GLM Science Meeting 2019: Cal/Val highlights

Overview presented by
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Results courtesy those listed on each slide

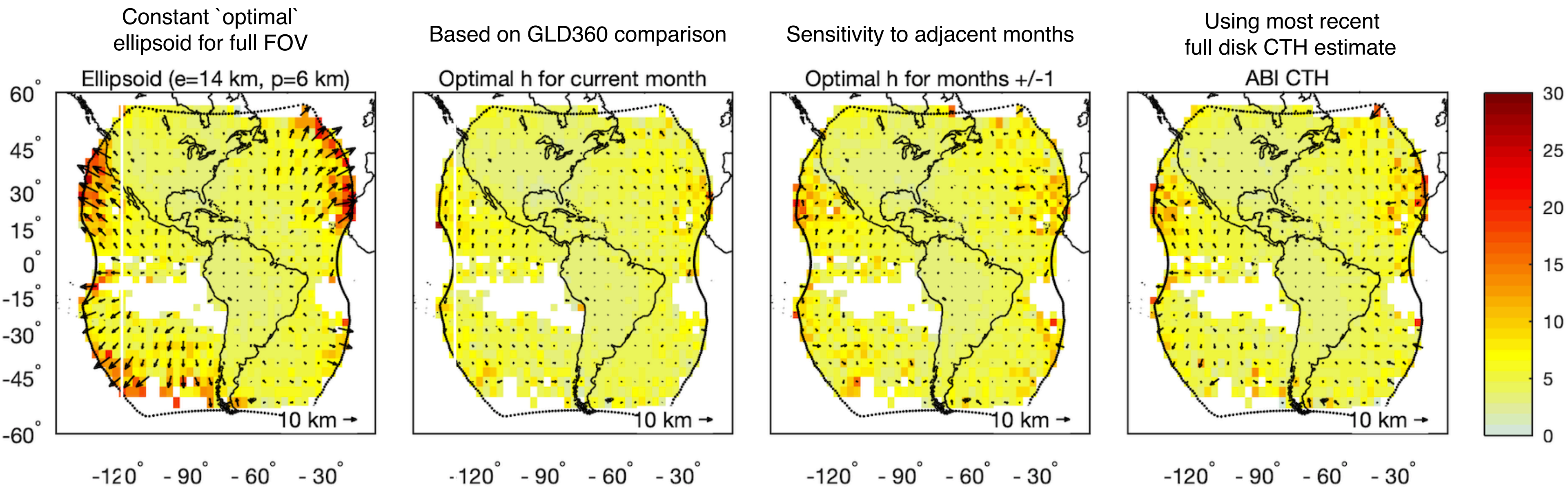
MTG LI MAG Meeting
EUMETSAT
Darmstadt, Germany
29-30 January 2020

SUMMARY OF CAL/VAL STATUS

- Based on comparison with global LF/VLF networks *(Bateman, Cummins)*:
  - *DE is ~70% (spec) over full field of view over 24 hours. Better at night.*
  - *Location and timing accuracy meet spec; are unbiased (Virts, Cummins)*
  - *As of September, FAR remained too high*
    - False events from glint, solar intrusion, blooming, subarray boundaries
    - A few really bad periods or locations overwhelm otherwise sound operation of the basic detection principle and filtering methods inherited from LIS
  - *Next ground system update (DO.09, April, TBC) should improve FAR:*
    - ADR 519 -- WR 5480 -- GLM Lightning L2 Radiation filter threshold
    - ADR 879 -- WR 6809 -- Incorrect GOES-17 GLM L2+ Event Longitude Values
    - ADR 903 -- WR 6865 -- GLM Geolocate does not handle empty EFRC output
    - ADR 961 -- WR 7129 -- Time Error in GLM Metadata
  - *GOES 17 Full Validation assessment expected May 2020.*
- Clustering sensitivity study *(Mach)*:
  - *Varying space and time parameters changes flash rate by less than 5-10% except for very high flash rates (~ 1 per second, 6% of all groups, 3% of flashes)*

LIGHTNING EMISSION HEIGHT OPTIMIZATION (*QUOTING VIRTS*)

- Lightning ellipsoid used operationally displaces observations toward nadir; largest location errors near the limb
  - *Lower ellipsoid (e=14 km, p=6 km) was implemented in fall 2018*
- Monthly optimal detection height maps are available that significantly improve location accuracy near the limb
- Further refinements possible for diurnal cycle and/or flash type

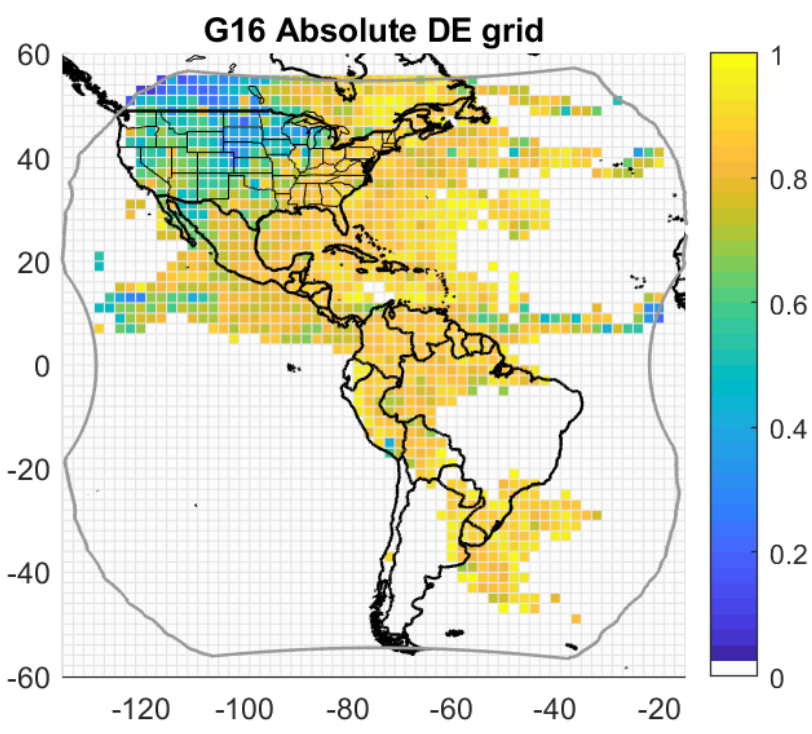


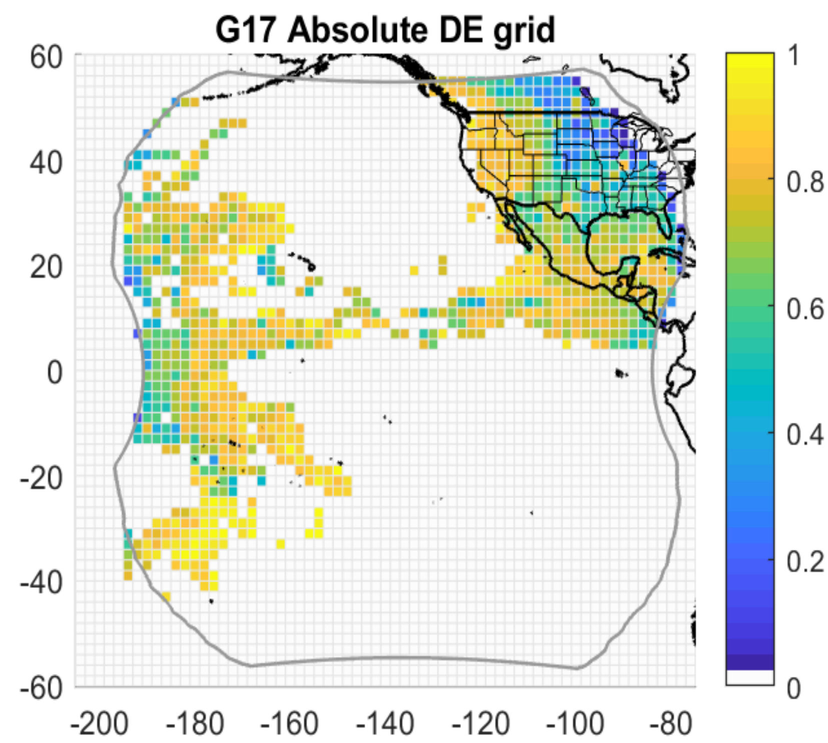
THERE IS GEOGRAPHIC VARIABILITY IN DE DUE TO VIEWING ANGLE AND METEOROLOGY

- For individual storms using more detailed measurements, especially at VHF, flash DE can be quite low. Why?
  - *10-60% is not unusual, especially in severe storms*
  - *A challenge for operational applications - how can we rely on lightning?*
- We'll look at some examples, but start with geographic variability over full field of view

MINIMUM DETECTABLE ENERGY IS MODIFIED BY METEOROLOGY AND LIGHTNING PHYSICS

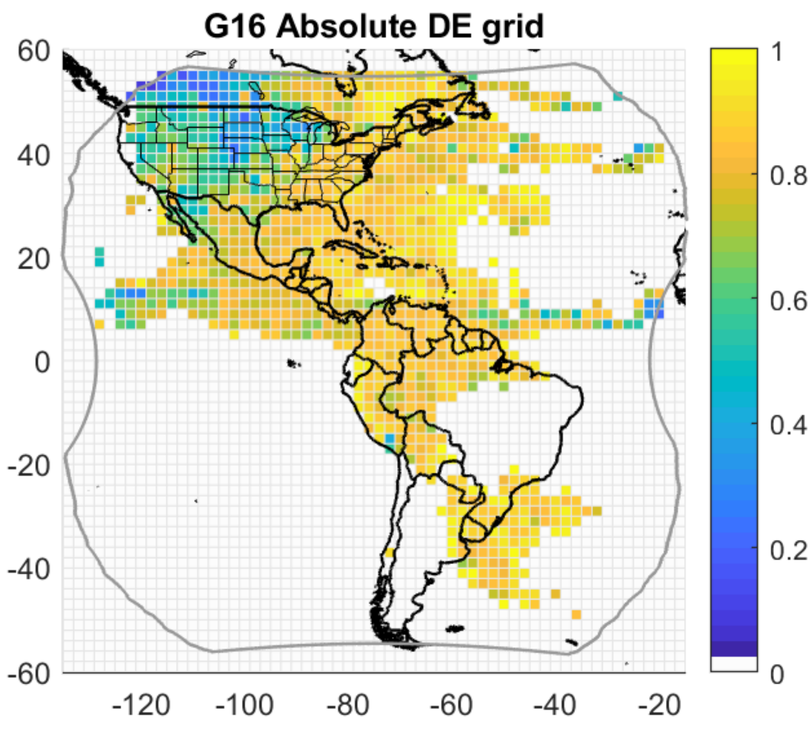
- Below: Comparison to GLD360, July 20-31 *(Cummins)*
- Study of Western, Central, and Eastern Canada, several cases per region *(Yang)*
  - *On average 48% of Southern Ontario LMA flashes detected by GLM*
  - *On average 52% of CLDN flashes detected by GLM but varies with location*
    - worst in WEST and CENTRAL regions

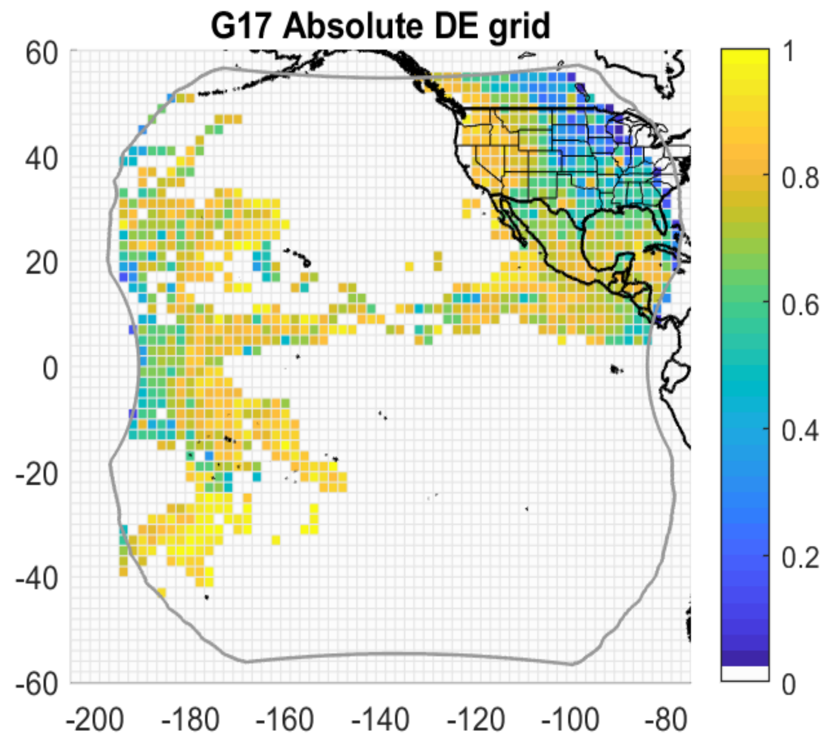




MINIMUM DETECTABLE ENERGY IS MODIFIED BY METEOROLOGY AND LIGHTNING PHYSICS

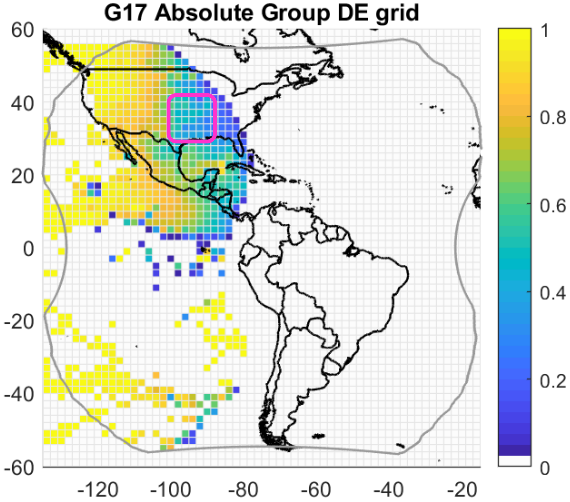
- We will soon see lots of DE variability that varies by storm, flash (type, size, duration), and cloud properties.
- First, a basic, systematic effect: geographic dependence on boresight-relative position.
- Can use GLM 16 vs. 17 in region of overlap to observe optical-optical with same detector

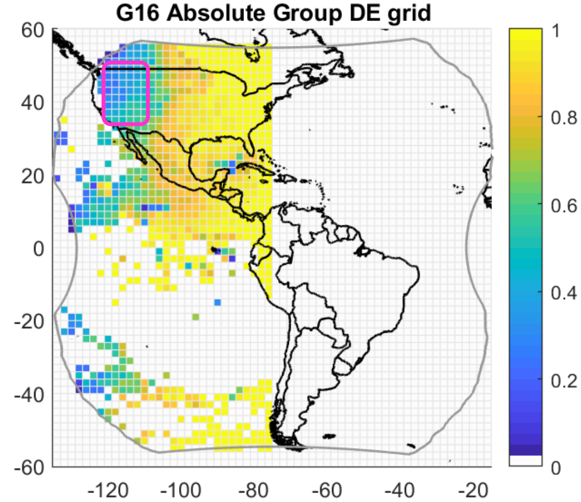


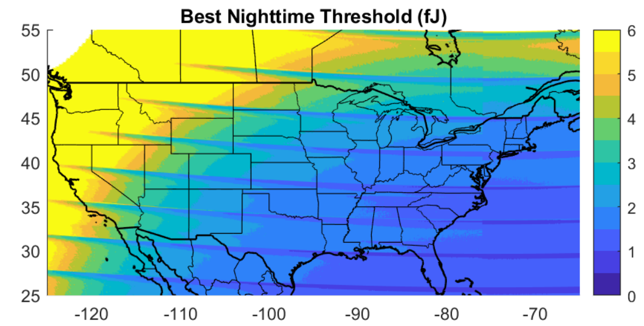


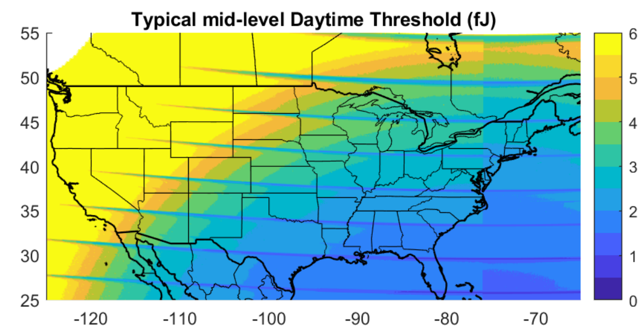
SYSTEMATIC VARIATION IN OBSERVED MINIMUM ENERGY AS A FUNCTION OF VIEWING ANGLE *(CUMMINS)*

17 / 16 20-31 July 2019 16 / 17









- Since we're looking at optical most other things are equal, but there is a clear bias toward lower DE on the periphery of each field of view. Also confirmed by *Thiel / Calhoun.*
- The minimum detectable event energy in any given location is shown on the right, and there is clearly an angular dependence, as well as stripes of higher DE at the position of CCD subarray boundaries.
    - *Pixel size/shape, chromatic aberration / filter cutoff, other hardware effects?*
- Minimum event energy can be monitored on relatively short intervals to assess effective threshold and infer DE — an idea under study by the GLM team. As we will see, there is a systematic relationship between the minimum energy threshold and detection efficiency. Important to reserve enough bits to monitor small threshold differences.
- There are other factors that contribute to DE, such as typical flash area and duration — the topic of the next few slides.

Highly variable DE from GLM East and West in Colorado (*Thomas*)

4 Small storms in Colorado

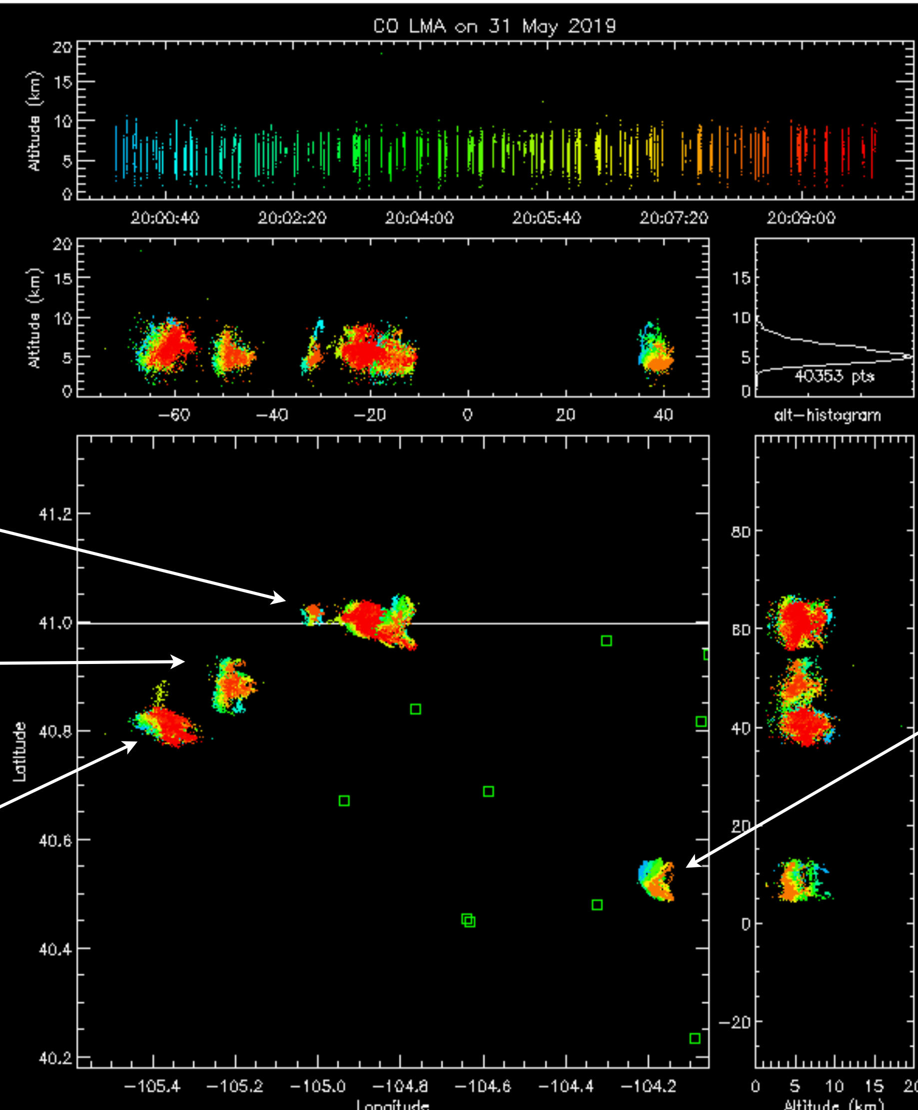
These storms have Negative layer over a Positive layer

North storm
DE=39% GLM-West
DE=28% GLM-East

North-Western Storm
DE=60% GLM-West
DE=20% GLM-East

West Storm
DE=13% GLM-West
DE=7% GLM-East

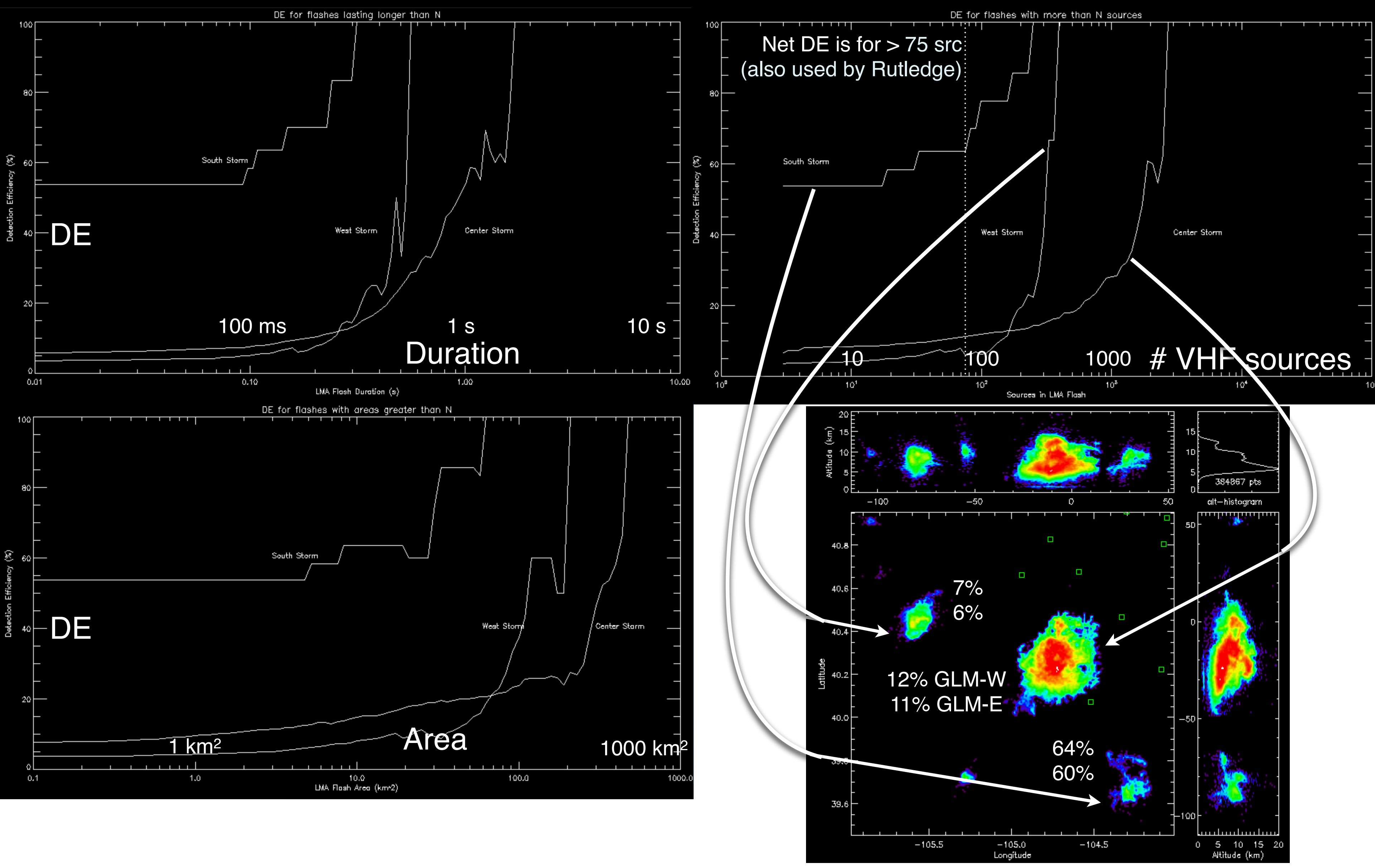
75 source minimum



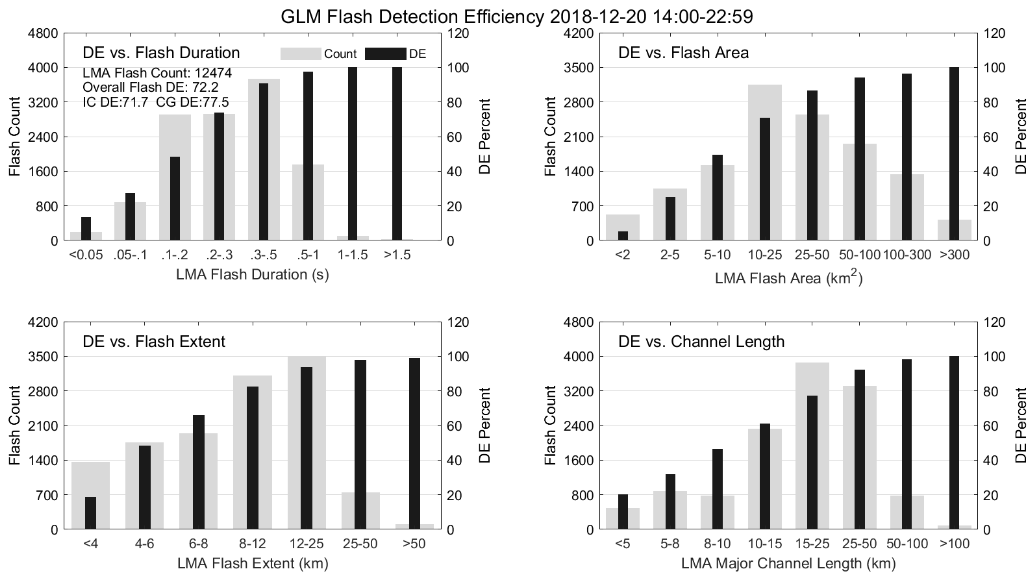
Highly variable DE illustrates a range of factors are in play, and wide variability in any given storm or scene or case is possible.

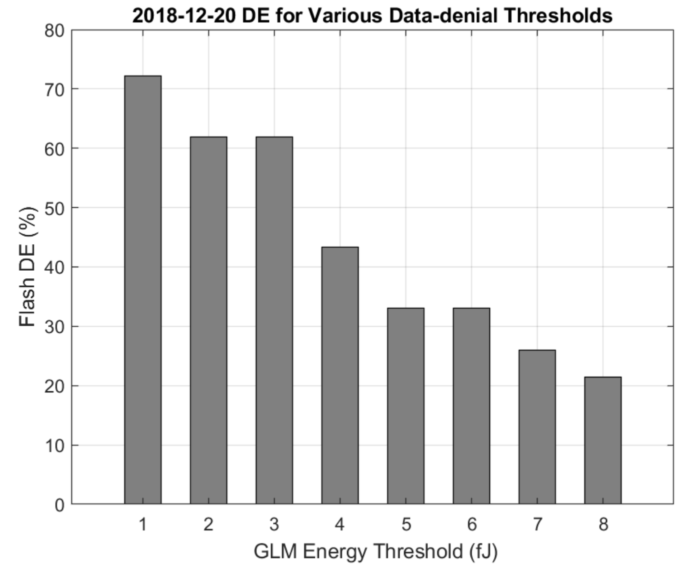
South-East storm
DE=33% GLM-West
DE=56% GLM-East

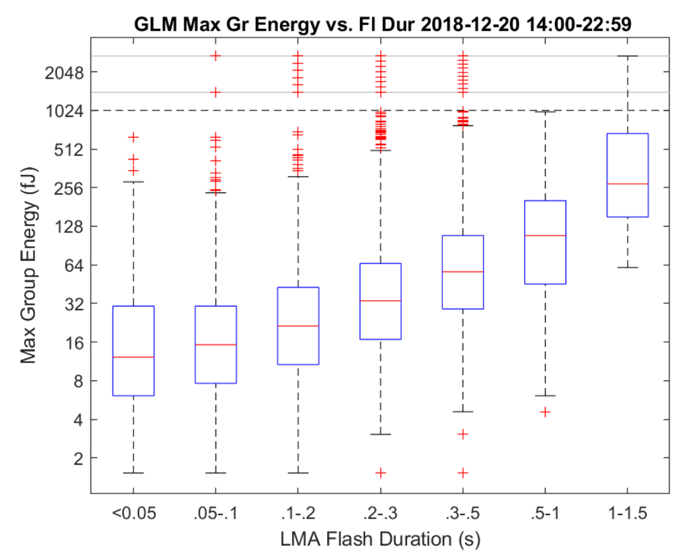
Variable DE in Colorado as a function of flash size, duration, and storm *(Thomas)*



DE for flash size, duration, and energy, KSC Florida LMA *(Cummins and Zhang, JGR in review)*







- G16 GLM: 72% overall DE. Better DE with larger flash area, width, duration (black bars)
- 1 fJ group energy minimum (above, right) is right at the edge of acceptable 70% performance. FDE drops ~10% with each additional fJ.
- Smallest LMA flashes have less energy

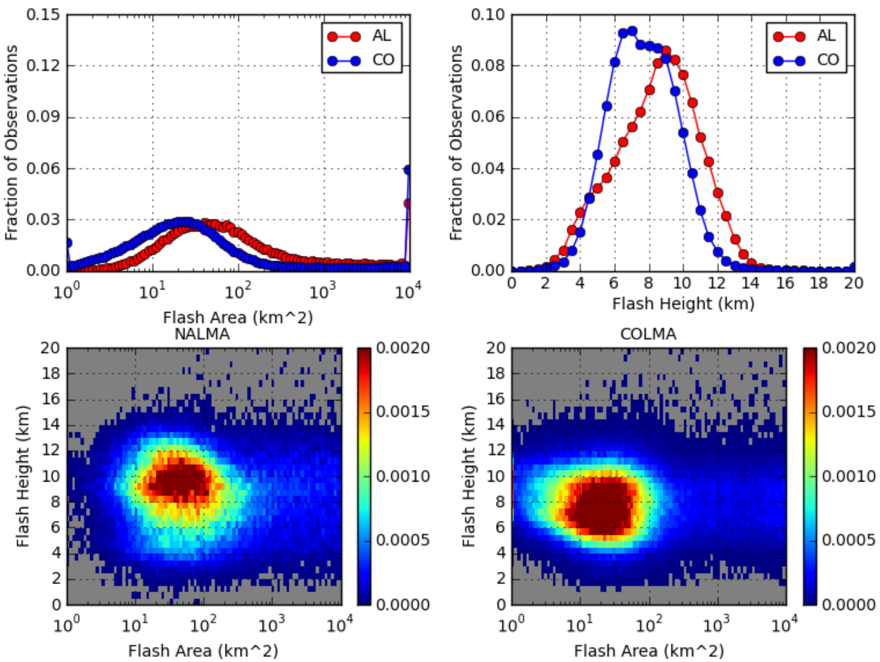
Ice water path and flash size only partially explains lower DE in central US *(Rutledge)*

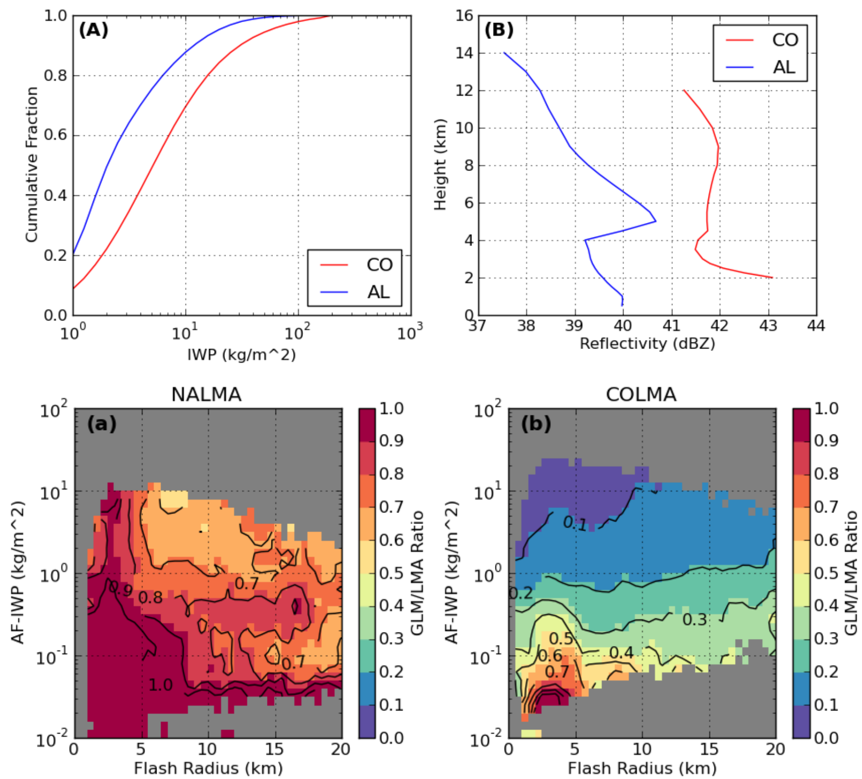
Many cases

- minimum 75 LMA sources/flash
- Colorado = 20-30% DE.
- Alabama = 70% DE.

LMA: AL flashes tend to be larger and closer to cloud top than in CO

Ice water path estimated from radar was larger in Colorado, and larger IWP had lower DE. Controlling for IWP as a function of flash width doesn't explain explain differences in AL vs. CO DE. Perhaps differences in non-precipitating cloud water and ice (not detectable by radar) explain the discrepancy. The systematic geographic variability of the minimum flash energy threshold plays a role.

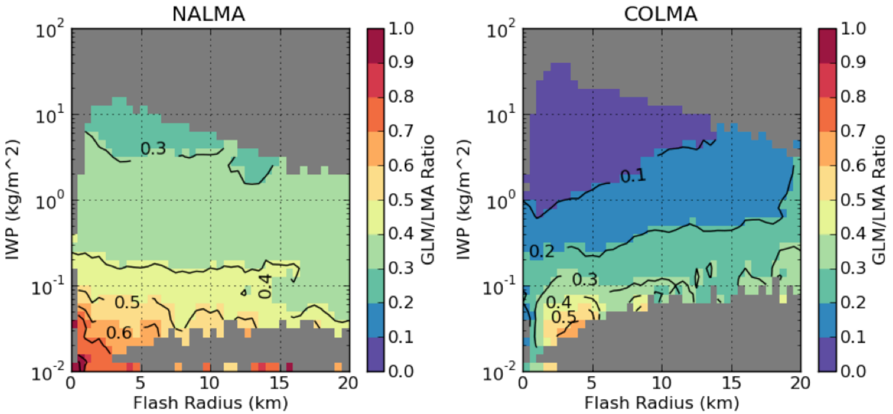




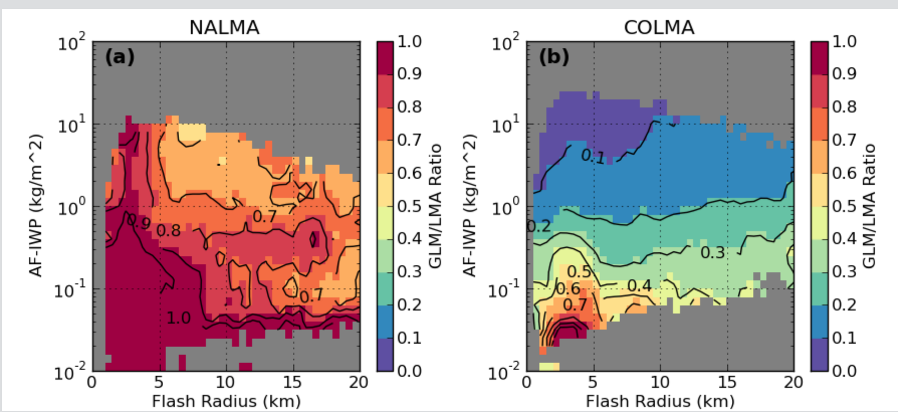
DE for cloud top water and above-flash ice water paths (Rutledge)

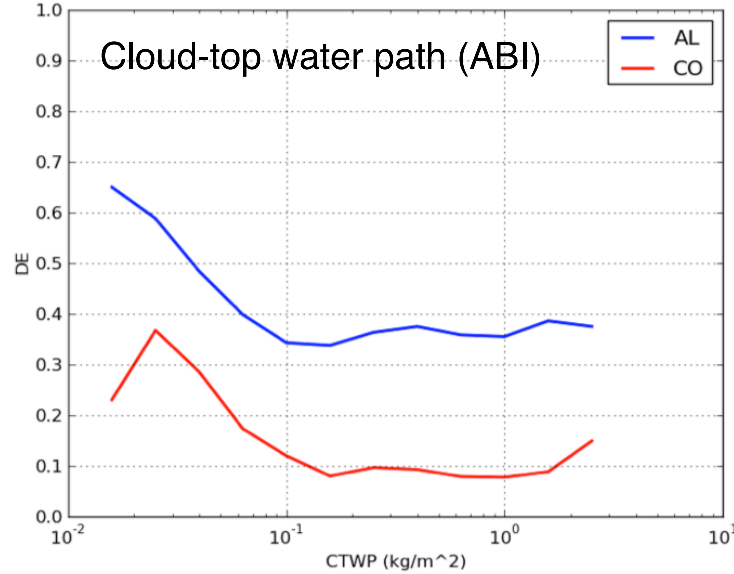
DE(*IWP* vs. *flash radius*)

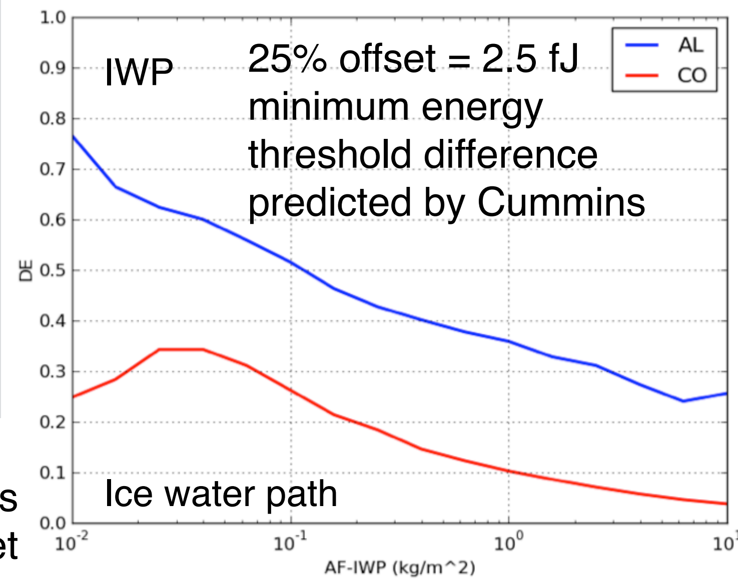
10 pt (this slide)



75 pt



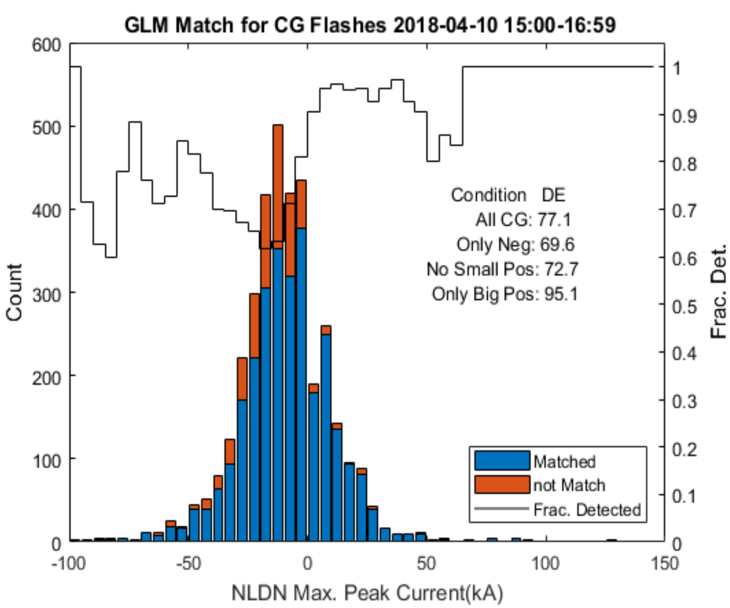


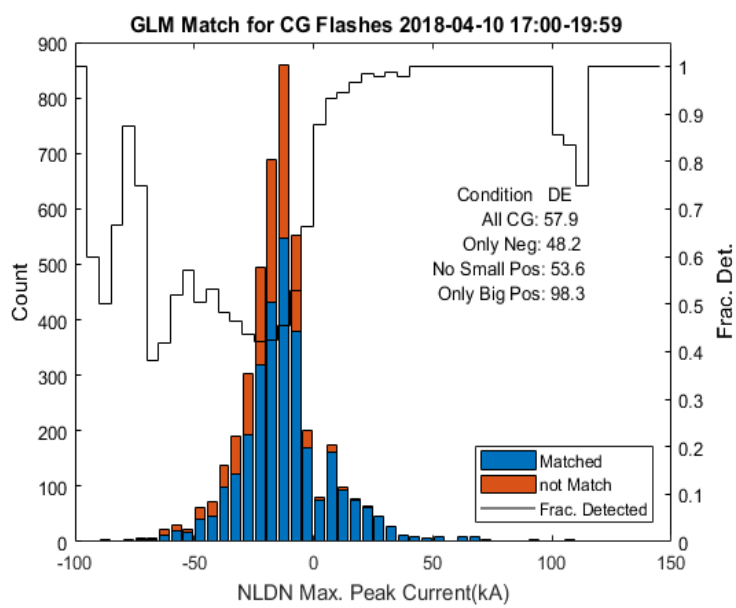


Some bias toward nocturnal storms in the NALMA dataset also may explain the offset

DETECTION DEPENDS ON FLASH TYPE AND PHYSICS OF LIGHT EMISSION ALONG THE FLASH

- DE was greater for CGs vs. ICs and for larger peak currents *(Said and Murphy, Bitzer, Zhang and Cummins)*
  - *Zhang: CG flashes have much larger initial areas and energies; both grow with time during first 400 ms of typical LIS flash.*
- Interferometer studies *(Stanley)* showed that best chance of detecting low-altitude channels (negative) corresponded to sudden extensive branching.





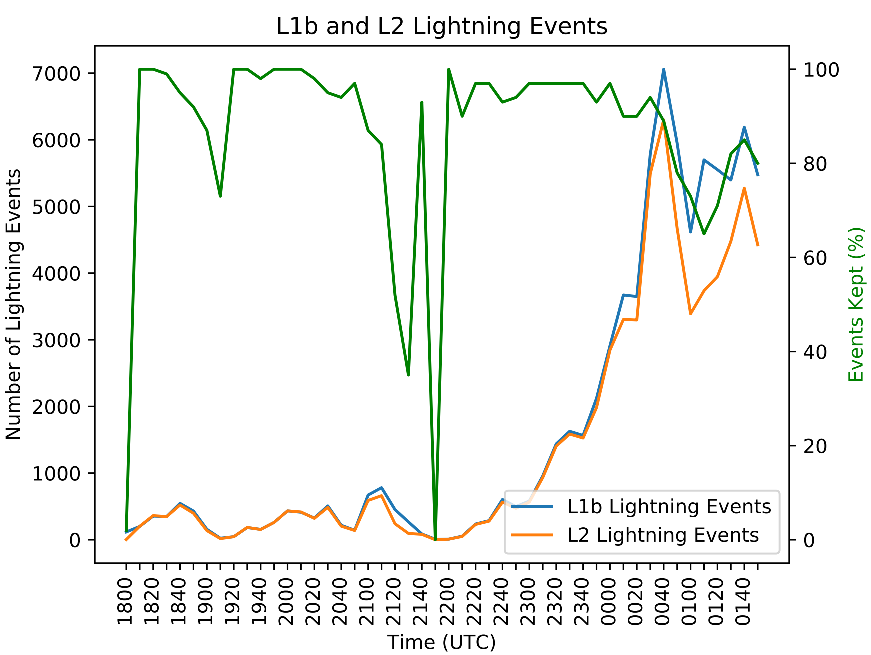
CG DE statistics for one case studied by Zhang and Cummins

First GLM group in each flash is crucial during high flash rates *(Weiss, Bitzer)*

***Bitzer's* study of L0 vs L2 in Colorado**:
First event in each lightning flash is often dropped between L1b and L2. 85% of all flashes had L0 event before L2 event (on average 51 ms prior)!
Reprocessing from L0:
Improved flash DE by 10-15%
and detected more, low peak current CGs.

All cells

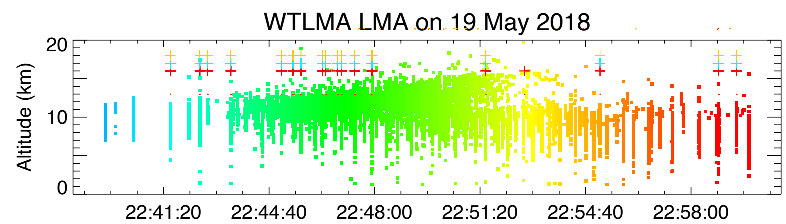
5-25% of events dropped between L1b and L2

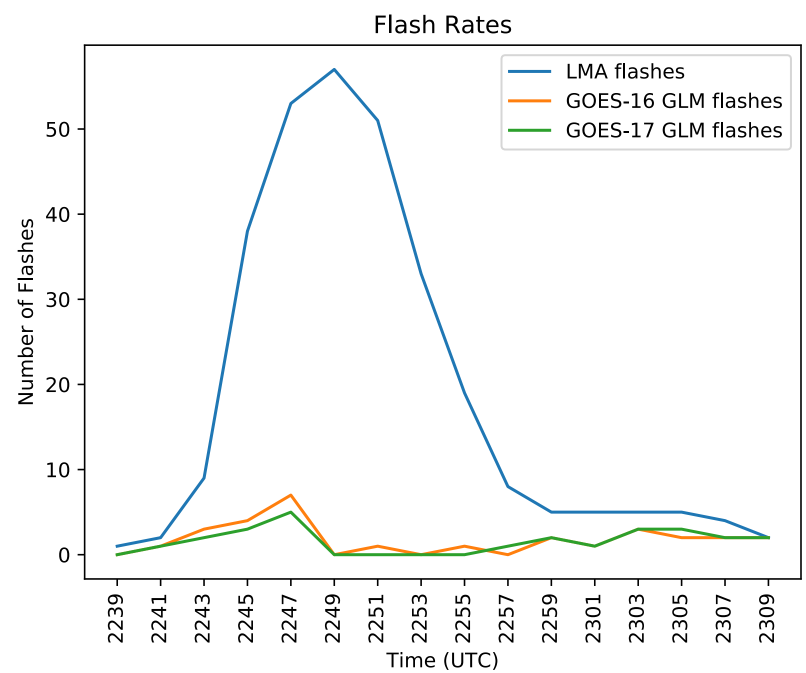


West Texas, 19-20 May 2018, GOES-16

Cell with updraft surge

Very low DE — small updraft discharges

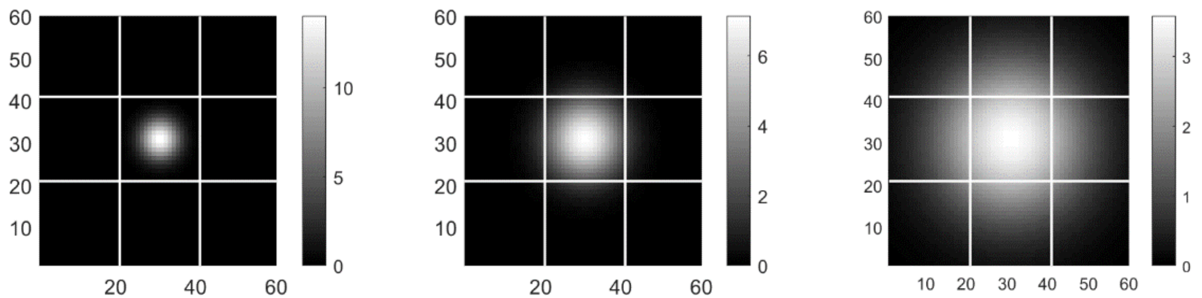




SINGLE-EVENT GROUPS AND PIXEL-FILLING (*ZHANG AND CUMMINS; QUICK*)

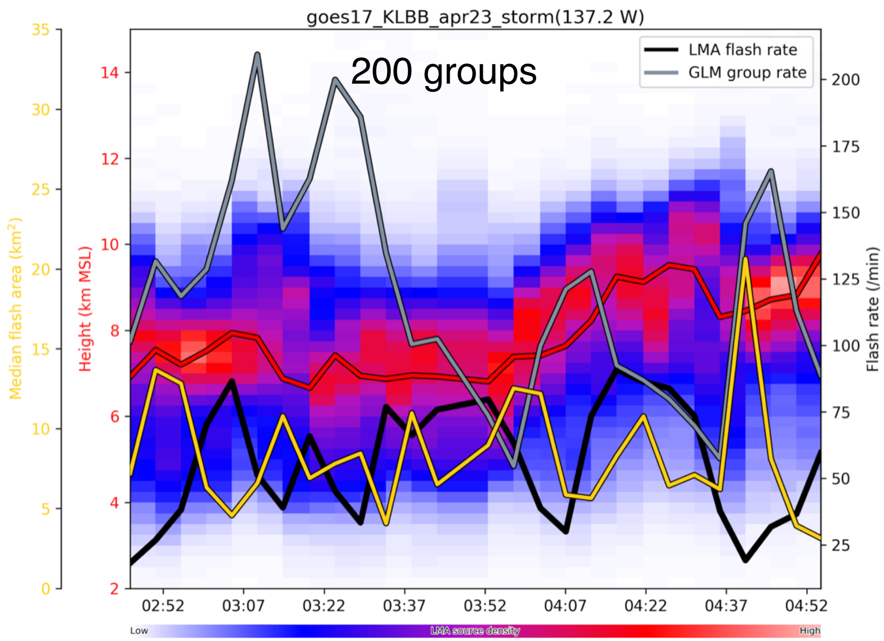
Minimum	Energy density	Pixel area	Energy
GLM	6.6 J/km^2	64 km^2	423 J
LIS	10.25 J/km^2	16 km^2	164 J

- GLM is more sensitive to low energy density, large optical sources, but LIS is better at detecting low-energy, single-pixel events (and LIS doesn't drop the first event in a flash)
- Consistent with results from FEGS *(Quick)*: small optical source area (under-filled GLM pixels) led to reduced GLM DE.
- As the previous slides showed, flash DE is lowest for small, low energy flashes. Spatial mapping of large flashes, but not their detection, would be more impeded by lack of sensitivity to energy density.
- For the same energy density sensitivity as GLM, the smaller pixel size of MTG LI will allow it to better detect high flash rate storms.

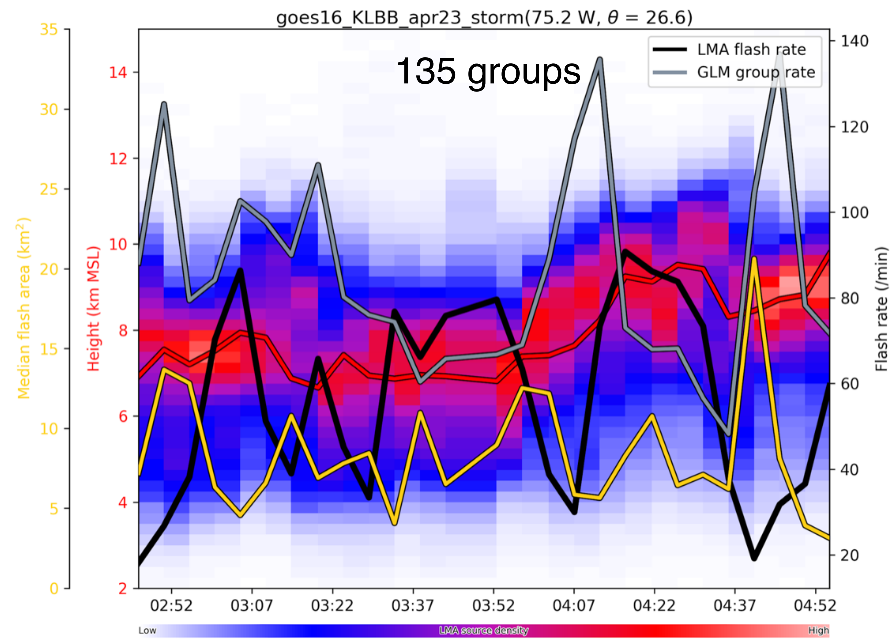


Group rate differences in G16 vs. G17 at about the same viewing angle *(Rutledge)*

From the West

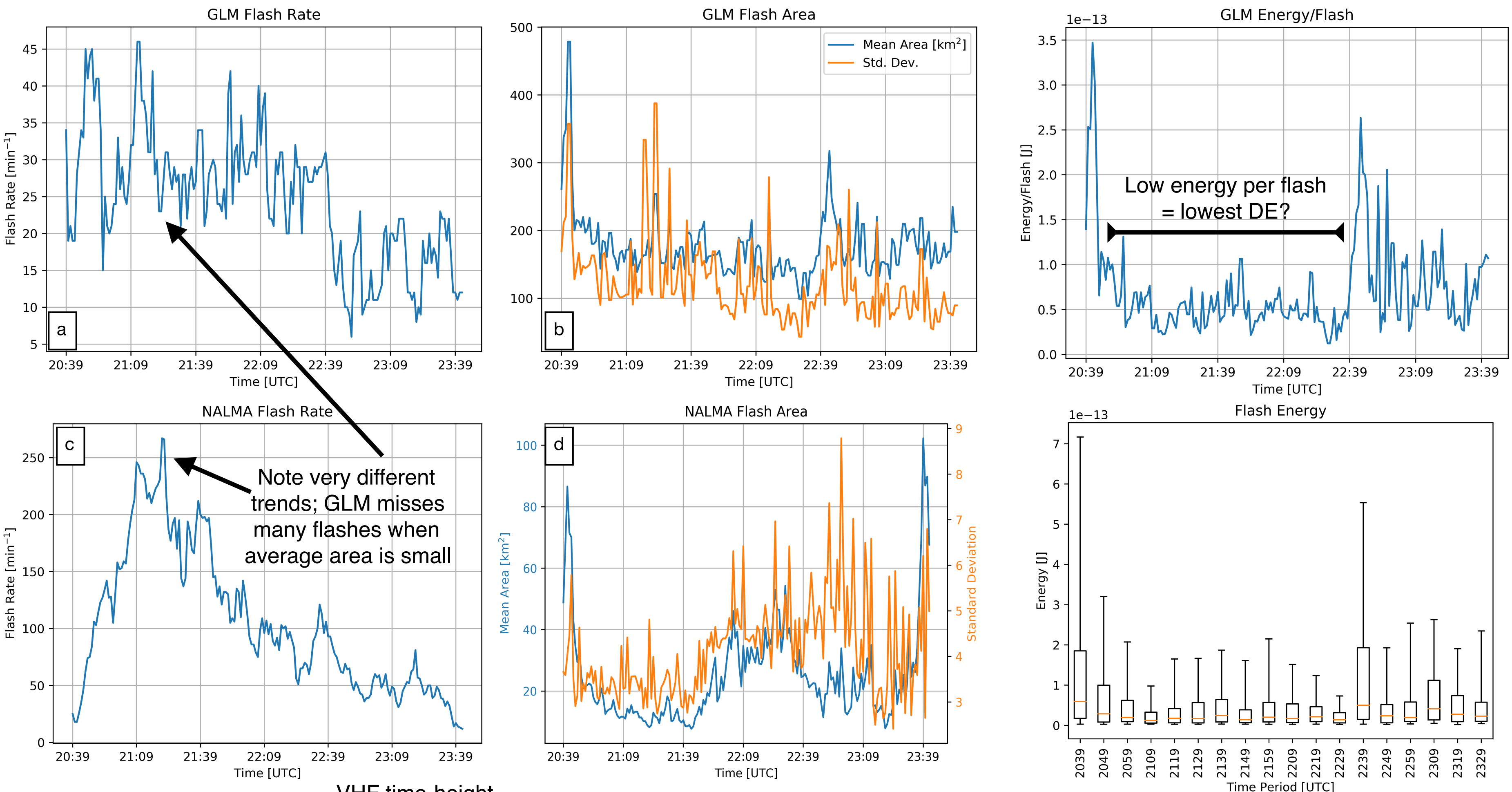


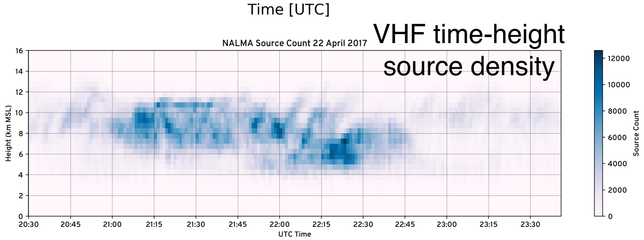
From the East



- The same storm in West Texas; 23 April 2018, view from the west and from the east
- Very different group rate trends
- Group rate is anti-correlated with LMA flash rate
- Similar findings in Utah *(Stanley)*: different views of the storm detect different groups
- Properties of intervening cloud would be expected to vary, especially for a complex cloud scene.

ENERGY PER FLASH DETECTS EXTINCTION CHANGES? *(CONRAD AND SCHULTZ)*





- In combination with systematic minimum energy threshold, a possible route to future operational assessment of reduced DE?

THEMES IN THIS SUMMARY OF GLM CAL/VAL

DE is greater …

- at night
- away from edges of the field of view
- with higher peak currents at LF/VLF
- when clouds are less optically thick
- when flash area and duration are greater
- for small optical sources when pixels are smaller

Subtleties:

- physics of light emission for different discharge processes during the flash
- meteorological influences on charge structure and flash type
- surprising variability in DE even within the same scene
- factors specific to hardware and ground processing choices

Work is ongoing to understand the relative importance of each effect

- MTG LI cal/val will likely face similar challenges

A FEW NOTES REGARDING RESOURCES FOR FURTHER STUDY

- RELAMPAGO dataset from South America (Timothy Lang)
  - *LMA sources, flashes, and grids*
    - Available thru http://dx.doi.org/10.5067/RELAMPAGO/LMA/DATA101. Free NASA Earthdata registration is required.
- The paper on GLM accumulated products is now published
  - *Bruning, E. C., and Coauthors, 2019: Meteorological imagery for the Geostationary Lightning Mapper. J. Geophys. Res., 124 (24), 14 285–14 309, doi:10.1029/2019JD030874.*