Integrating Space-Borne Lightning Characteristics and Ground-Based Metrics for Assessing Thunderstorm Intensity

Christopher J. Schultz[1], Themis Chronis[2] Daniel J. Cecil[1], Lawrence D. Carey[3], Phillip M. Bitzer[3] and William J. Koshak[1]

1- NASA Marshall Space Flight Center, Huntsville, AL
2- Earth System Science Center, University of Alabama-Huntsville, Huntsville, AL
2- Department of Atmospheric Science, University of Alabama-Huntsville, Huntsville, AL

This work is supported by NASA A.25 Severe Storms Research Award NNM11AA01A

Motivation

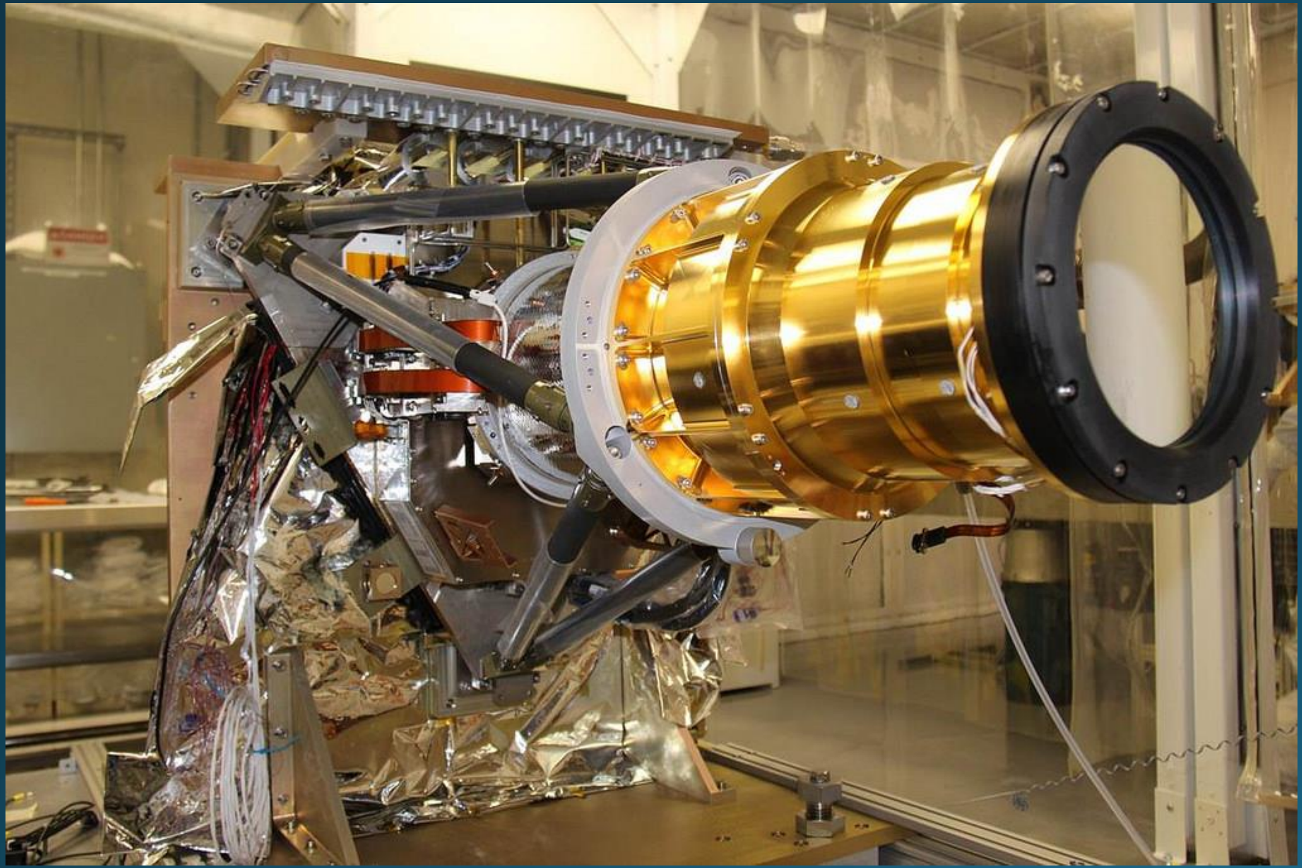


Image of the Geostationary Lightning Mapper, courtesy of www.goes-r.gov

- How do Geostationary Lightning Mapper observations align with ground based relationships between lightning and storm intensity?

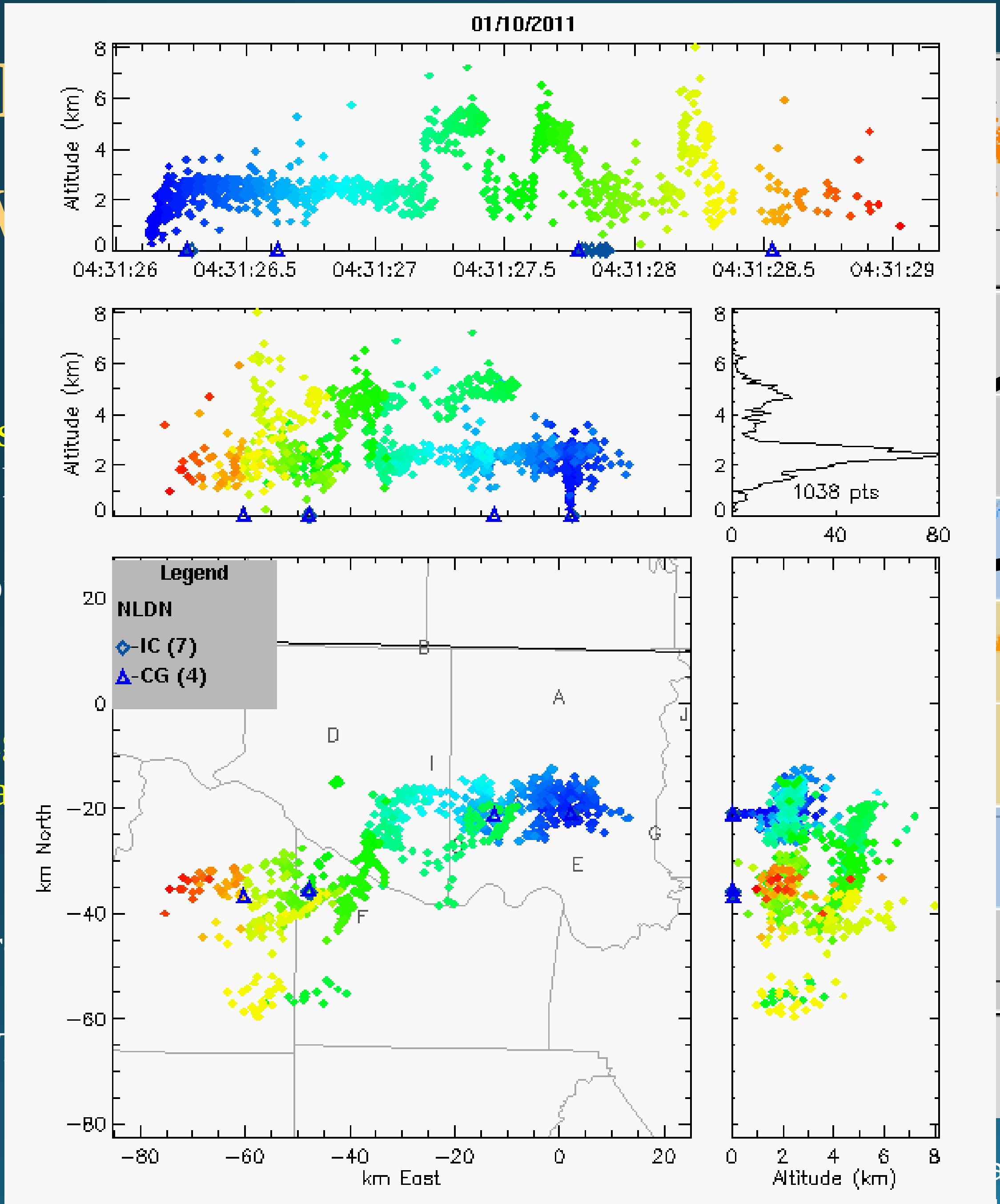
- What are some of the characteristics of sub-flash properties in a variety of storms?

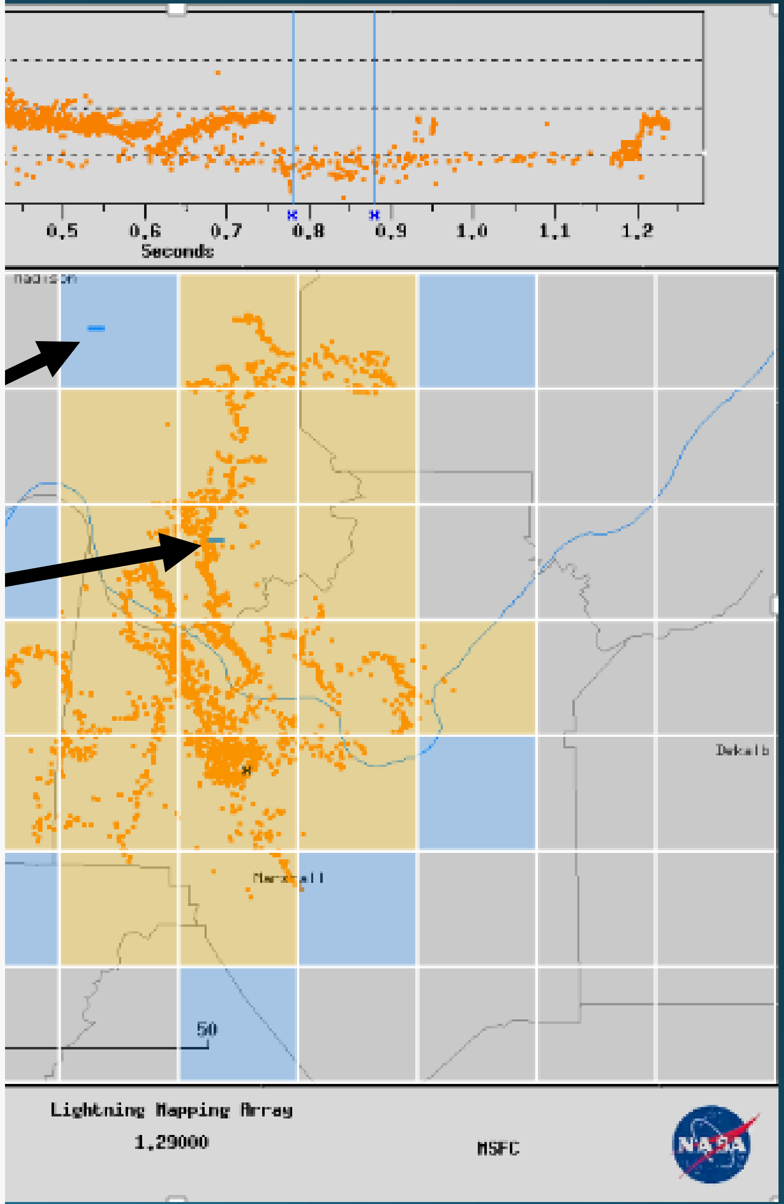
GOAL: take a first glance of well characterized storms to determine how GLM properties can enhance thunderstorm intensity measurements.

Why grou
networks w

Lightning Mapping Arrays
- limited in range (~150
  domain center). A
- Detect different parts o
  lightning flash.

LF/VLF (e.g., National Li
Detection Network and Ea
Networks)
- have larger domains
- detect fewer flashes/str
  LMA or TRMM-LIS
    - Bitzer et al. 2016, J
- No spatial component.

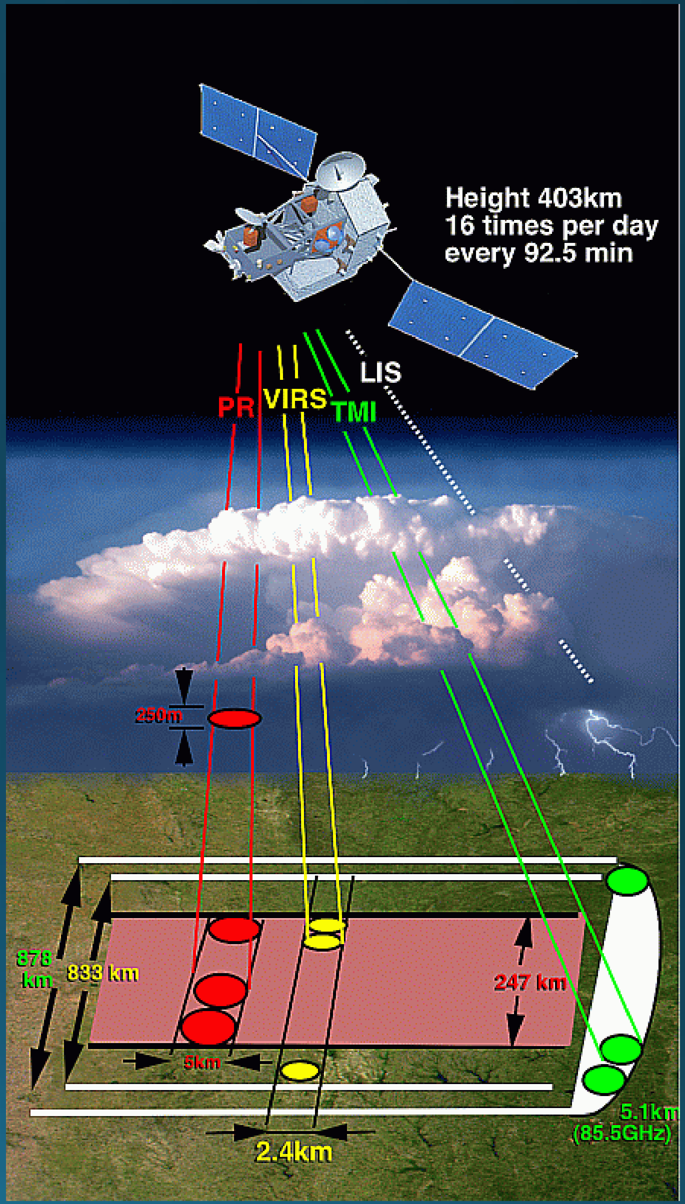




and NLDN (minus signs) overlaid for a single flash
Schultz et al. (2017), J. Operational Meteorology, in review

The Temporary Solution

- The best spaceborne lightning data is from the Tropical Rainfall Measuring Mission-Lightning Instrument Sensor (TRMM-LIS; Kummerow et al. 1998, Christian et al. 2000)
  - Limited temporal observations at a single location.
  - Lightning measurements very similar to GOES-16's GLM.



Data for Analysis

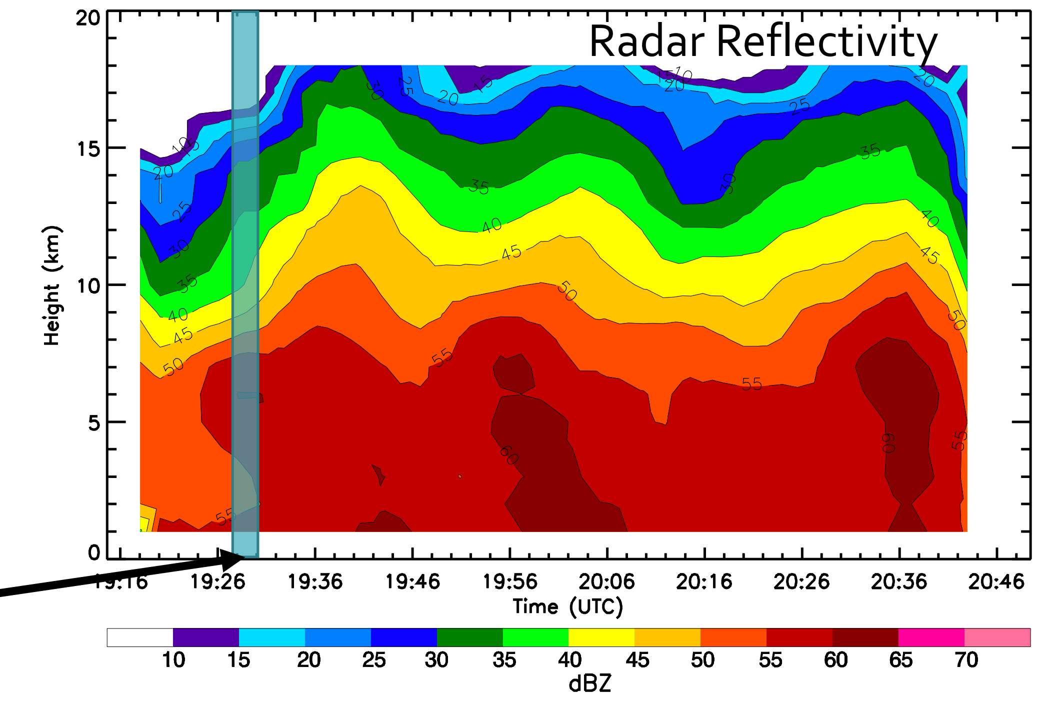
- Lightning data
  - Tropical Rainfall Measuring Mission (Kummerow et al. 1998)
    - Lightning Imaging Sensor (Christian et al. 2000)
  - North Alabama Lightning Mapping Array (NALMA)
    - Rison et al. 1999, Koshak et al. 2004

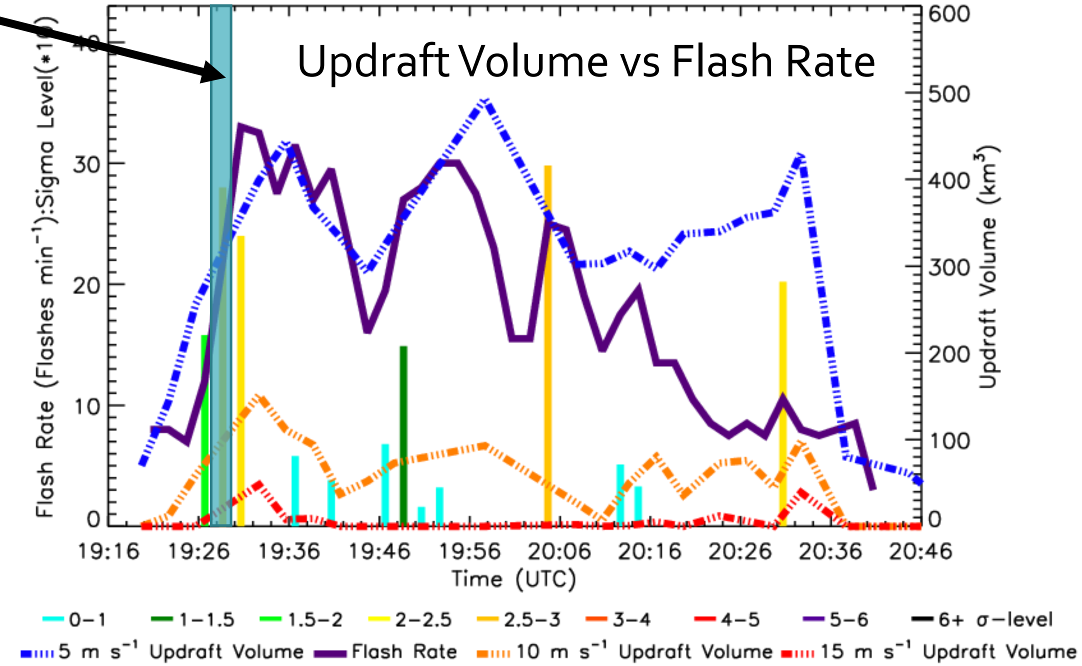
- Weather Service Radar, 88D (NEXRAD) radar information
  - Crum and Alberty (1993), Parks et al. (2009)
  - Horizontal reflectivity (Z), maximum expected size of hail (MESH)

Methods

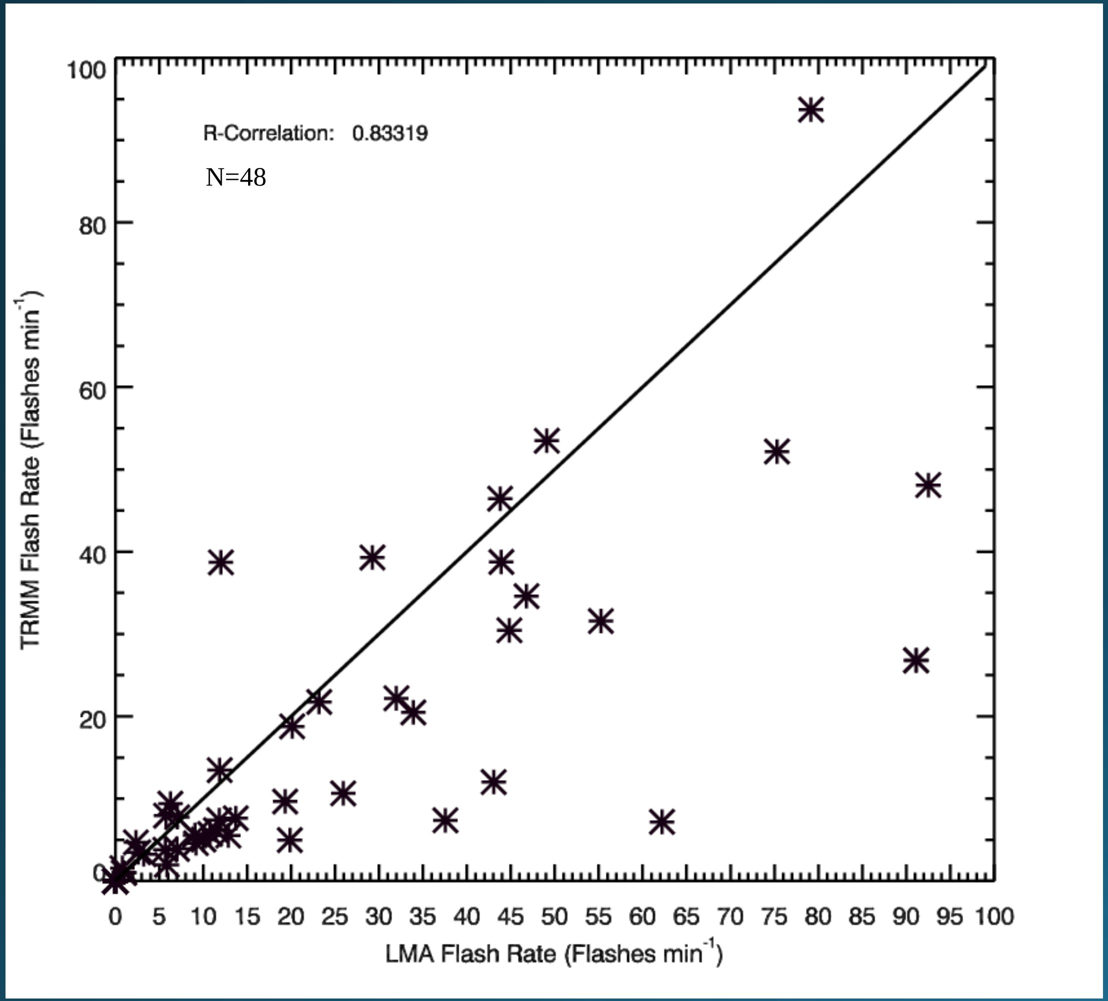
- 68 TRMM overpasses that were coincident with a 1500 thunderstorm database in Schultz (2015).
  - Data range 2002-2012
- These storms contained:
  - Location (time, latitude, longitude)
  - LMA flash rate
  - Reflectivity profile from NEXRAD
  - Maximum expected size of hail
  - Severity information
- Normalized flash rate based on satellite overpass duration.
- Used Conditional Probability Metrics to quantify utility in identifying severe thunderstorms.

Blue box represents time of TRMM overpass





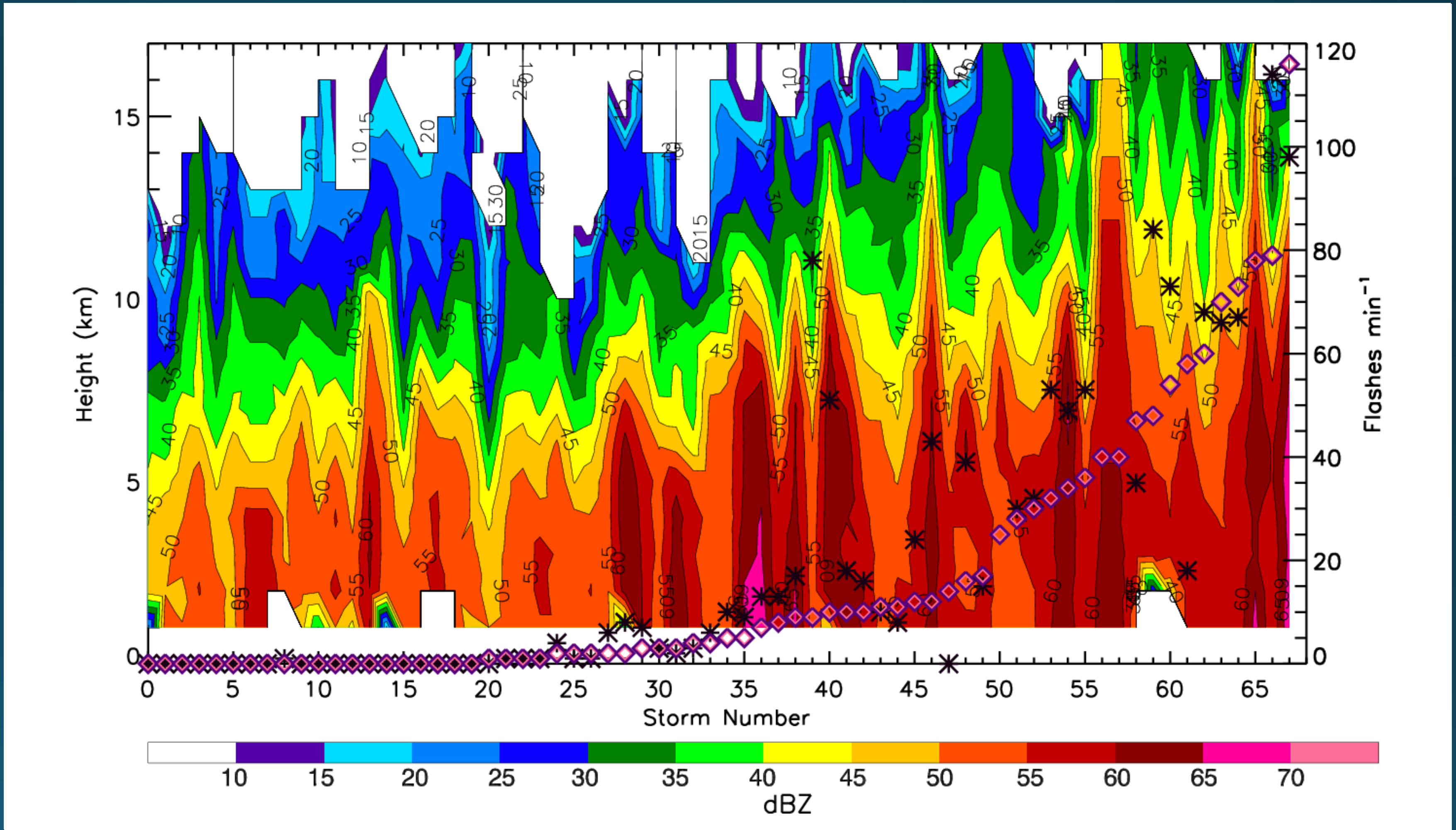
LMA Flash Rate vs TRMM Flash Rate



- Strong correlation between LMA flash rate and TRMM-LIS flash rate.
  - R=0.88, not using zero flash storms.
- Range from LMA and small parallax offsets have not been accounted for yet.
  - Tracking at 6-7 km, TRMM-LIS assumes 13 km height.

Reflectivity Profile of Thunderstorms vs TRMM-LIS Flash Rate

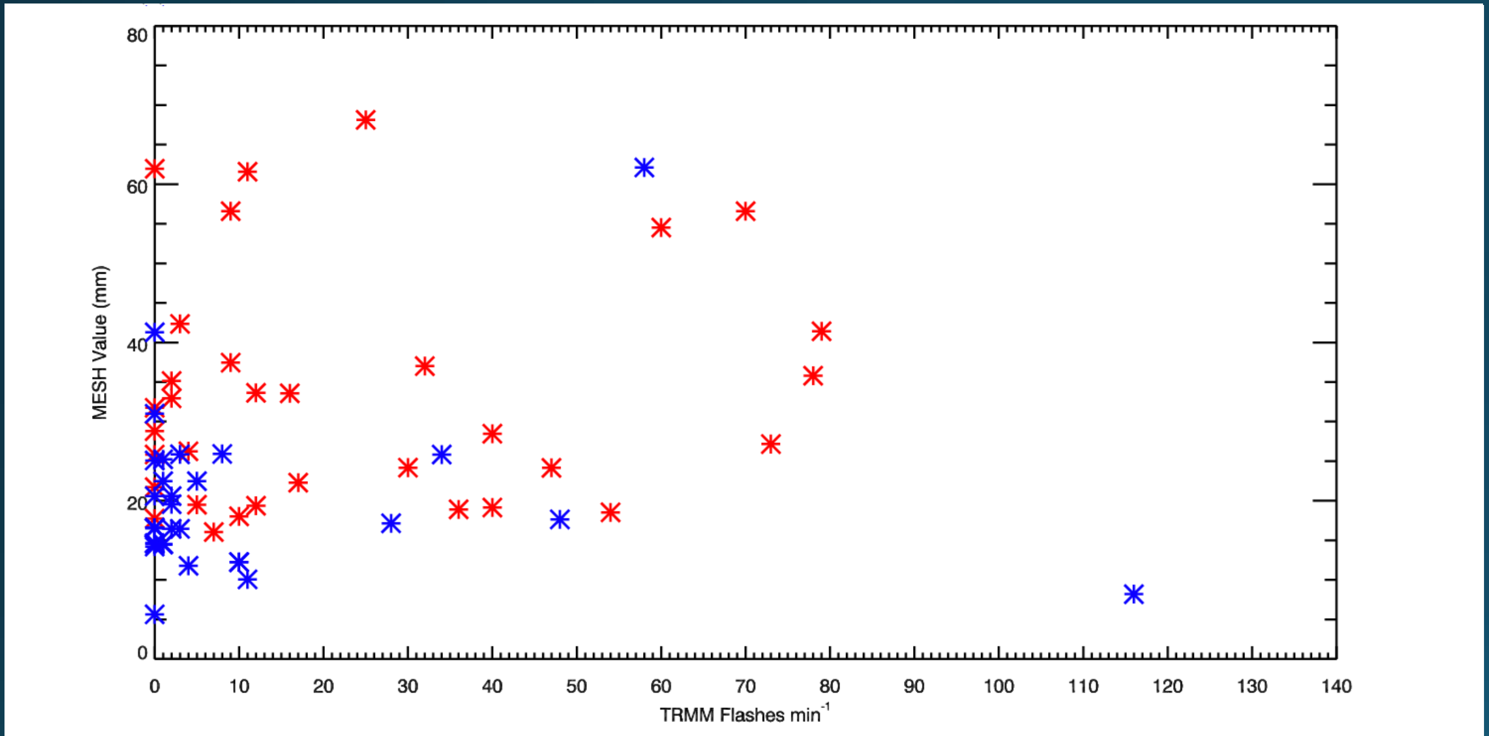
- As expected, different reflectivity profiles produce different flash rates.
- For the most part, LMA flash rates are higher than TRMM-LIS flash rates.
- Useful though to see how the order of "intensity" changes with different flash properties.



Less Intense

More Intense

MESH and TRMM Flash Rate



- Chronis et al. (2015) demonstrated that storms with lightning jumps and higher flash rates had larger MESH values.
- Schultz et al. (2016) showed that combining storms with MESH and lightning jumps objectively identified severe storms better than MESH alone.

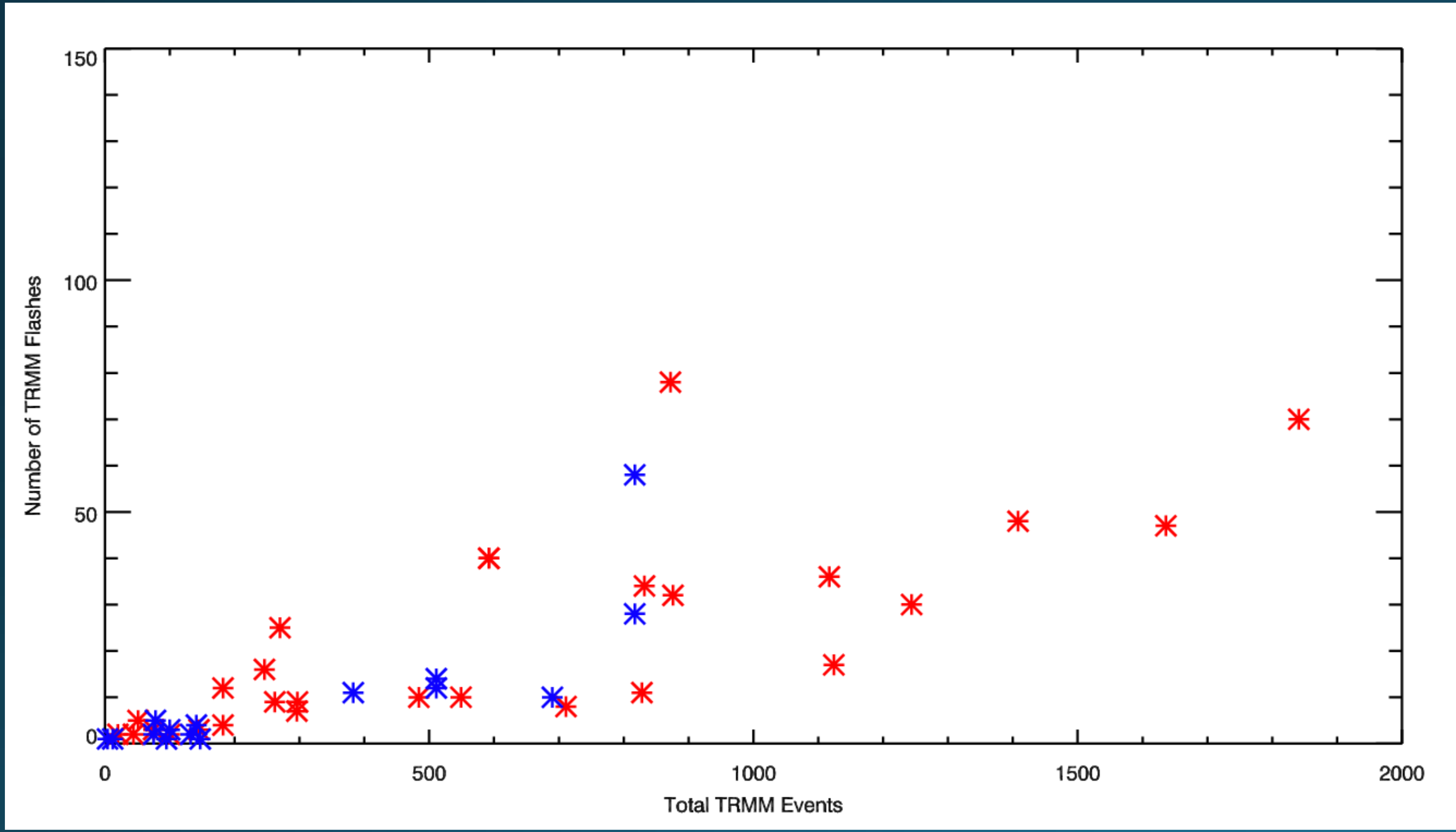
Conditional Probability of a storm being identified as severe:

MESH Alone (MESH≥ 25.4 mm): 48.6% (18/37)

Flash Rate ≥10 flash min^{-1}: 69.6% (16/23)

Flash Rate ≤10 flash min^{-1}: 40.0% (18/45)

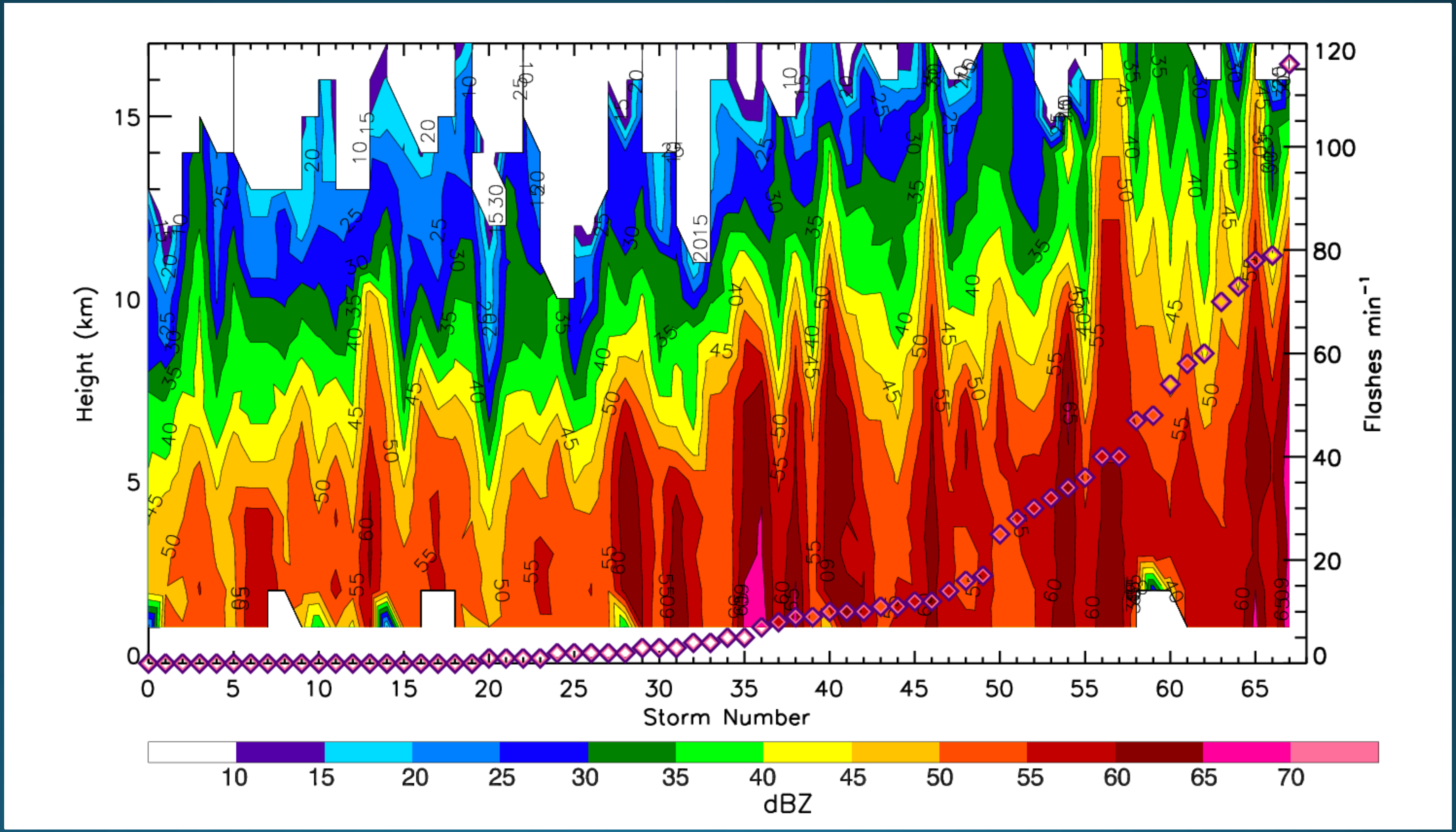
What are the range of LIS event rates?



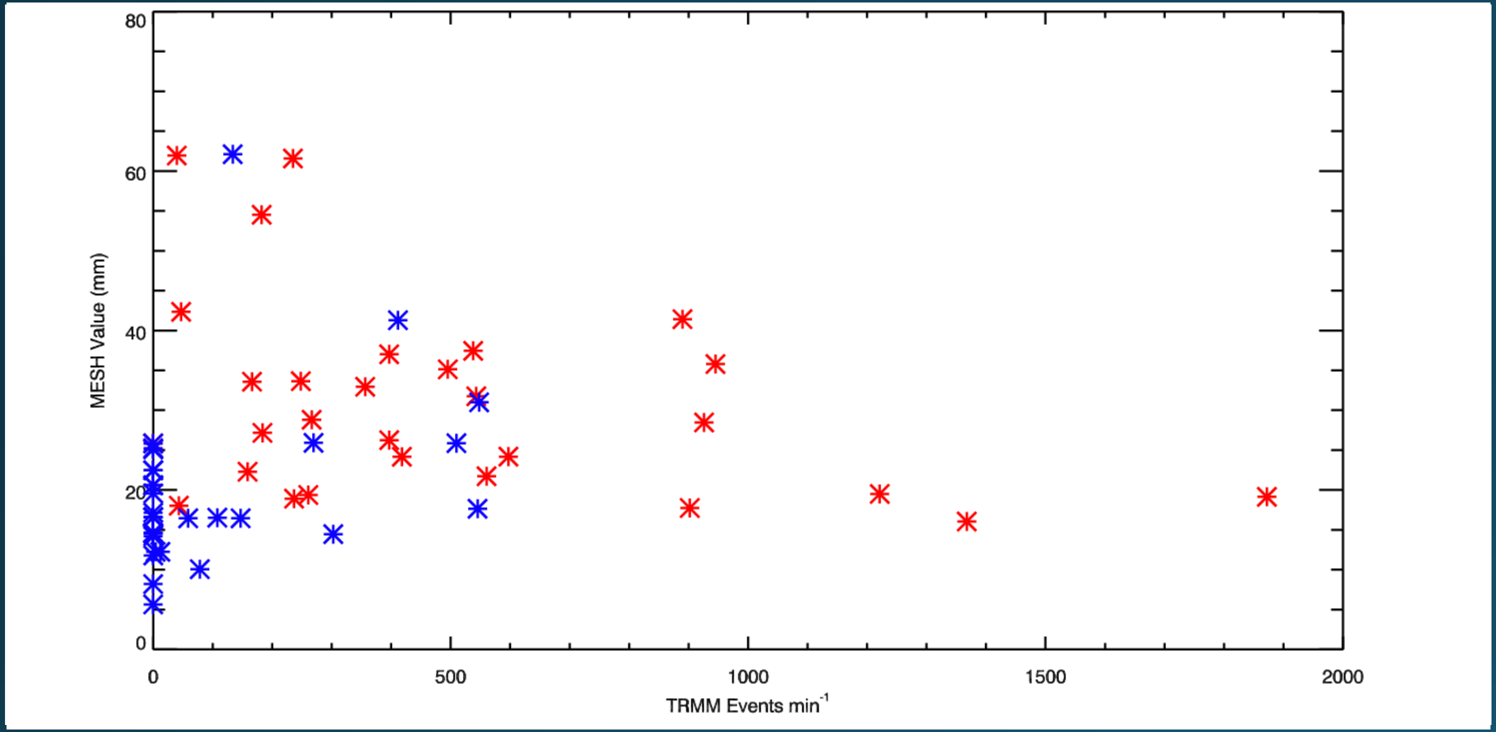
- More flashes should result in higher event rates.
- R-correlation with number of flashes is strong
    - R=0.93

Reflectivity Profile of Thunderstorms vs TRMM-LIS Event Rate

- Slight differences in reflectivity profiles if the event rate is chosen as the intensity metric instead of flash rate.



MESH and TRMM event rates



- Highest event rates don't necessarily correspond to the strongest mesh values.
- Seem to separate severe from non-severe in this limited sample.
  - Conditional probabilities slightly higher than using flash rates.

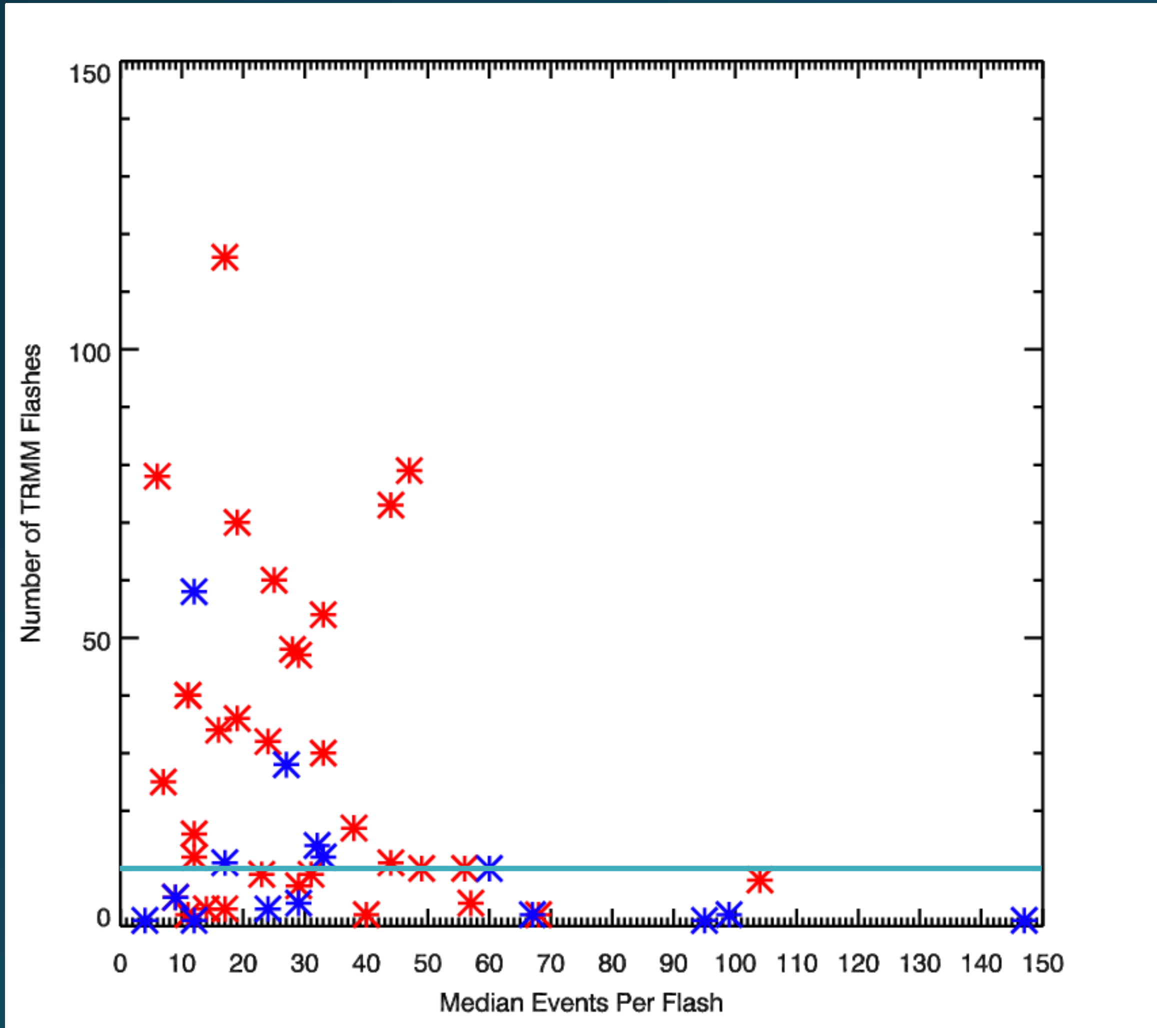
Conditional Probability of a storm being identified as severe:

MESH Alone (MESH≥ 25.4 mm): 48.6% (18/37)

Events Alone (≥100 events min^{-1}): 76.9% (30/39)
Events Alone (≥200 events min^{-1}): 73.5% (25/24)

Events Alone (≤100 events min^{-1}): 13.7% (4/29)
Events Alone (≤200 events min^{-1}): 17.5% (6/34)

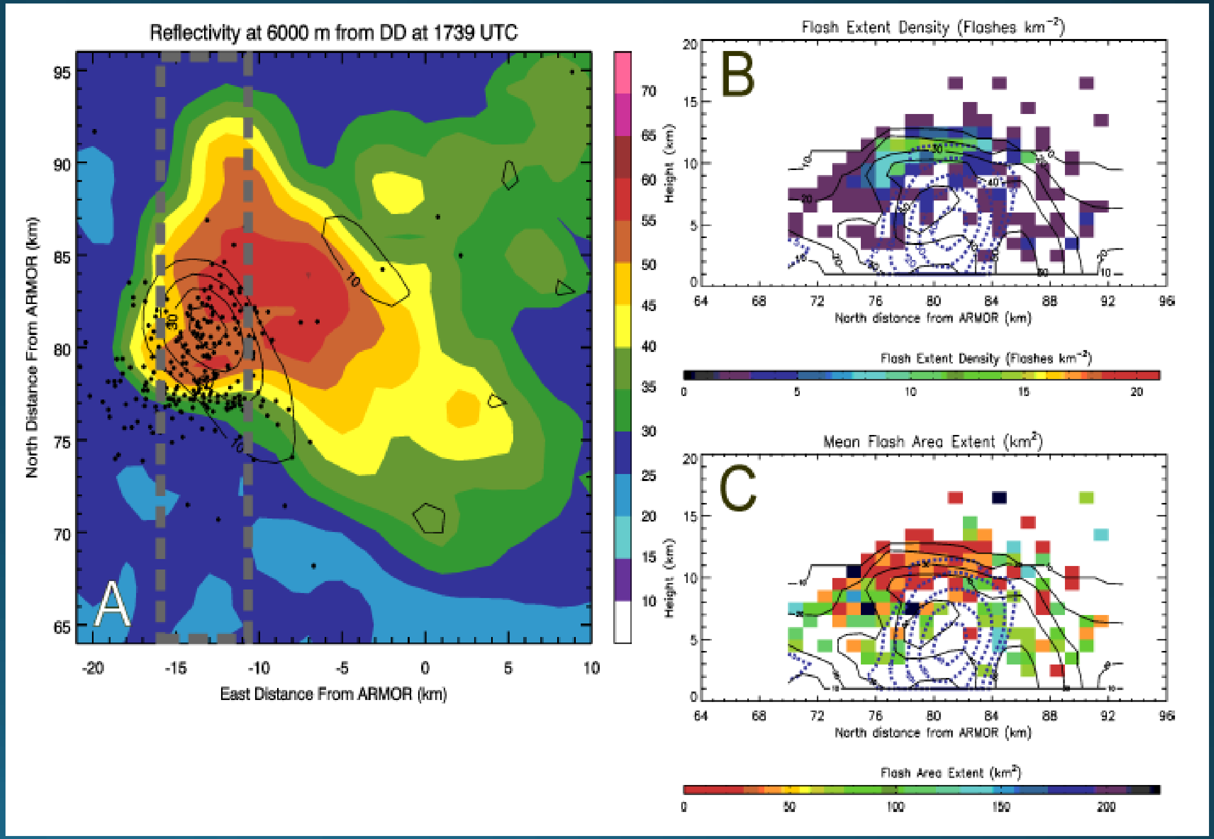
TRMM Flash Rate vs Events per Flash



- Flash rates > 20 flashes min^{-1} tend to have fewer than 50 events per flash.
- Probability of severity increased in this sample as flash rate increased and events per flash decreased.
  - 25 of 34 severe storms reached 10 flash min^{-1} threshold for 2σ lightning jump algorithm.
  - 6 of 34 non-severe reached this flash rate threshold.

Evidence of Flash Rate vs Flash Size Relationships?

- Increasing flash rate results in a decrease in flash size.
  - Bruning and MacGorman (2013)
  - Calhoun et al. (2013)
  - Schultz et al. (2015, 2017)
- Provides an idea of kinematic texture (i.e., updraft location, turbulence).



Schultz et al. (2017), WAF, EOR

Discussion/Conclusions

- TRMM flash rates are in good correlation with the LMA flash rates.
- Flash rate and intensity metrics to extend to the satellite realm.
- Event rates and events per flash show additional promise of helping discern storm intensity.
  - Highest conditional probabilities for severe identification was with events, followed by flashes, then MESH alone.
- This work did not incorporate any lightning jump information.
  - Have to wait for GLM data to examine how to alter the current lightning jump algorithm.
  - Important because the jump provides the lead time on peak intensity (Schultz et al. 2009, 2011, 2015, 2016).
- Plan to also incorporate flash energy information into the algorithm.