On the relationships between sprite production and convective evolution

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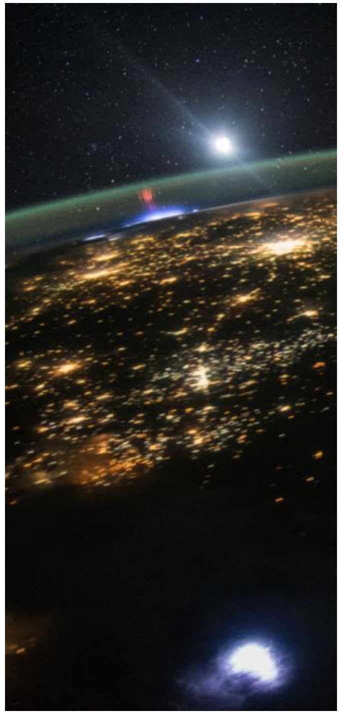
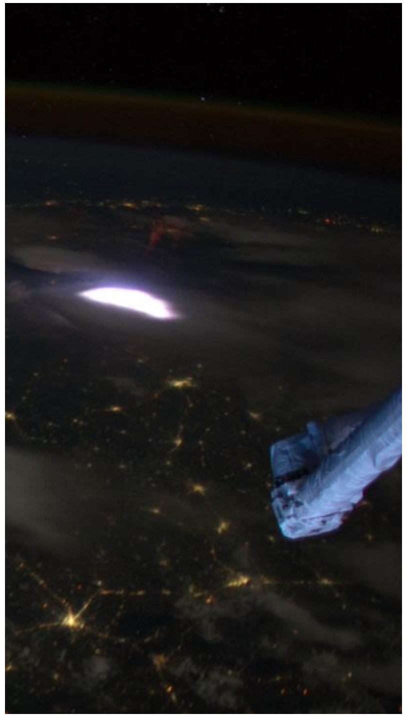
Acknowledgments on Individual Slides



https://eol.jsc.nasa.gov/

Scientific Questions

- What are the meteorological and thunderstorm conditions that lead to the production of sprites in the upper atmosphere?

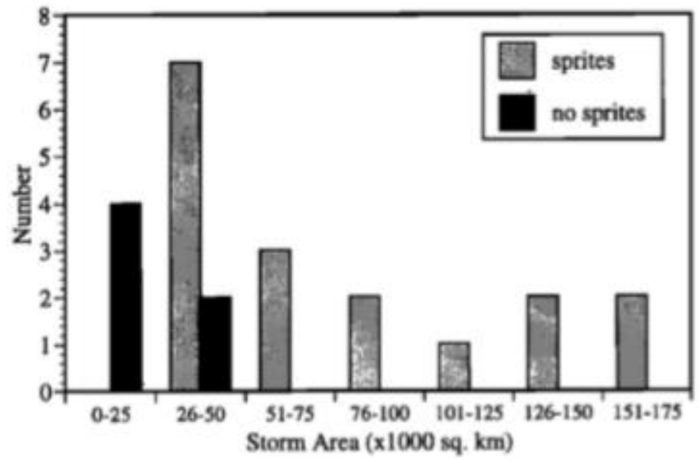
- Why do some storms produce dozens or hundreds of sprites, and some don’t produce any?

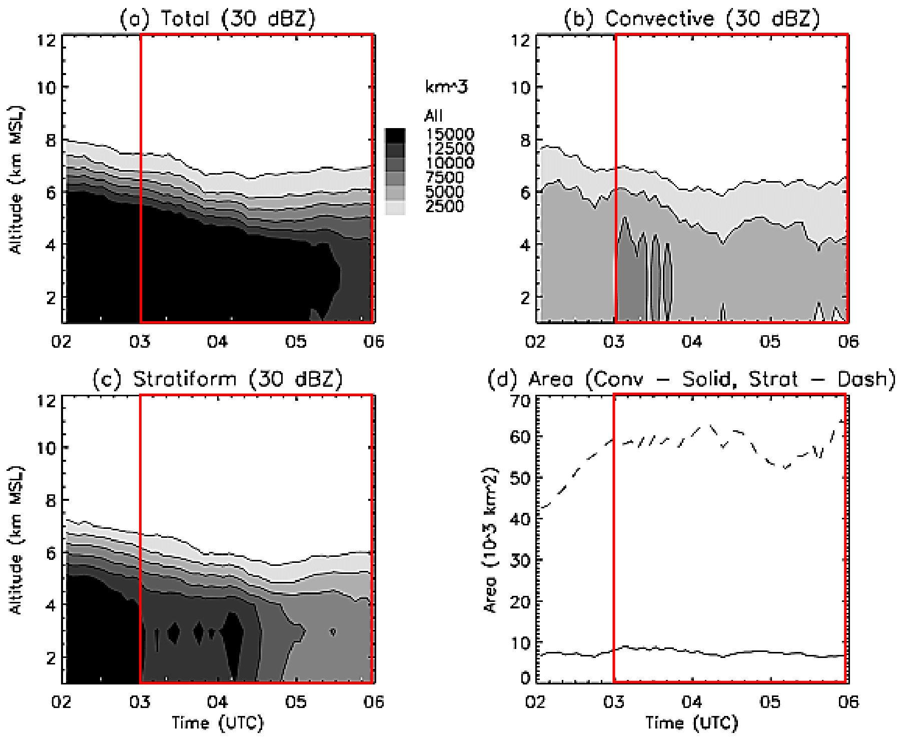
- How can we take advantage of modern observing infrastructure to better understand sprite-parent thunderstorm evolution?

Classic Model for Positive Sprites from Mesoscale Convective System (MCS)

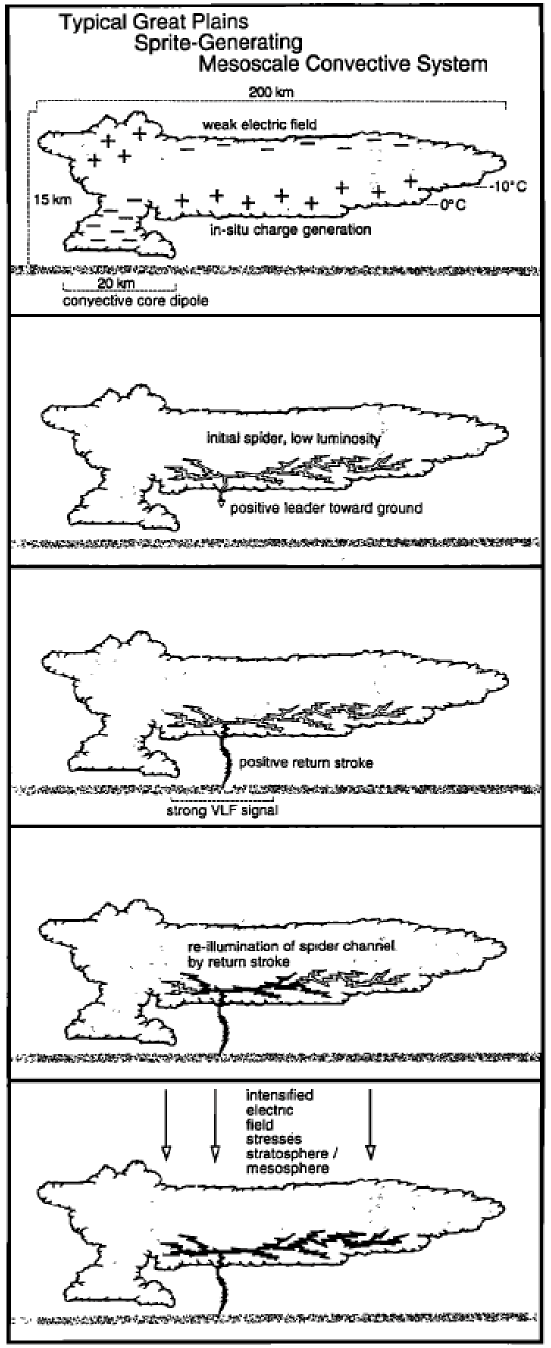
- Large, long-lived storm
- Powerful positive cloud-to-ground (+CG) lightning in the stratiform region
- Large charge moment changes (CMCs) – 100s of C km
- Sprites begin during mature to weakening phases of MCS

Lyons (1996)



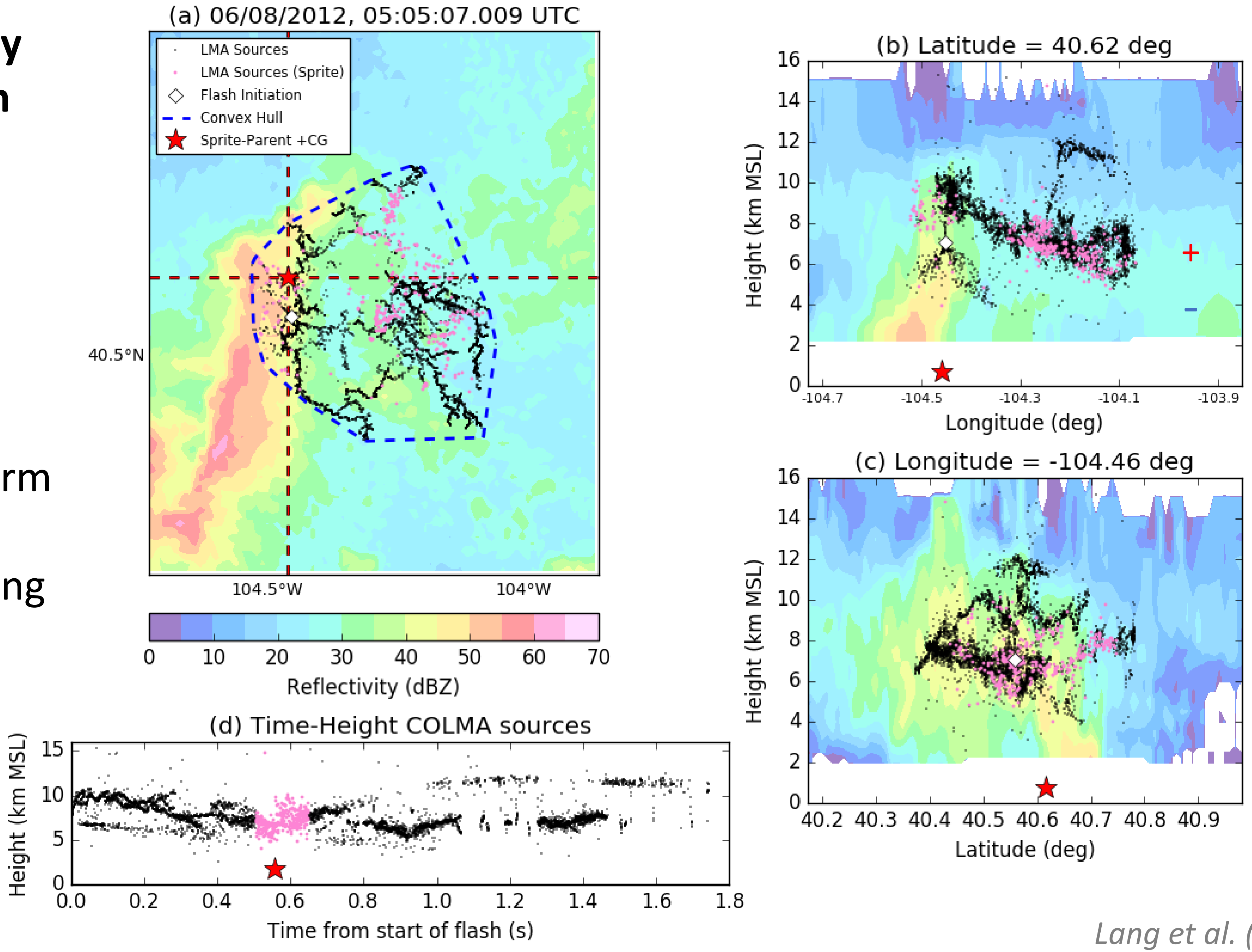


Lang et al. (2010)



Classic Convectively Initiated Stratiform Sprite-Parent +CG

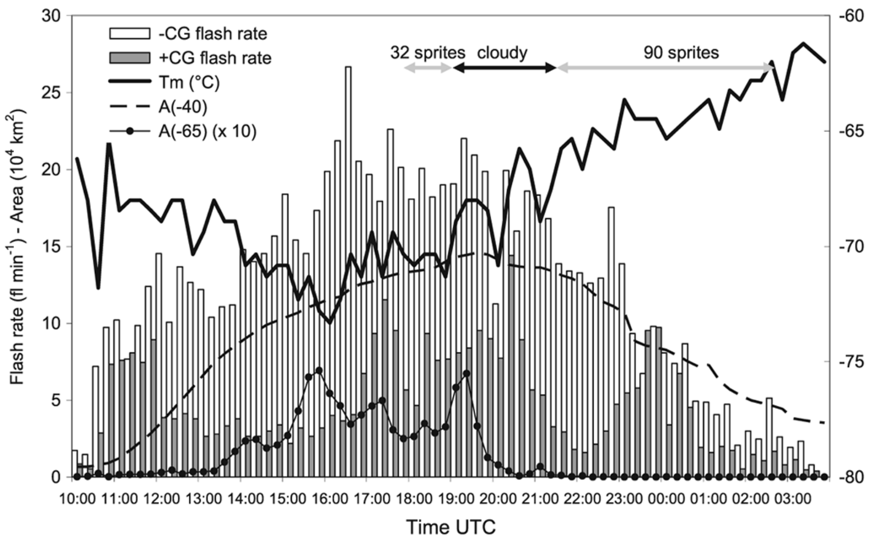
- Initiate in convection
- Propagation to adjacent stratiform
- Downward-sloping positive charge layer



Lang et al. (2016)

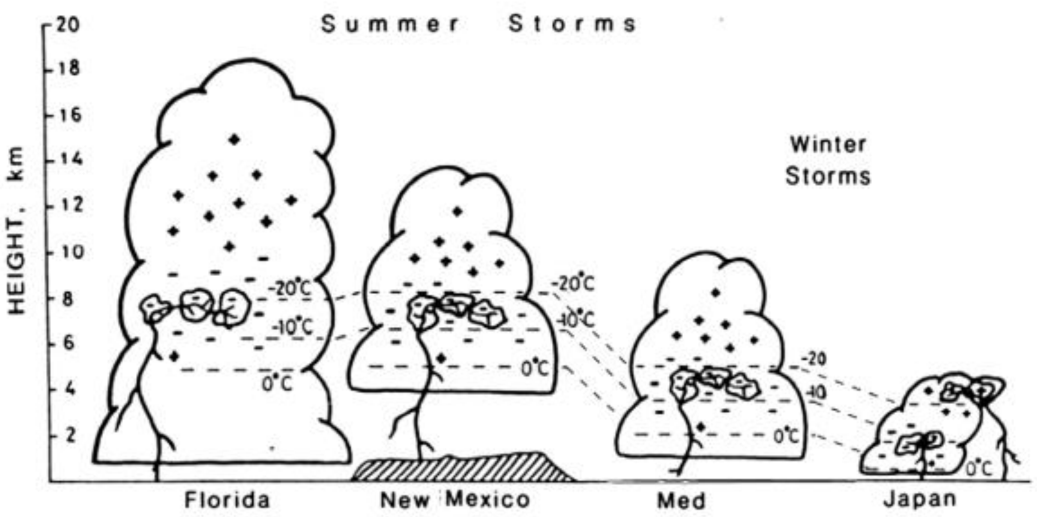
Fall & Winter Storm Sprites

- Common in Mediterranean and Sea of Japan
- Inferred shallower, more compressed vertical charge distributions
- Parent storms (e.g., Cyprus Lows) are comparable in size to summertime MCS
- Sprite production follows classic pattern relative to storm evolution

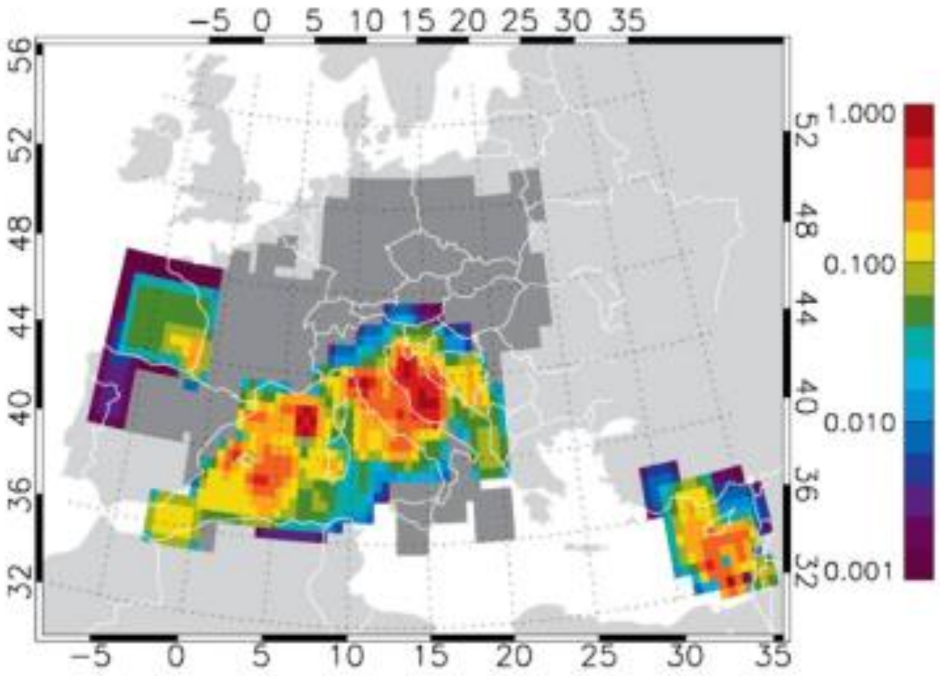


Soula et al. (2017)

Thunderstorm Comparison



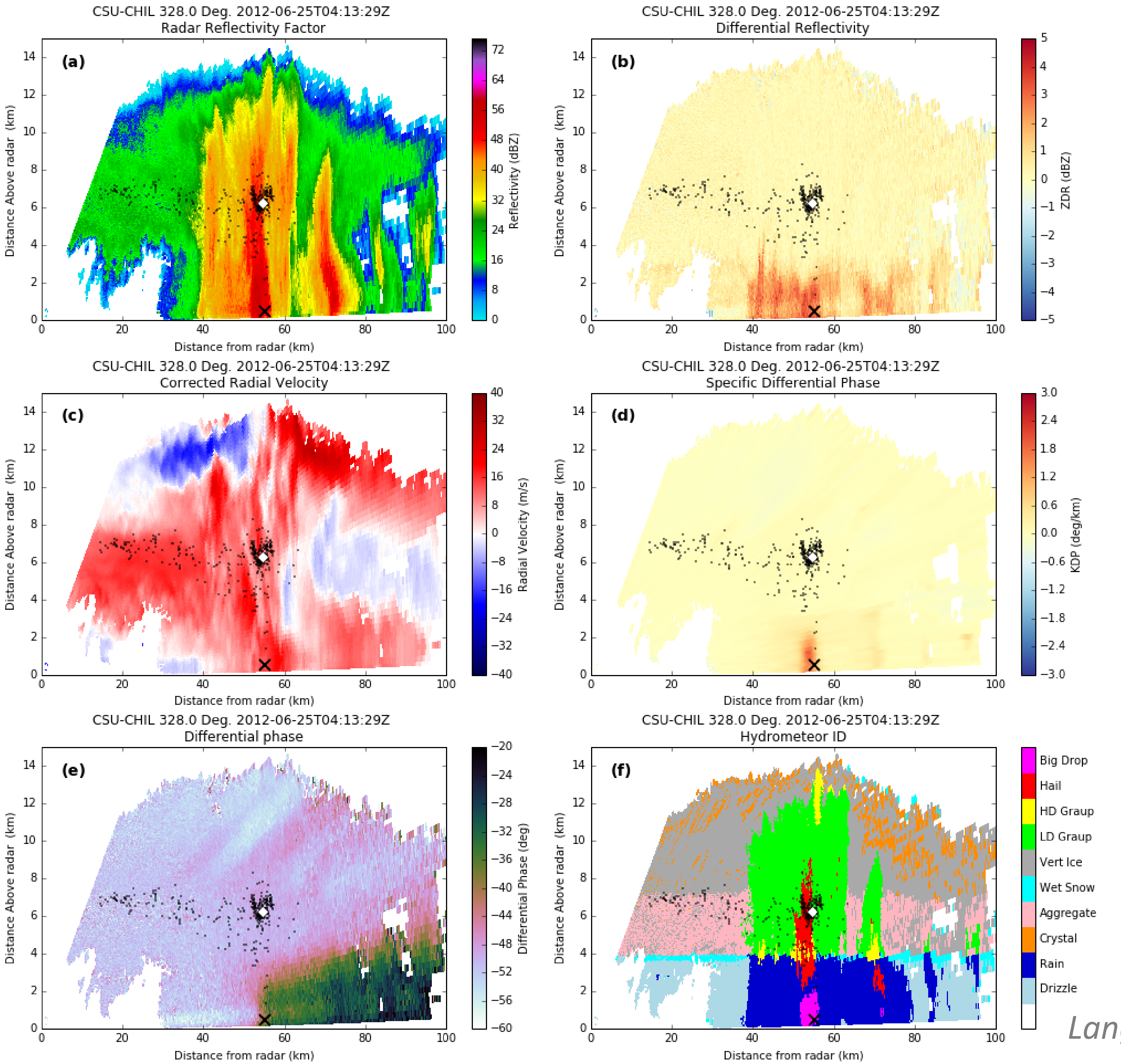
DJF Climatology



Yair et al. (2015)

Anomalously charged storm with positive charge in mid-levels (e.g., -20 C)

- Sprites from convective +CGs
- Propagation to adjacent anvil



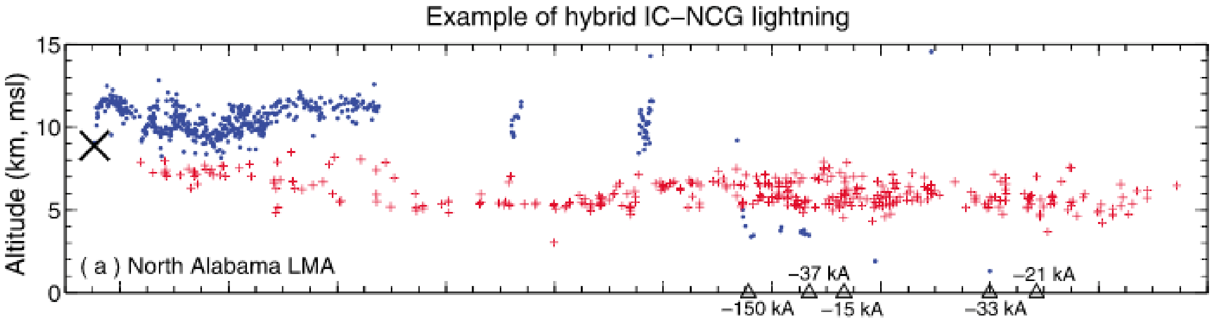
Lang et al. (2016)

Negative Sprites

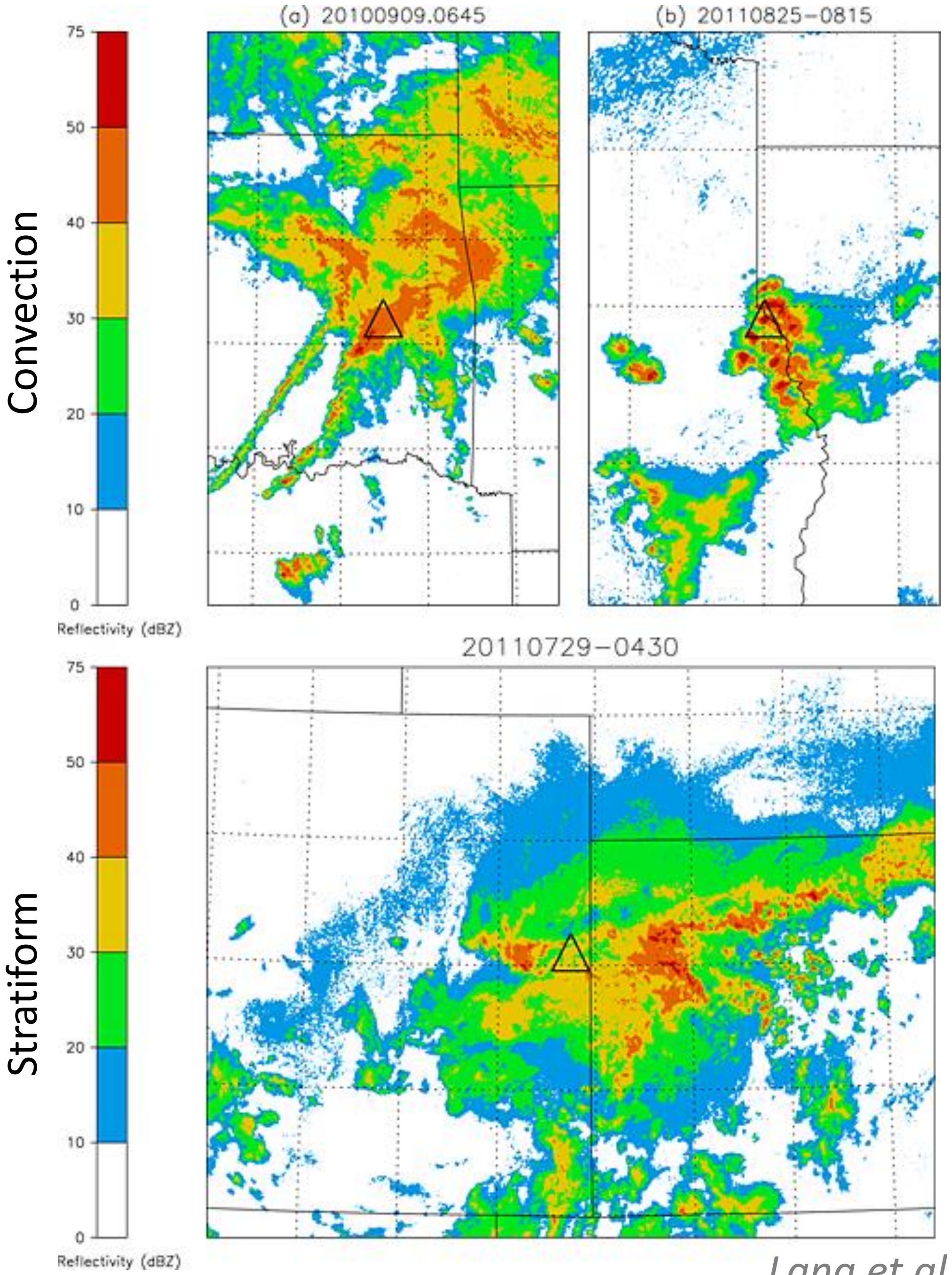
- Two common modes
  - Powerful –CGs in convection
  - Powerful –CGs in stratiform

- Highly impulsive CMC – little continuing current contribution

- Hybrid IC-NCG lightning likely culprits, especially for convective sprite parents



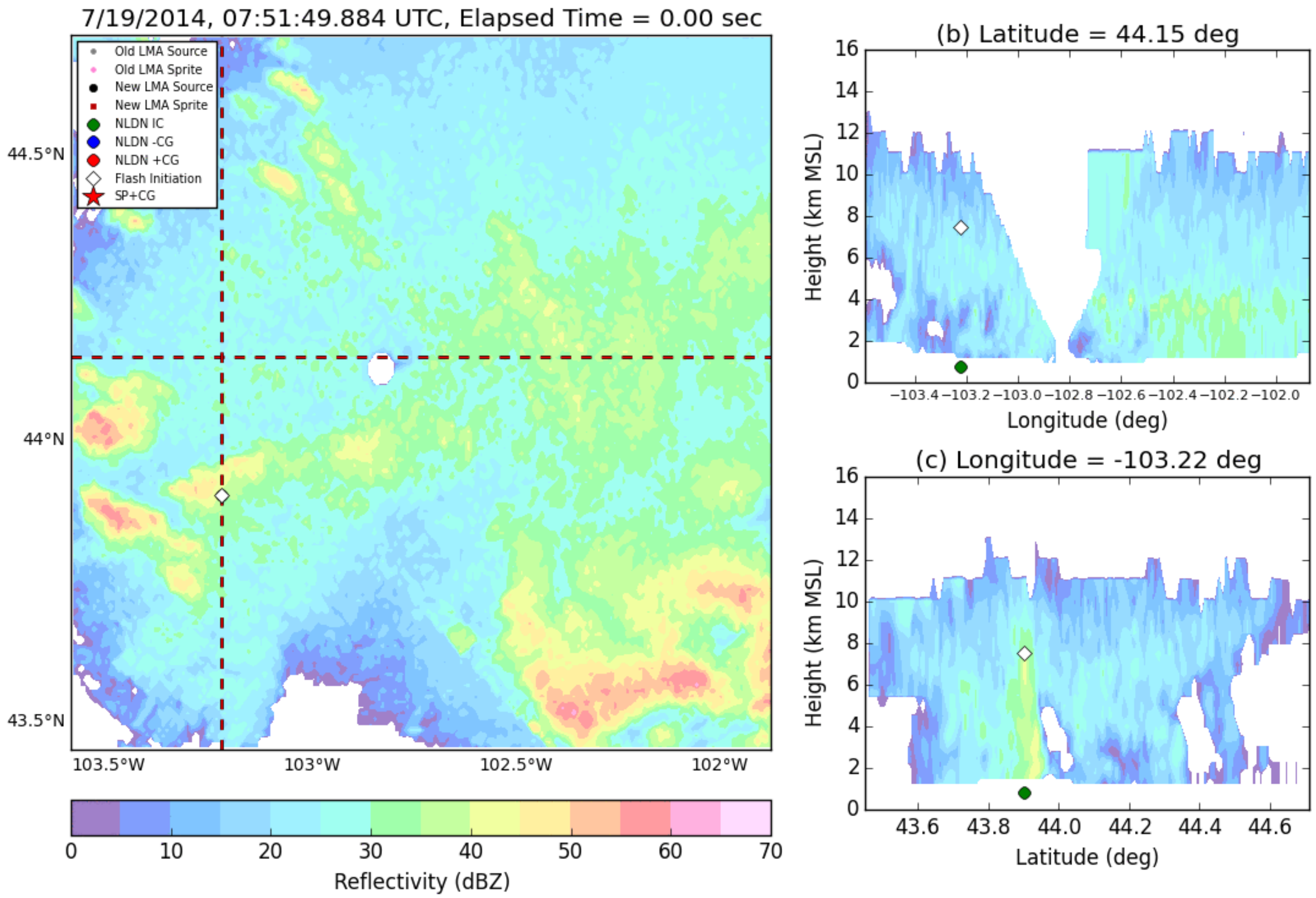
Lu et al. (2012)



Lang et al. (2013)

Marginal Sprite Producers

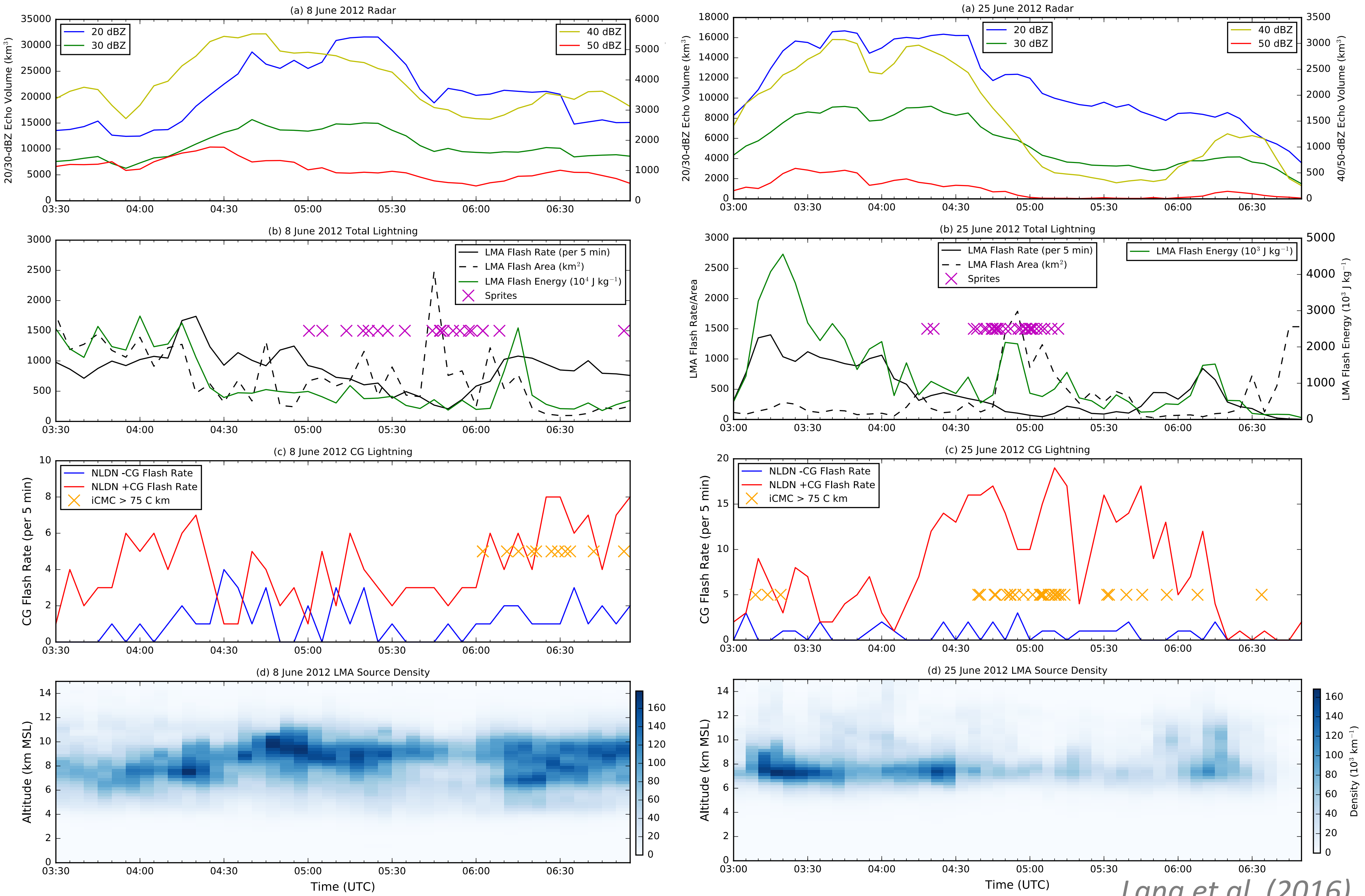
- Storms that produce only one or just a few sprites are often associated with weak convection in the presence of nearby stratiform precipitation
- However, the sprite-parent flashes often are long-lived (> 1 s) and feature horizontally extensive in-cloud components (> 100 km)



https://github.com/nasa/MMM-Py

Putting it all together …

- The power of combined observations, including total lightning
- Sprites occur during mature to weakening phases of long-lived storms

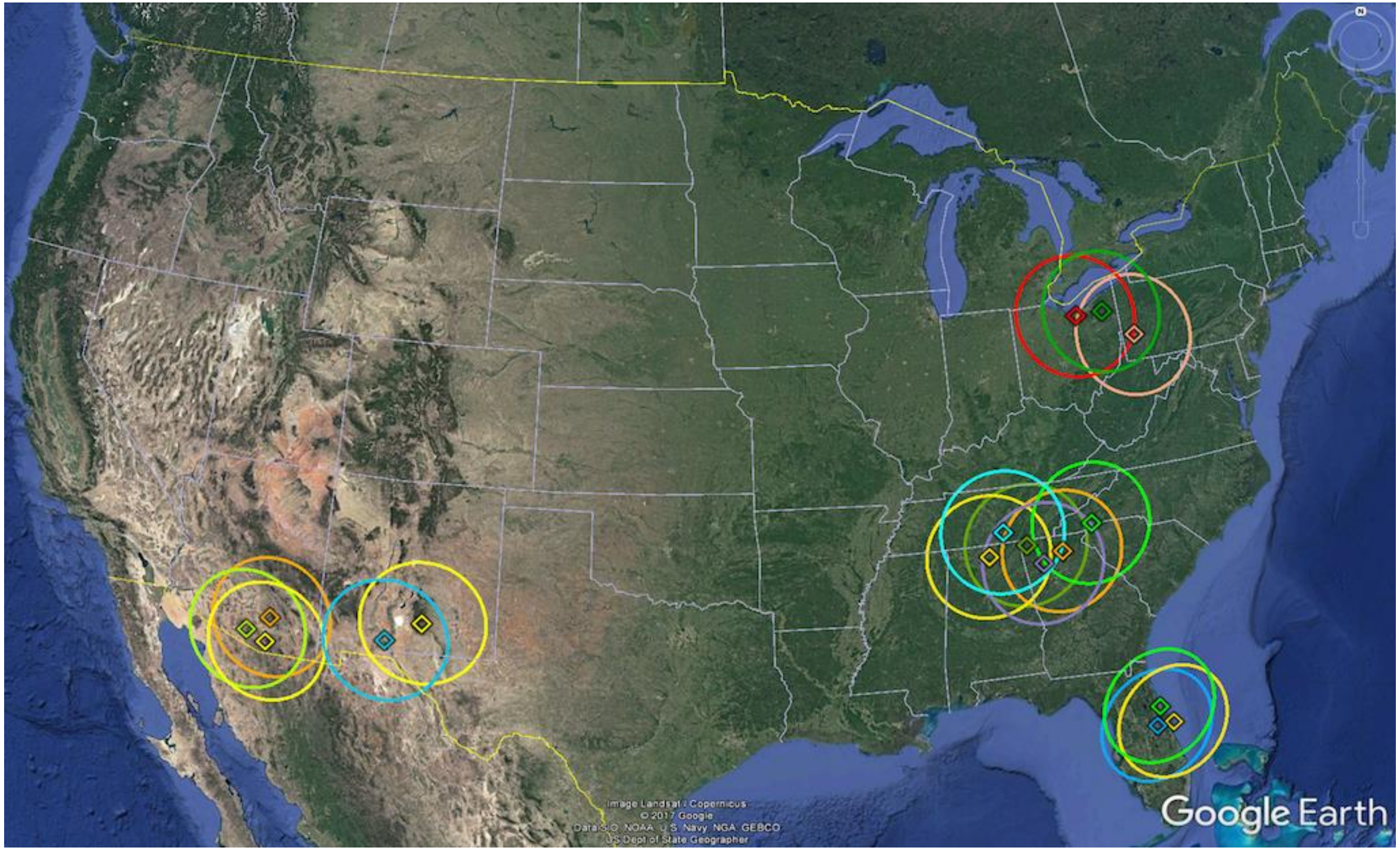


Lang et al. (2016)

GLM Observations of a Sprite-Producing Storm

Note: GLM data are preliminary and not operational

NASA All-Sky Fireball Network



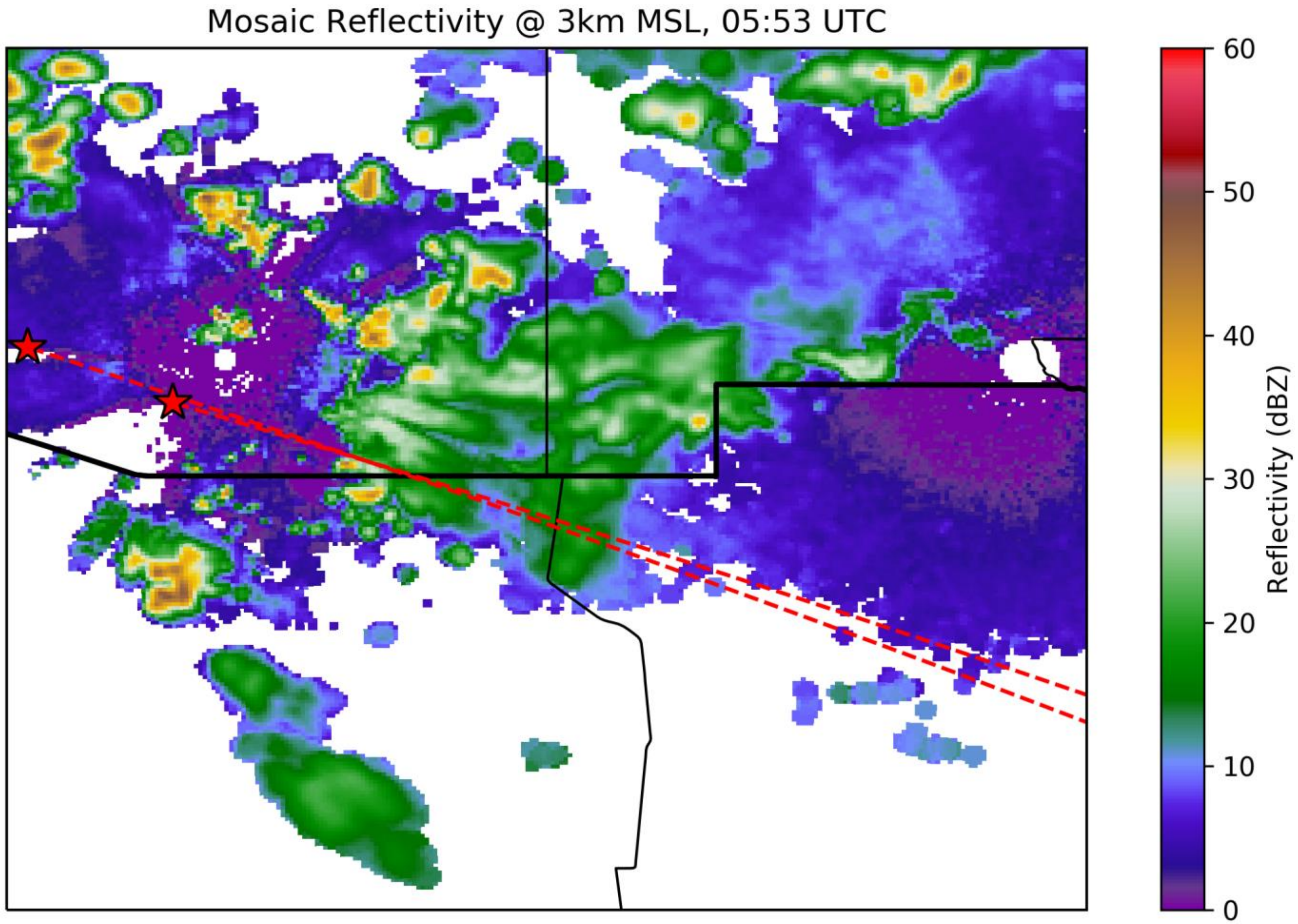
https://fireballs.ndc.nasa.gov/

- Check out AE23A-2469 (Garnung and Celestin) this afternoon for TLE research using the French all-sky network

Danielle Moser, NASA MSFC

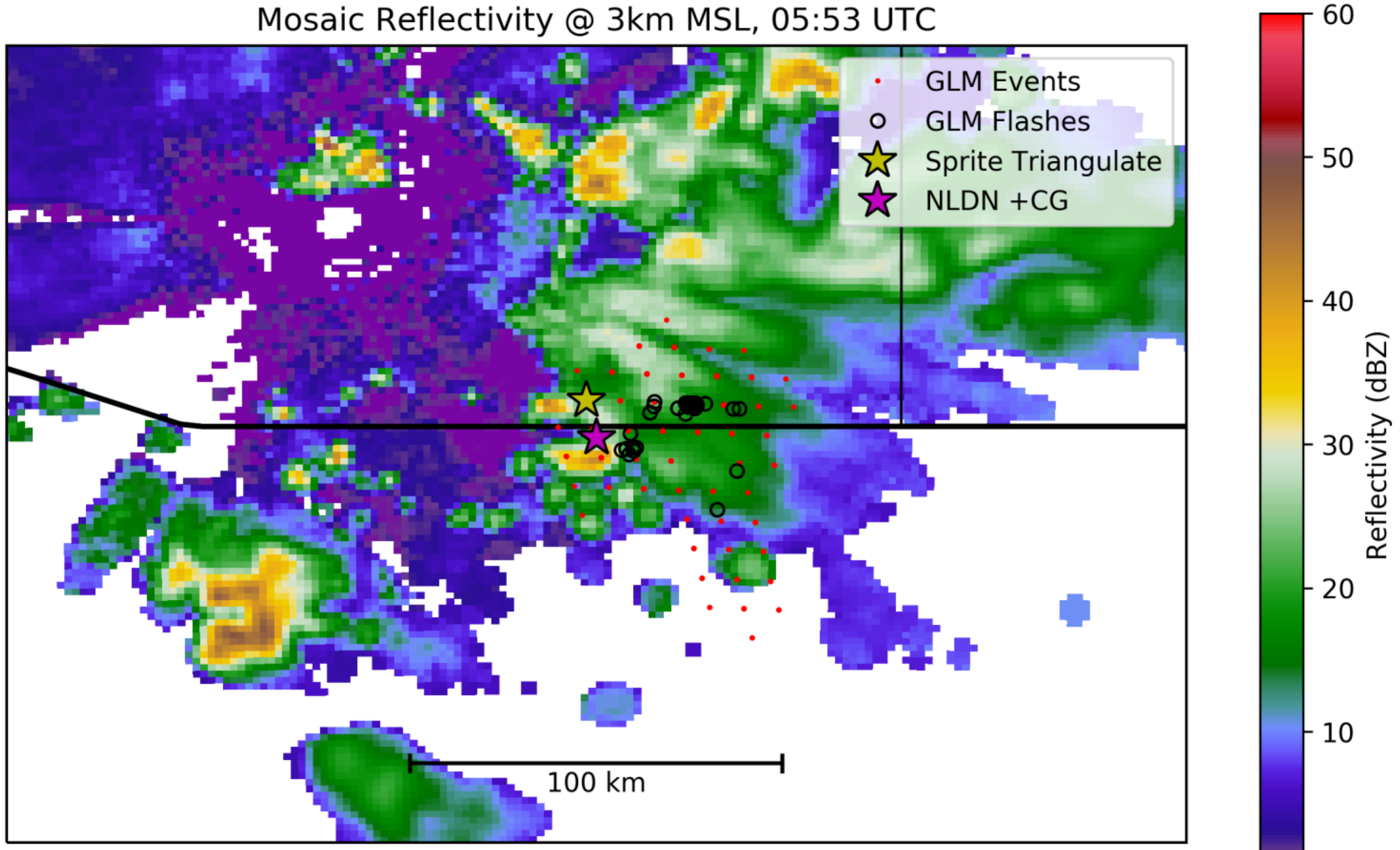
Danielle Moser, NASA MSFC

- Triangulation of Sprite Location



#MadeWithPyART

- Radar, GLM, and NLDN

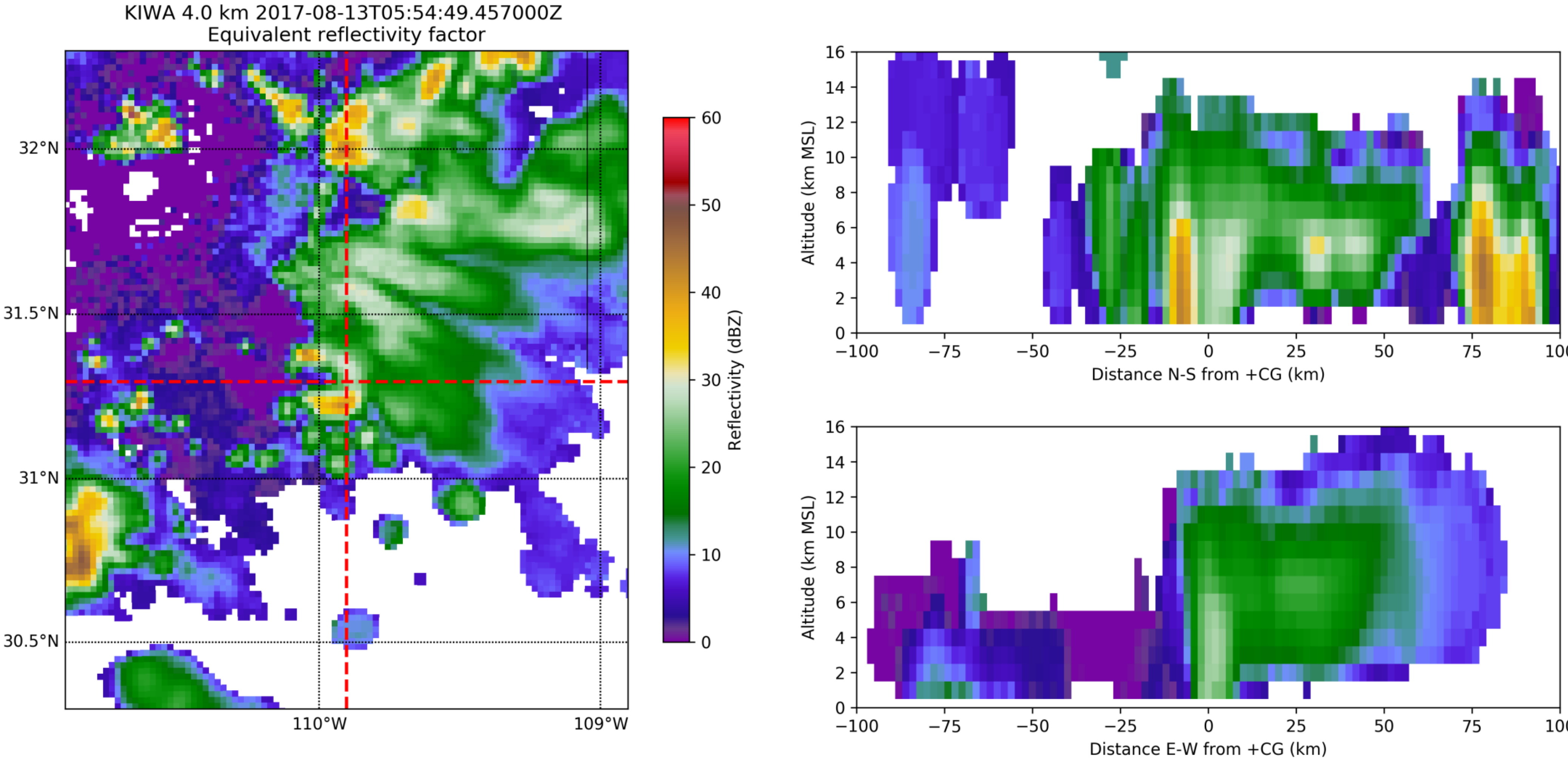


NLDN +CG

- 05:53:20.509 UTC
- +19.9 kA
- Within 50 km of sprite location

#MadeWithPyART

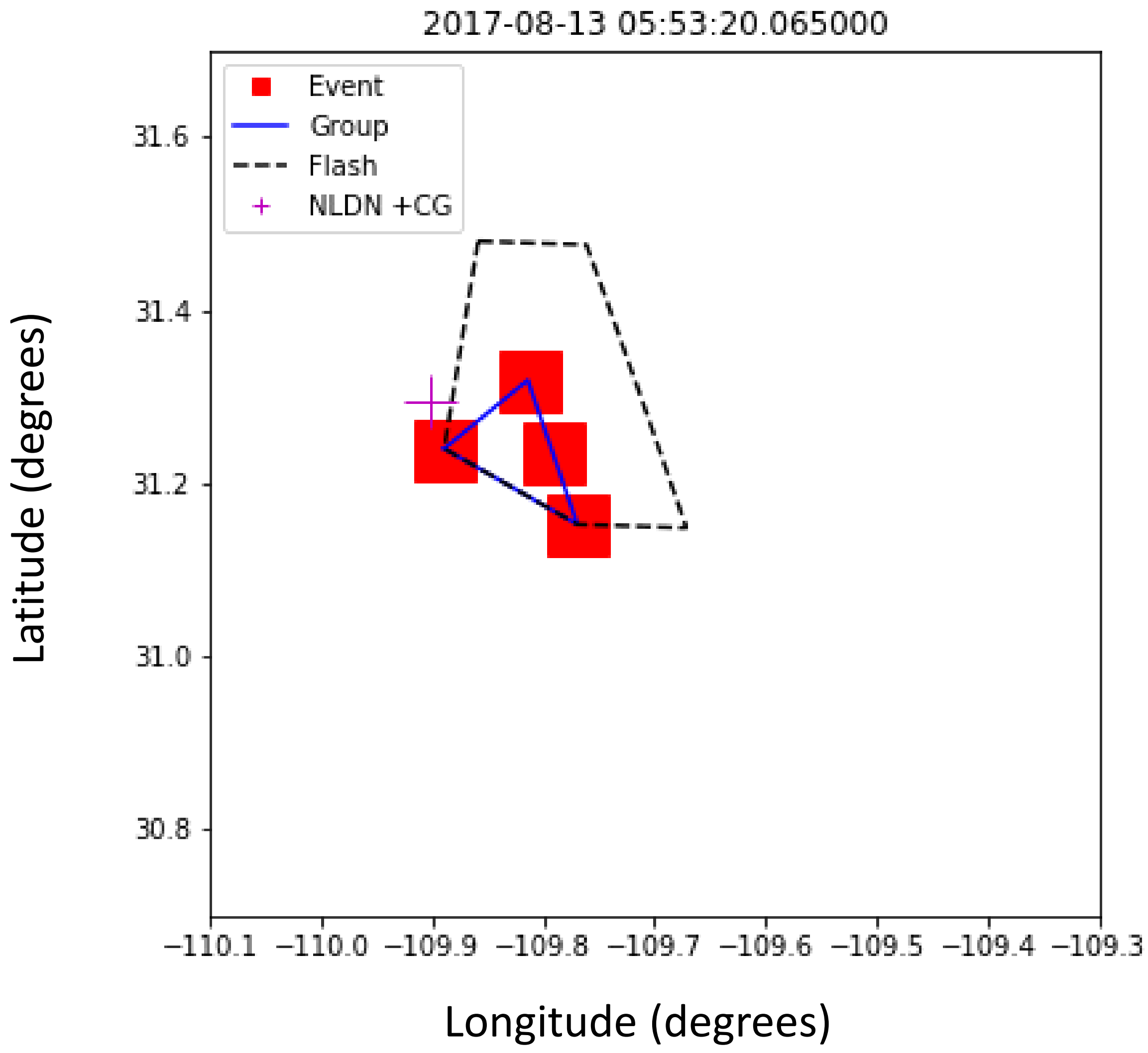
- Weak convection with nearby stratiform anvil



#MadeWithPyART

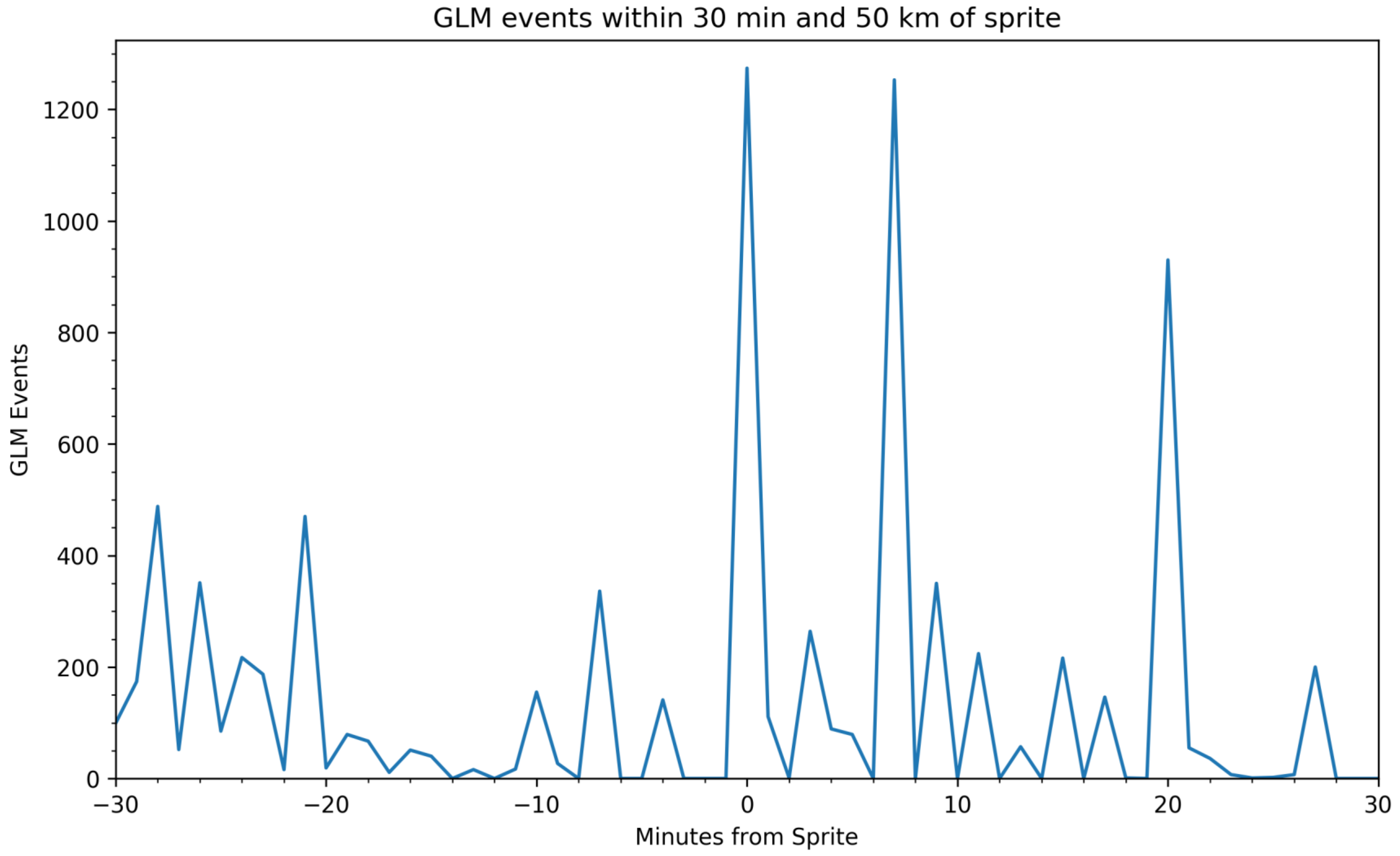
- GLM “Flash” Animation

- West to east propagation (i.e., toward stratiform)
- Big increase in area associated with +CG and sprite (~05:53:20.46 sec)
- GLM baseline algorithm splits activity into dozens of flashes



Thanks to Eric Bruning for Event Lat/Lon Correction

- GLM lightning intermittent around time and location of sprite

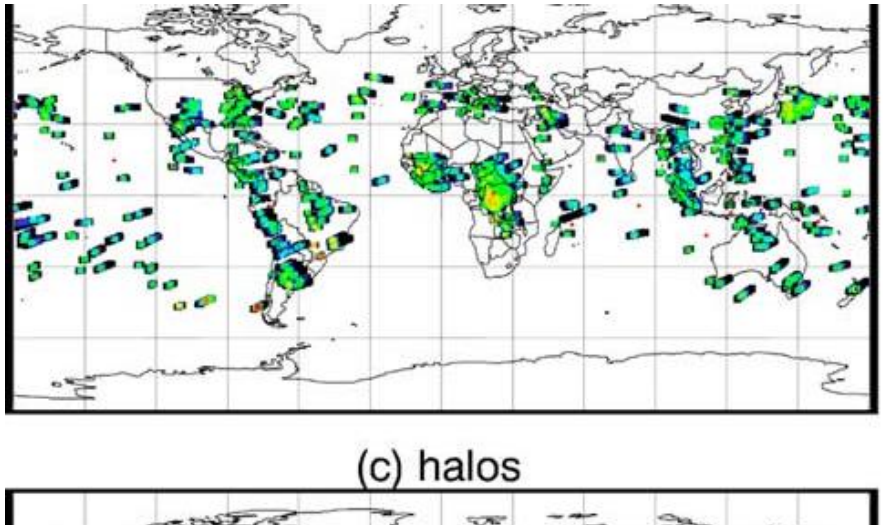


Working toward the future of research on sprites and convective evolution

Current/Past TLE Missions

ISUAL (Imager of Sprites and Upper Atmospheric Lightning)

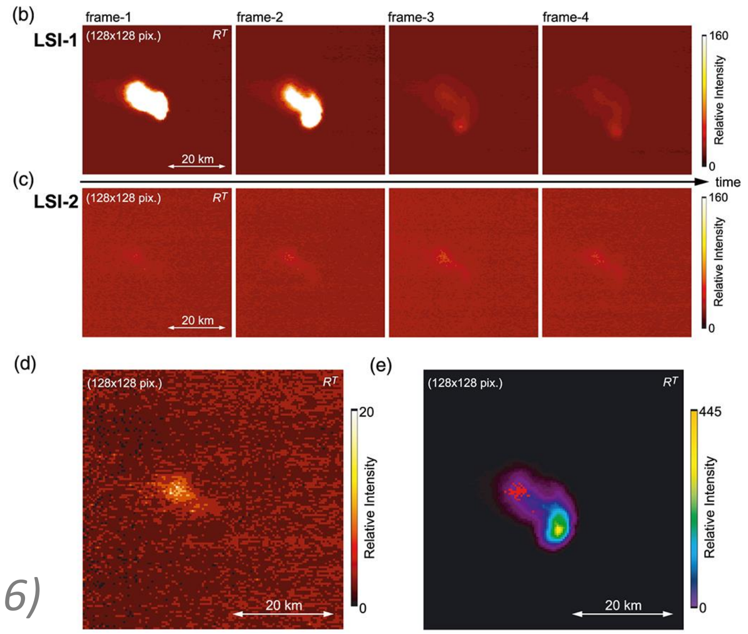
- On board FORMOSAT-2 satellite, launched 2004
- Sun-synchronous orbit
- Cameras/Photometers
- Views perpendicular to orbital plane



Chen et al. (2008)

JEM-GLIMS (Global Lightning and Sprite Measurements on Japanese Experiment Module)

- Integrated on International Space Station (ISS) in 2012
- Cameras/Photometers
- Electromagnetic wave receivers
- Nadir observations of TLEs and parent lightning



Sato et al. (2016)

Future TLE Missions

CNES

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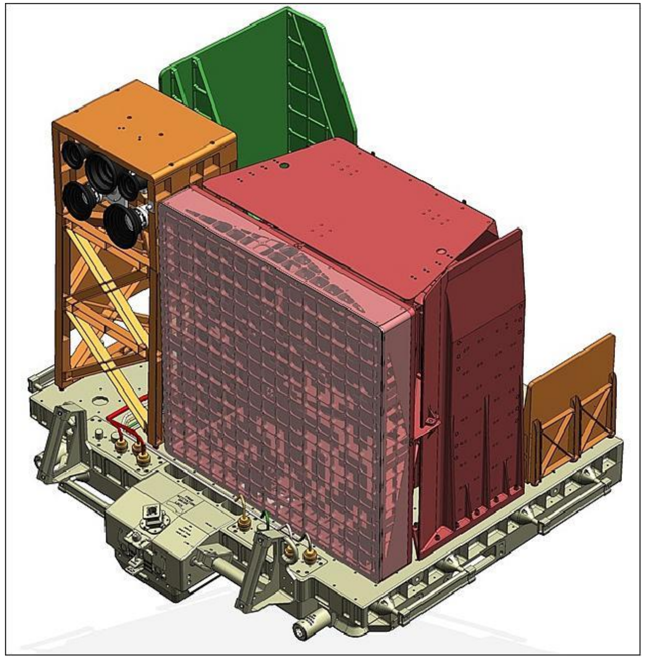
<u>TARANIS (Tool for the Analysis of RAdiations from lightNIngs and Sprites)</u>

- Polar-orbiting, sun-synchronous satellite
- Cameras/Photometers
- X-ray/Gamma-ray/HE electron detectors
- HF/LF antennas
- Magnetometer

<u>ASIM (Atmosphere-Space Interactions Monitor)</u>

- Integrate on International Space Station (ISS)
- Simultaneous observations of sprites and parent lightning
- MMIA (Modular Multispectral Imaging Array)
- MXGS (Modular X-ray and Gamma-ray Sensor)



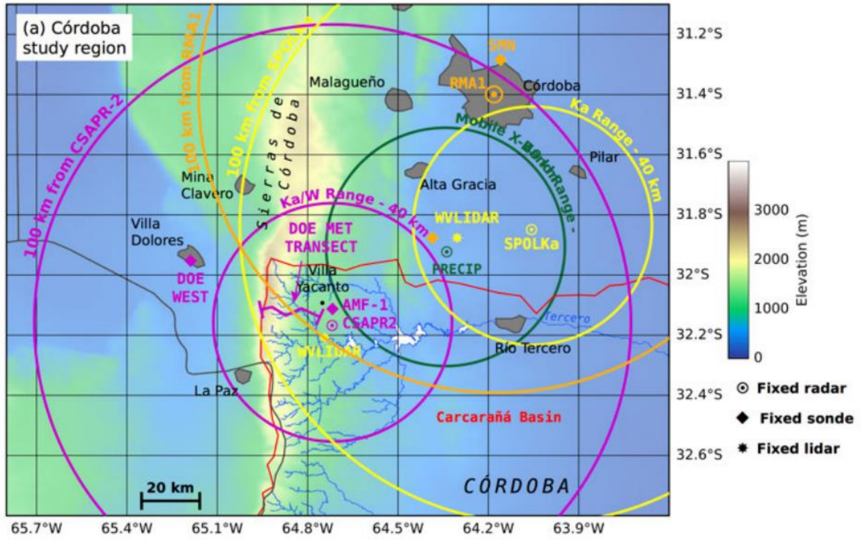
ASIM Team

projecto RELÁMPAGO • CACTI
NSF • DOE • NOAA • NASA • SMN • CONICET • INPE

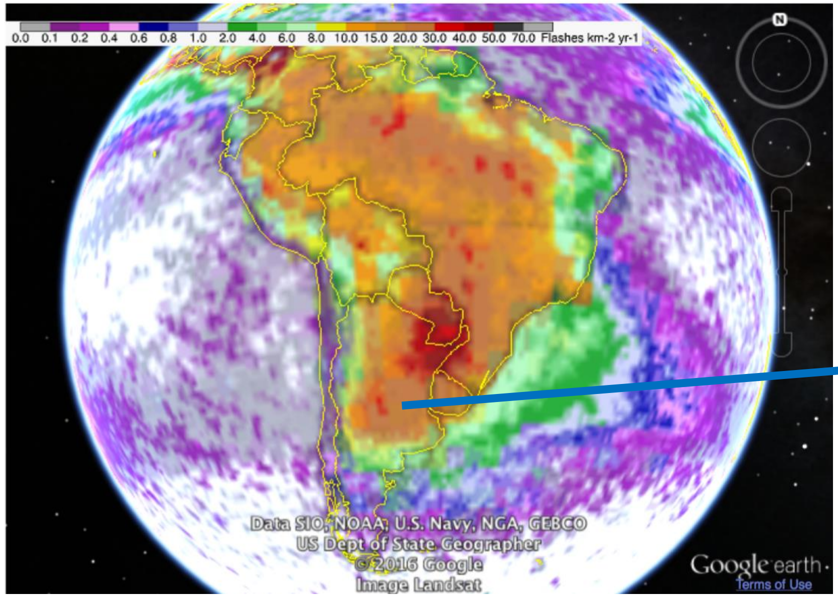
RELAMPAGO Field Campaign

- November-December 2018
- Enhanced radar/sounding network
- LEONA TLE observing network
- Lightning Mapping Array (s?)
- GOES-16 Support – ABI + GLM

RELAMPAGO Radar/Soundings

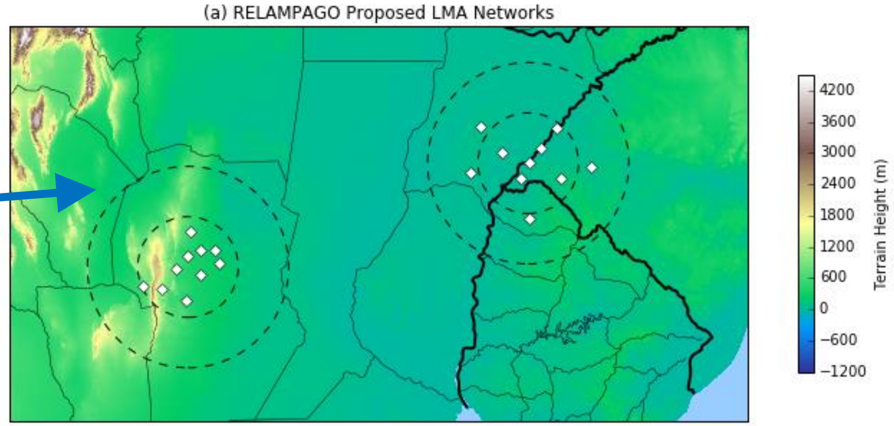


Steve Nesbitt



GHRC DAAC

RELAMPAGO LMAs



LEONA Network

Sao Sabbas Tavares (2013)

Future Analysis Paradigm

Moving toward global combined statistical analysis of sprites and convective storms

Data

- TLE observations – Spaceborne (TARANIS, ASIM, etc.), all-sky, and other dedicated camera networks
- Radar observations – GPM/IMERG, national radar networks (e.g., NEXRAD)
- Visible/IR – GOES-16/S ABI, Himawari, etc.
- Lightning – Geostationary (GLM, MTG-LI, etc.), ISS-LIS, ground VLF/LF networks (GLD360, WWLLN, etc.), LMAs

Methods

- Ground observations can provide time series of extremely large number of cases, need effective automation
- LEO sats can provide snapshot views, build up climatological database using IMERG, ISS-LIS/GLM, VIS/IR imagers