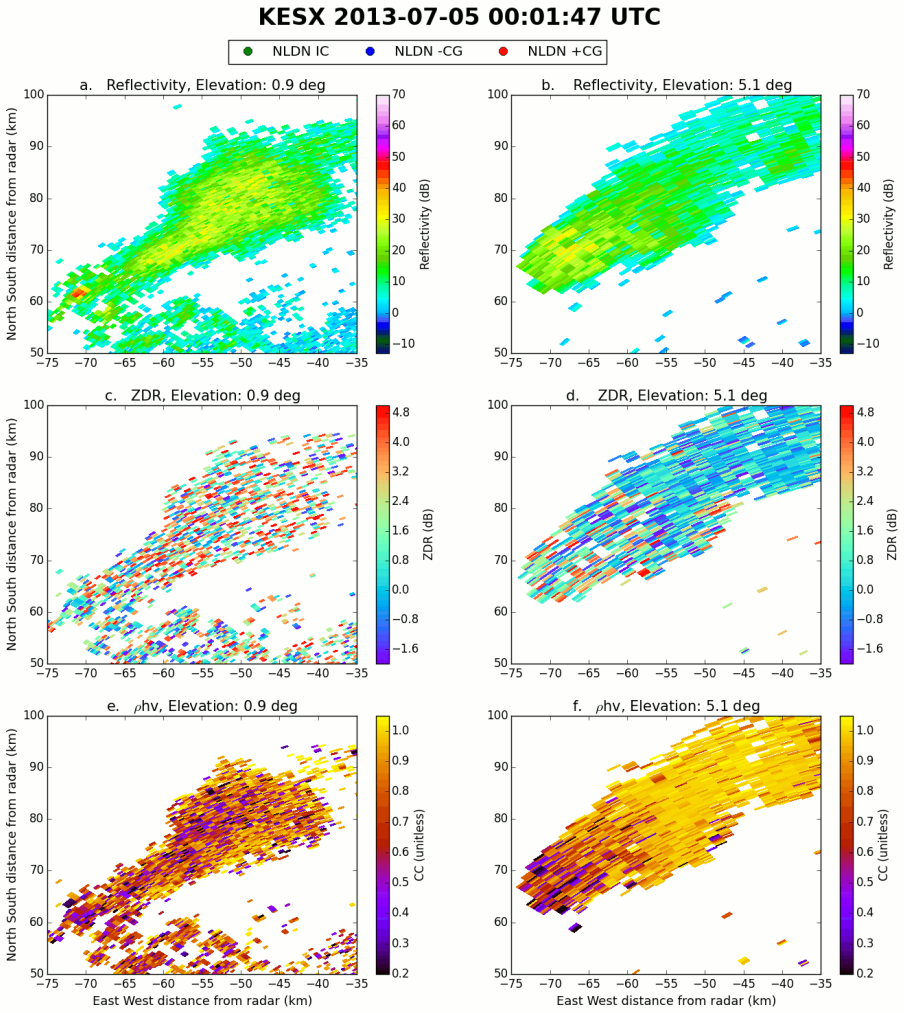
2013 Cases

10 Total - 7 Lightning, 3 Null

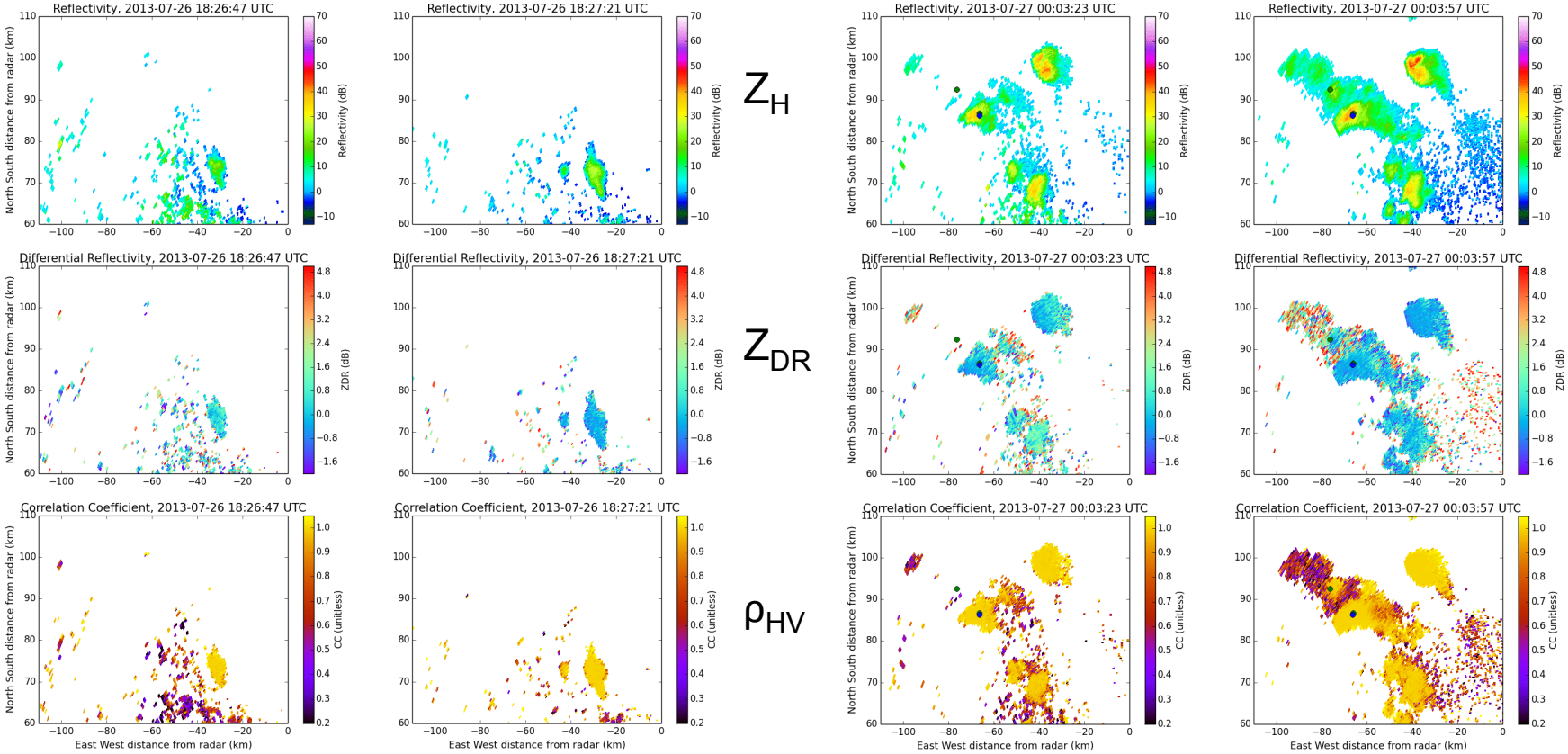




Carpenter 1

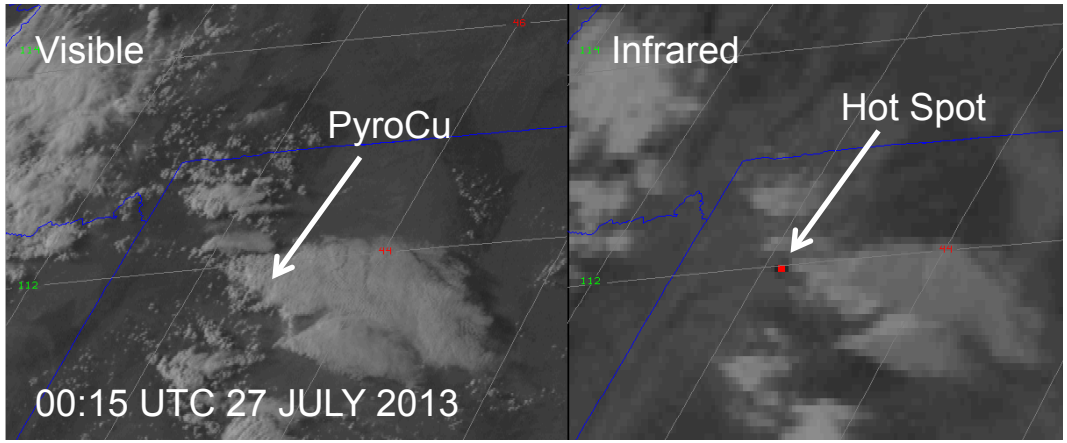
GOES Visible and Shortwave IR
4-5 July 2013 (~2200-0200 UTC)
(Source: pyrocb.ssec.wisc.edu)

Las Vegas polarimetric NEXRAD
0.5° & 5.1° sweeps
00:00-01:00 UTC, 5 July 2013
NLDN IC @ 00:23:20 UTC, I_{pk} = +4.5 kA
NLDN IC @ 00:25:16 UTC, I_{pk} = +7.6 kA
NLDN -CG @ 00:35:54 UTC, I_{pk} = -8.5 kA



Hardluck Fire (Wyoming)

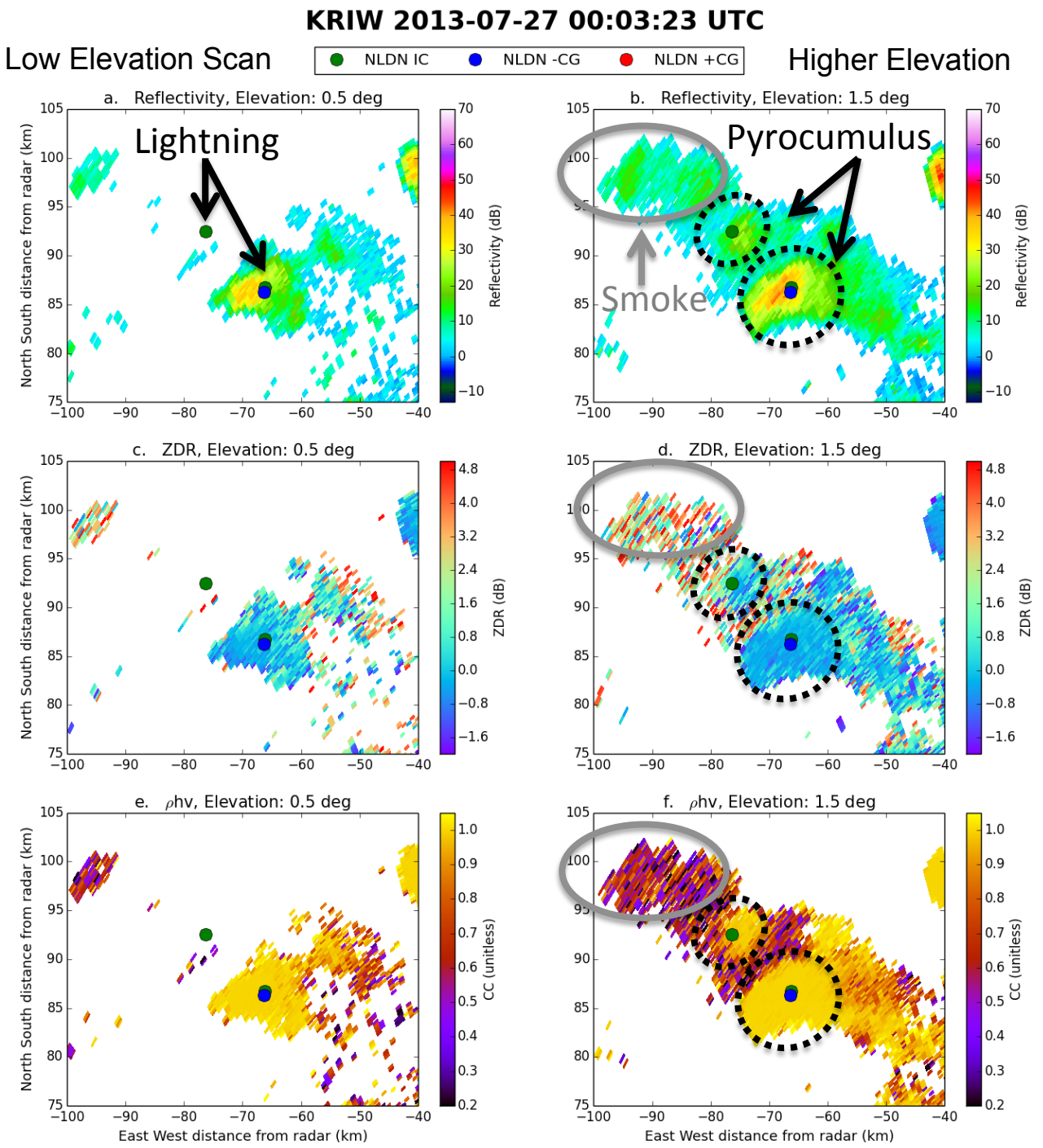
- Pyrocumulus development and lightning during 26-27 July 2013



Radar Values in Hardluck Pyrocumulus

- Z_H: 15 to ~40 dBZ
- Z_{DR}: 0.5 to -0.5 dB
- ρ_{HV}: 0.7-1.0 (unitless)
- Indicates ice particles
- Pyrocumulus echo-top height: ~8.0 km
- 18 NLDN lightning flashes in 151 minutes

Similar results for other 2013 incidents – West Fork (CO), Rim (CA), Silver (NM), Yarnell Hill (AZ), Elk Complex (ID)



Null Case

Radar Values in Black Forest (CO) Smoke Plume

- Z_H: 0 to ~30 dBZ
- Z_{DR}: 1-5 dB
- ρ_{HV}: 0.7 or less
- Indicates <u>smoke particles</u>
- Plume echo-top height: ~5.0 km
- No NLDN lightning

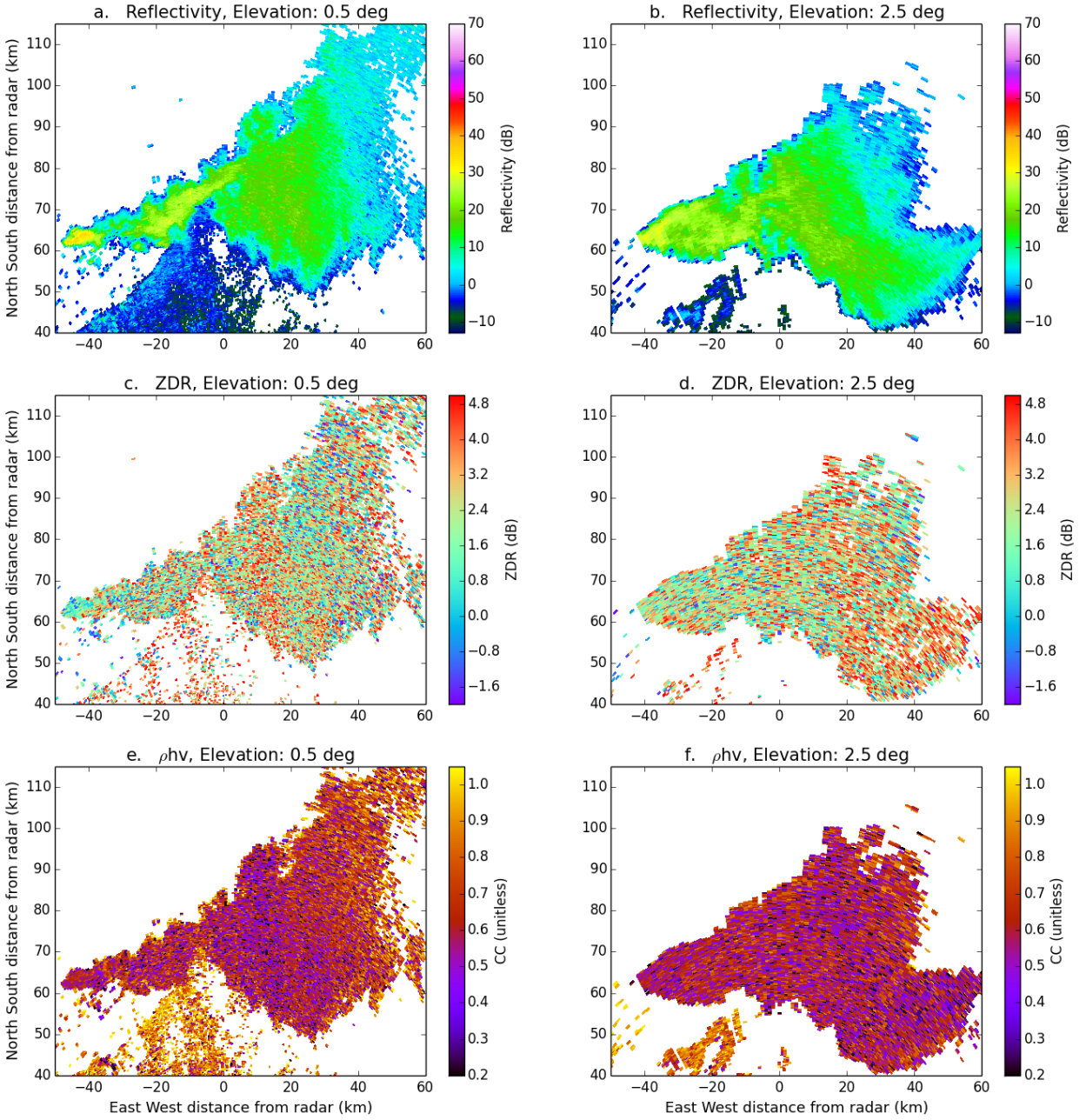
Similar results for other 2013 incidents – Royal Gorge (CO), Miner Paradise Complex (MT)

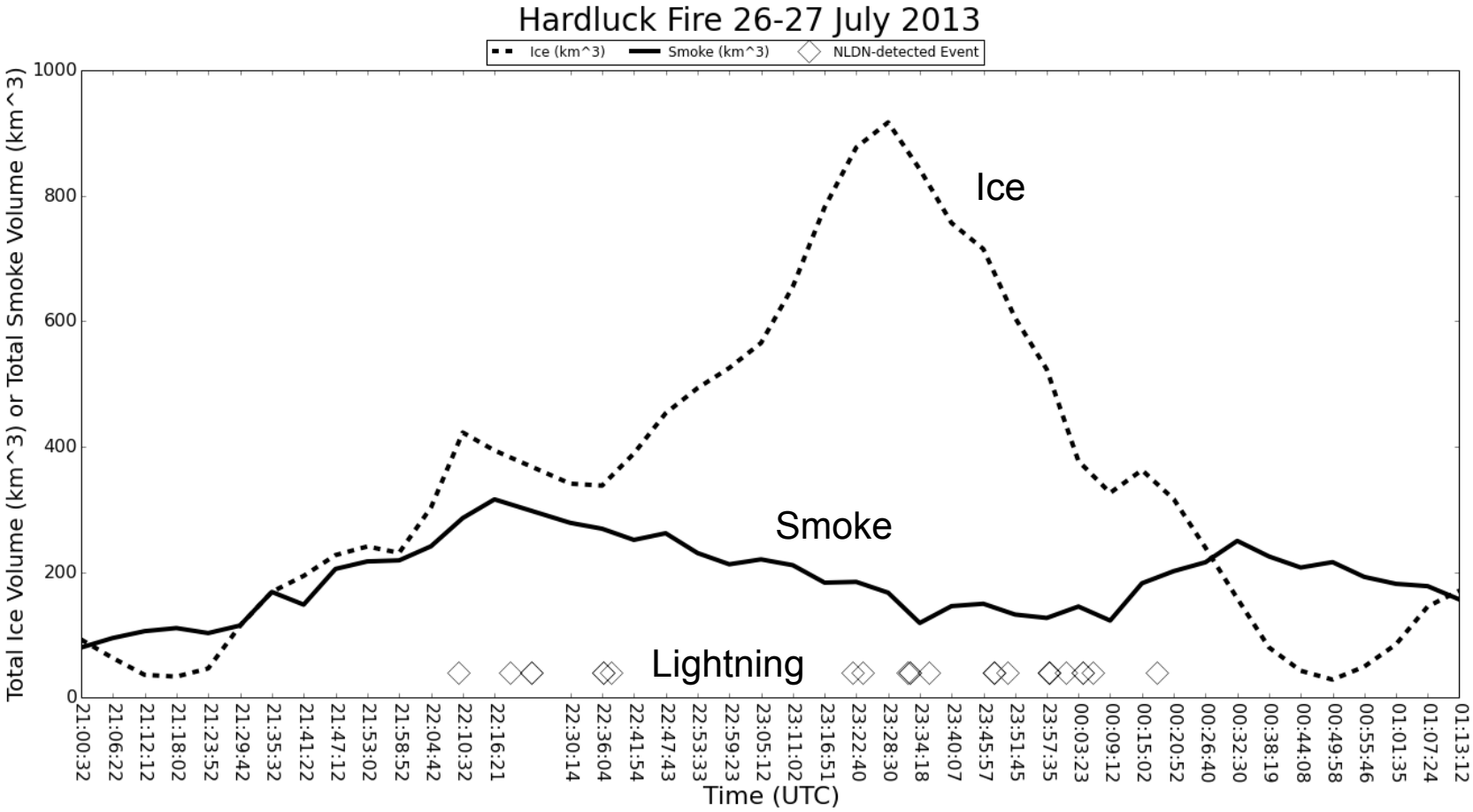
Low Elevation Scan

KPUX 2013-06-12 00:09:14 UTC

NLDN IC NLDN -CG NLDN +CG

Higher Elevation





Simple particle identification

- Ice vs. Smoke
- Ice development leads occurrence of lightning

Table 1. List of radar parameter values used for determining if the radar was detection ice or smoke (from Lang et al. 2014)

	Parameter	Parameter Minimum Value	Parameter Maximum Value
Ice	Reflectivity (dBZ)	>= 20	< 70
	ZDR (dB)	>= -1	<= 1
	ρHV	>= 0.7	<= 1.0
Smoke	Reflectivity (dBZ)	>= 0	< 30
	ZDR (dB)	> 1	<= 5
	ρHV	>= 0	< 0.7

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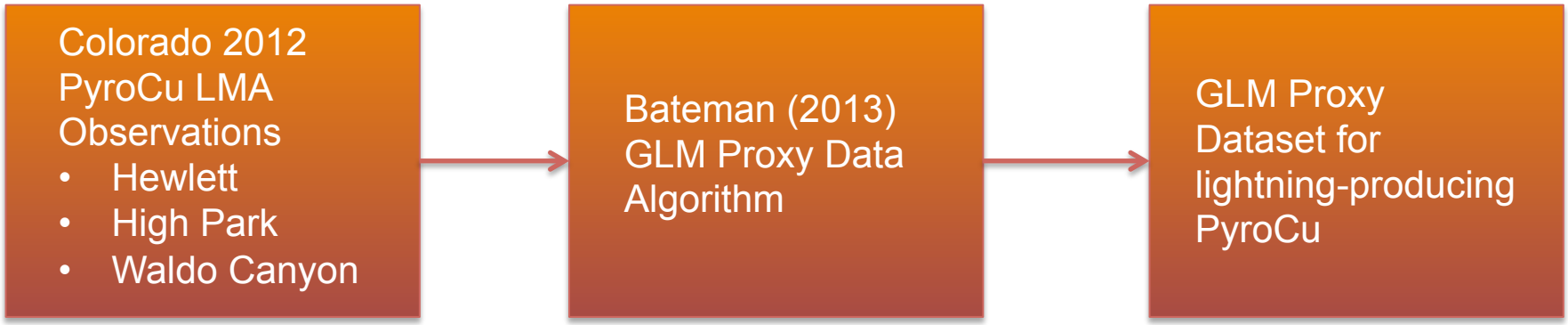
Geostationary Lightning Mapper Proxy Data

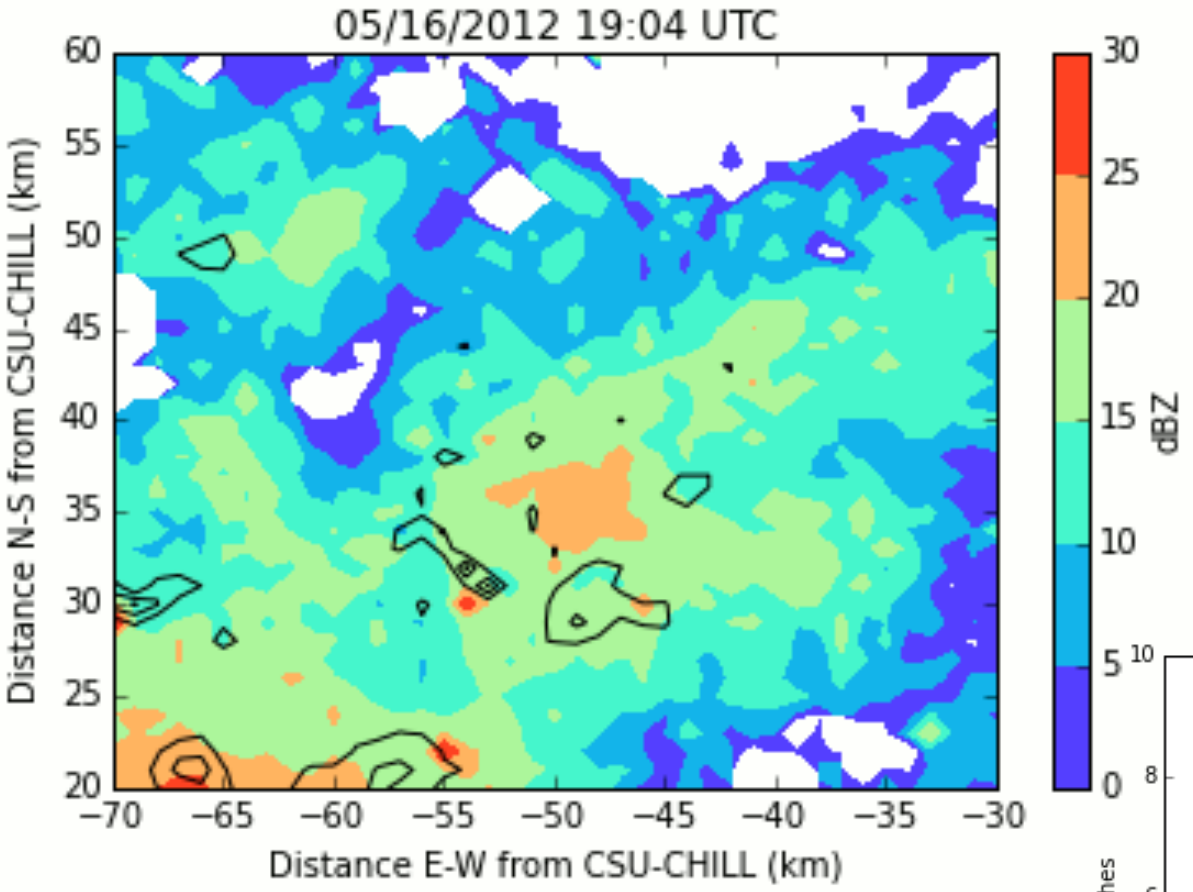
Motivation

- Many of these PyroCu flashes are small, low-current ICs
- Will GLM be able to provide information about them?

Method

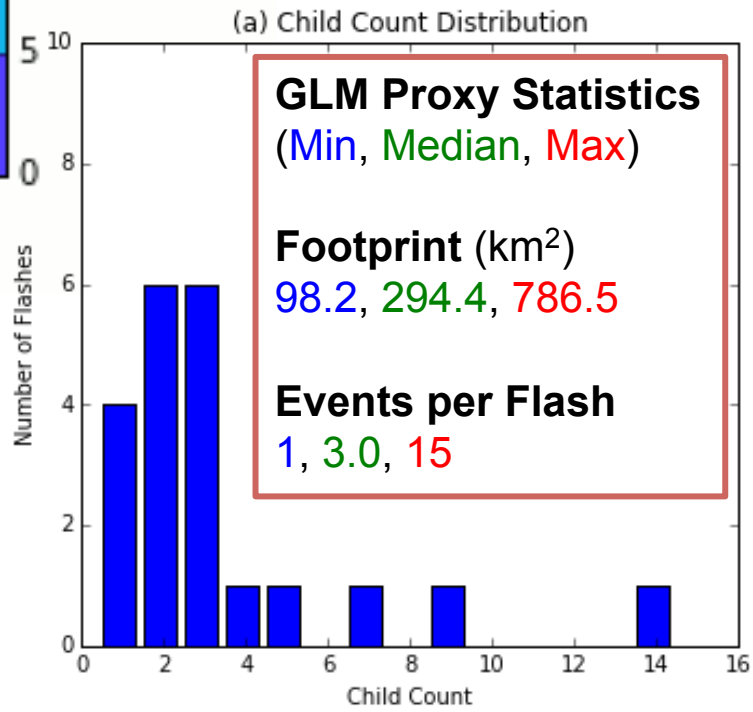
- GLM proxy data were created using algorithms developed at MSFC (Bateman 2013)
- Algorithms based on statistical comparison of LMA and Lightning Imaging Sensor (LIS) observations of same lightning
- Proxy optical events clustered into proxy flashes
- Applied to Lang et al. (2014) LMA-mapped PyroCu lightning dataset





Magenta Stars
GLM Proxy Flashes

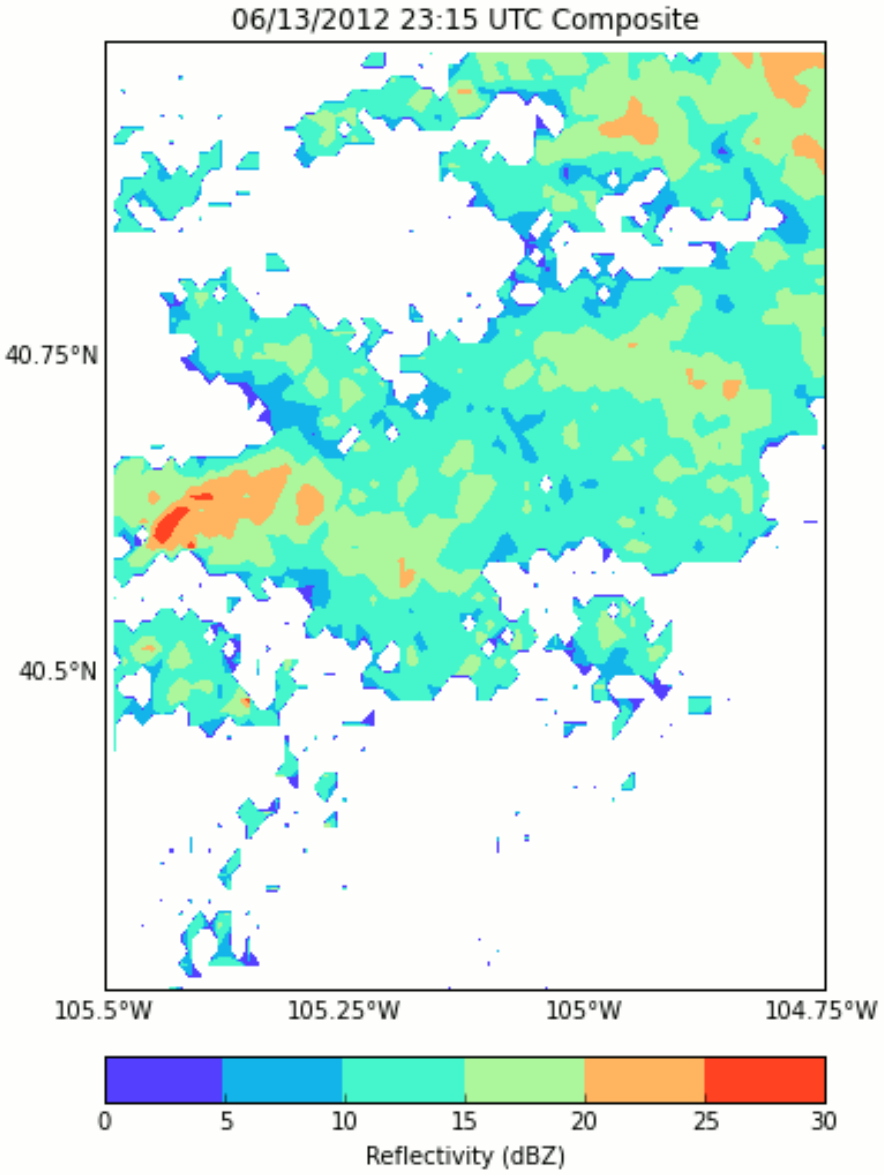
Black Contours
1 m s^{-1} updraft



Hewlett Fire Lightning

5/16 1948-2005 UTC

- LMA = 20 Flashes (10+ sources)
- GLM Proxy = 21 Flashes



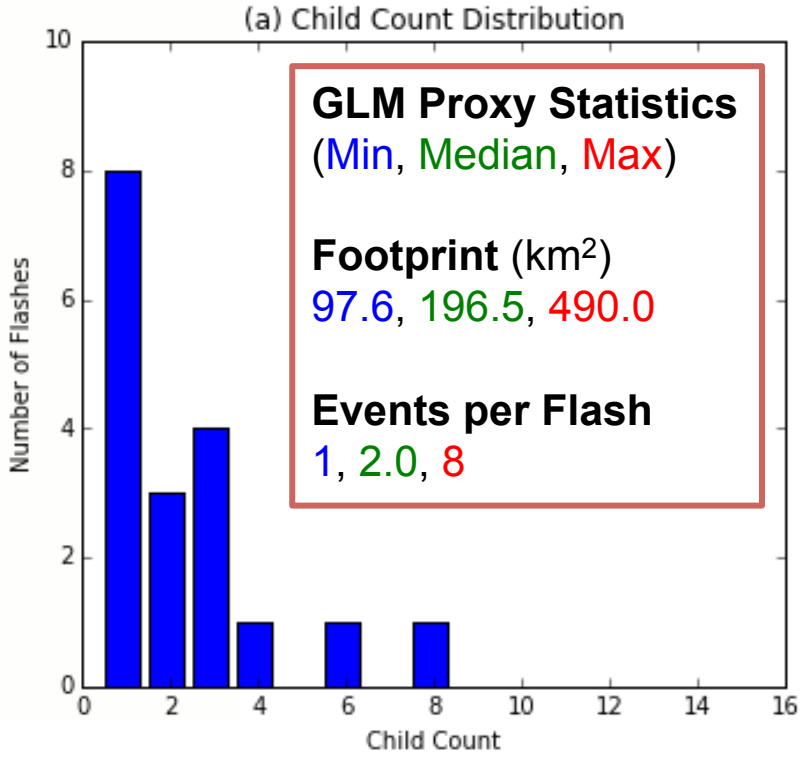
High Park Fire Lightning

6/13-14 2328-0033 UTC

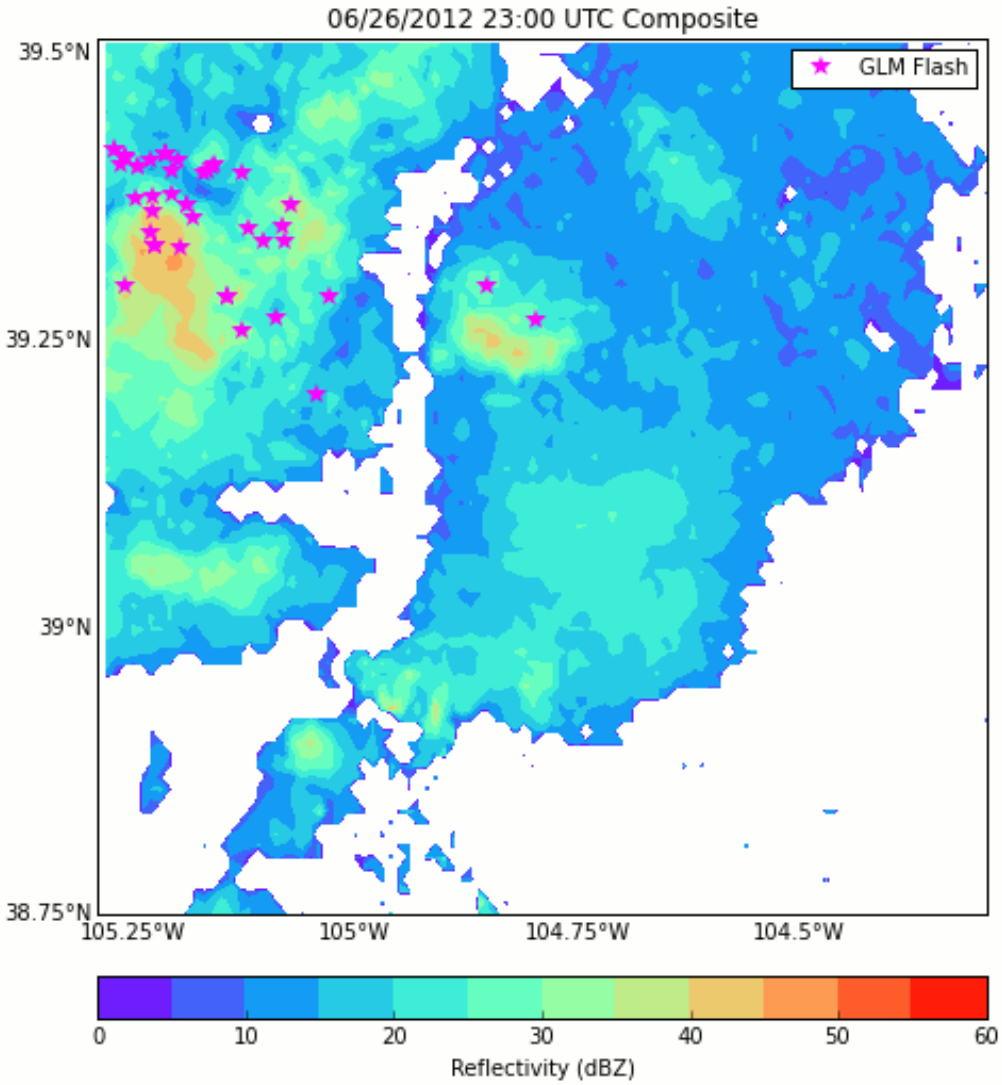
- LMA = 28 Flashes (10+ sources)
- GLM Proxy = 18 Flashes

Magenta Stars

GLM Proxy Flashes



Waldo Canyon Fire Lightning

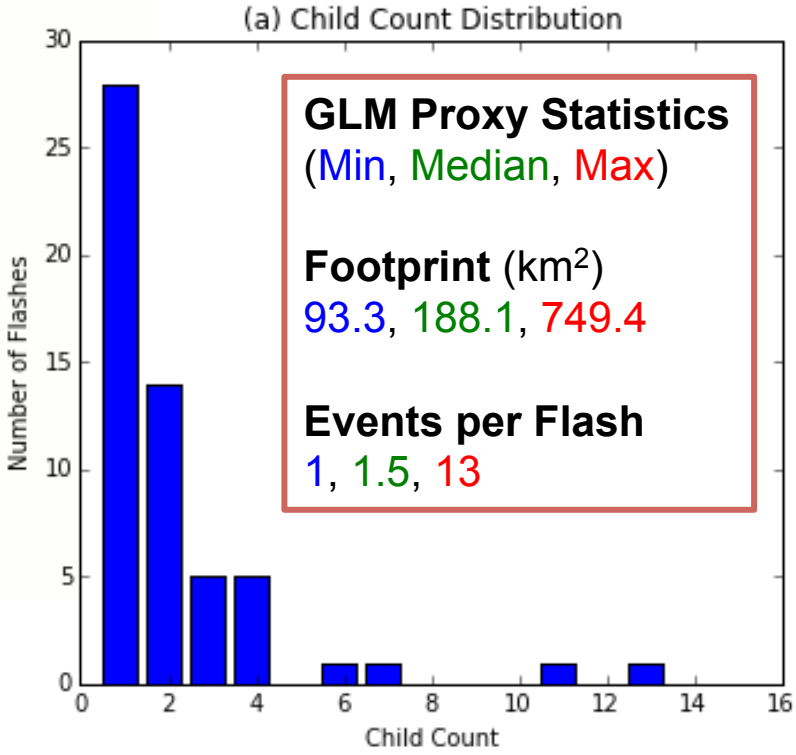


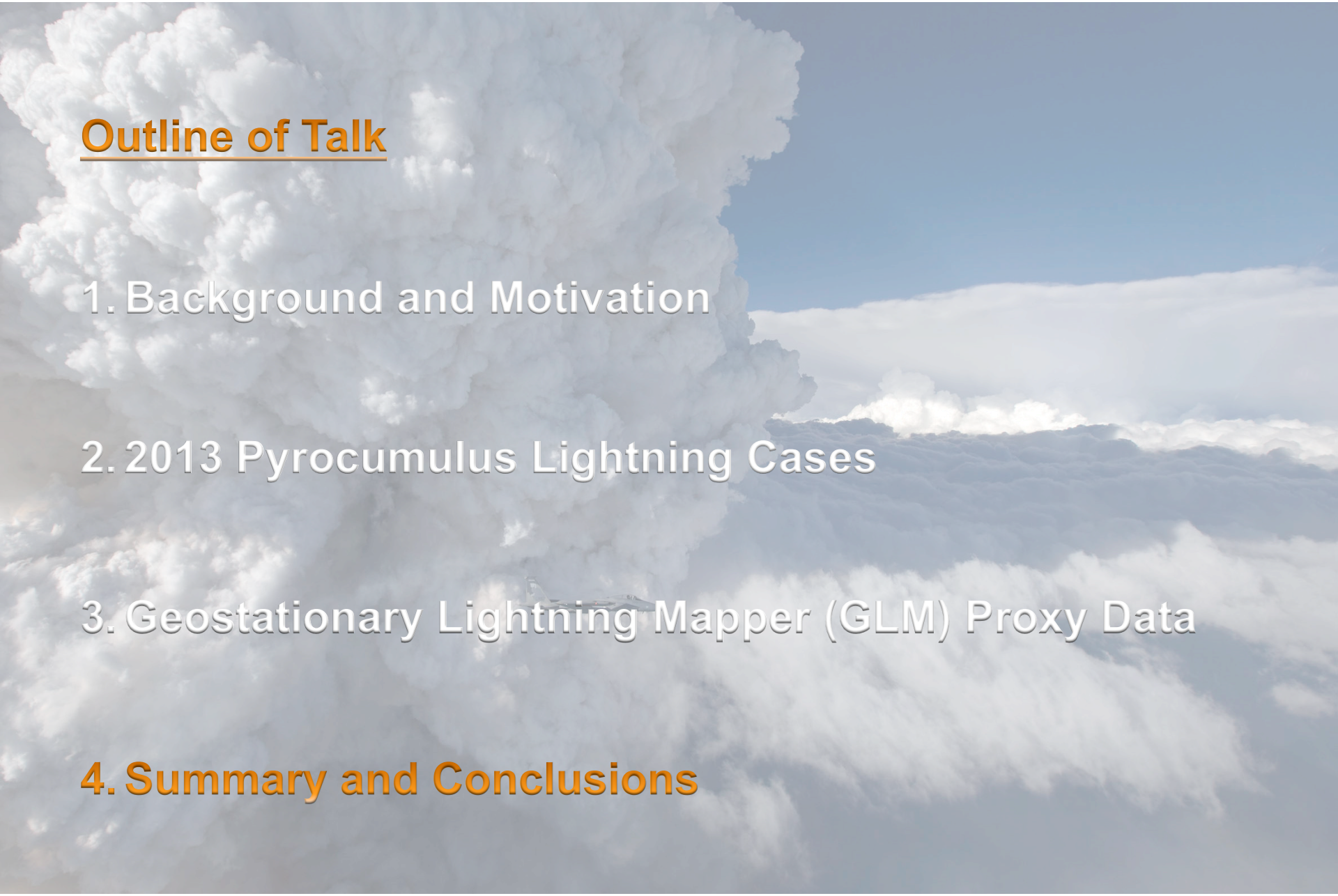
6/26-27 2310-0006 UTC

- LMA = 117 Flashes (10+ sources)
- GLM Proxy = 56 Flashes

Magenta Stars

GLM Proxy Flashes





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Summary and Conclusions

- Ten additional case PyroCu studies (lightning and non-lightning) examined
- The novel 2012 pyrocumulus lightning observations described in Lang et al. (2014) were not an exception!
  - Vertical growth of cloud leads to development of precipitation-sized ice signature in polarimetric radar data, distinctive from smoke signature
    - Modest to high Z_H, noisy but near-0 Z_{DR}, improved correlation
    - Presence of ice associated with occurrence of lightning
    - No ice signature, no lightning!
  - Higher-sensitivity NLDN detects at least some of the weak ICs
  - GLM appears capable of detecting many of these ICs
  - Pyrocumulus development and lightning associated with significant fire growth

Dual-Pol NEXRAD + Upgraded NLDN + GOES-R/GLM =
Nationwide Pyrocumulus Electrification Observing Network