GLM Lightning Energetics

Space and Endo-atmospheric Nuclear detonation detection Surveillance Experimentation and Risk-reduction (SENSER) Science Meeting

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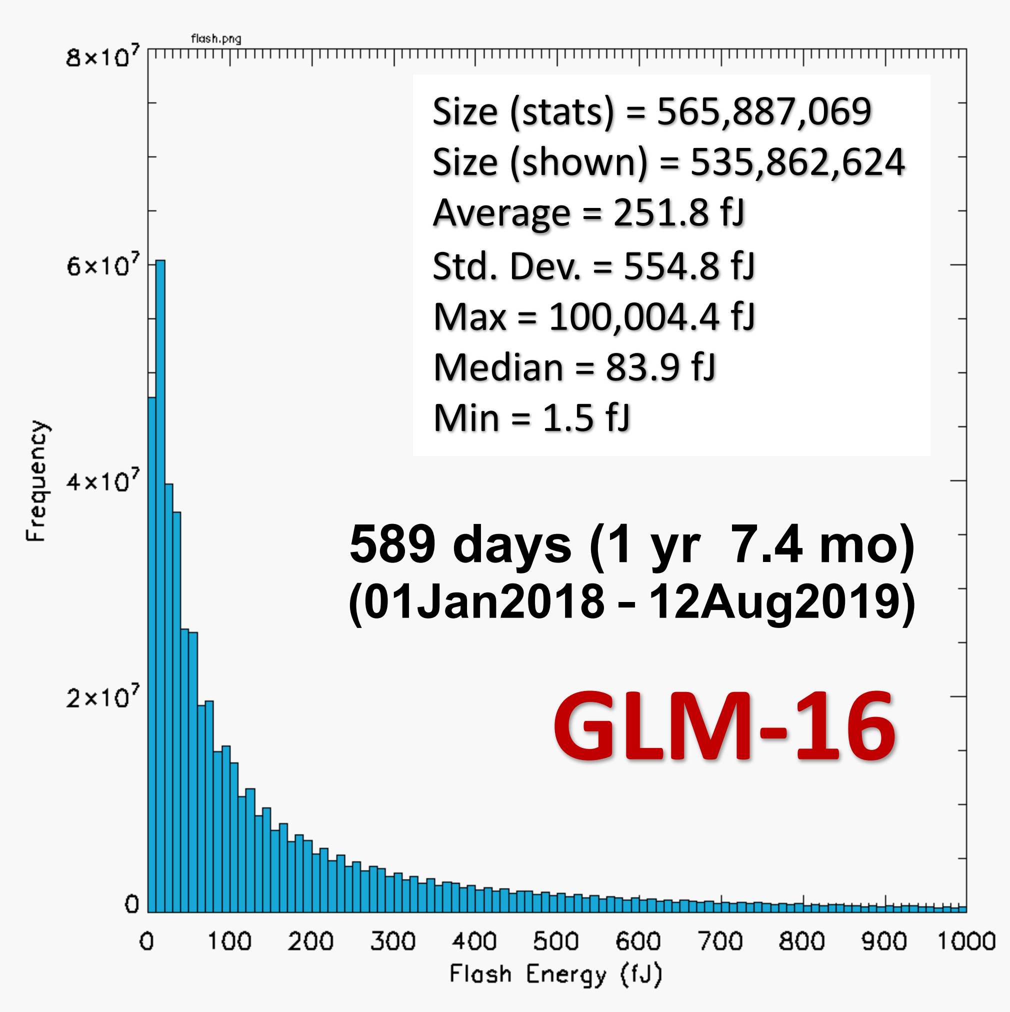
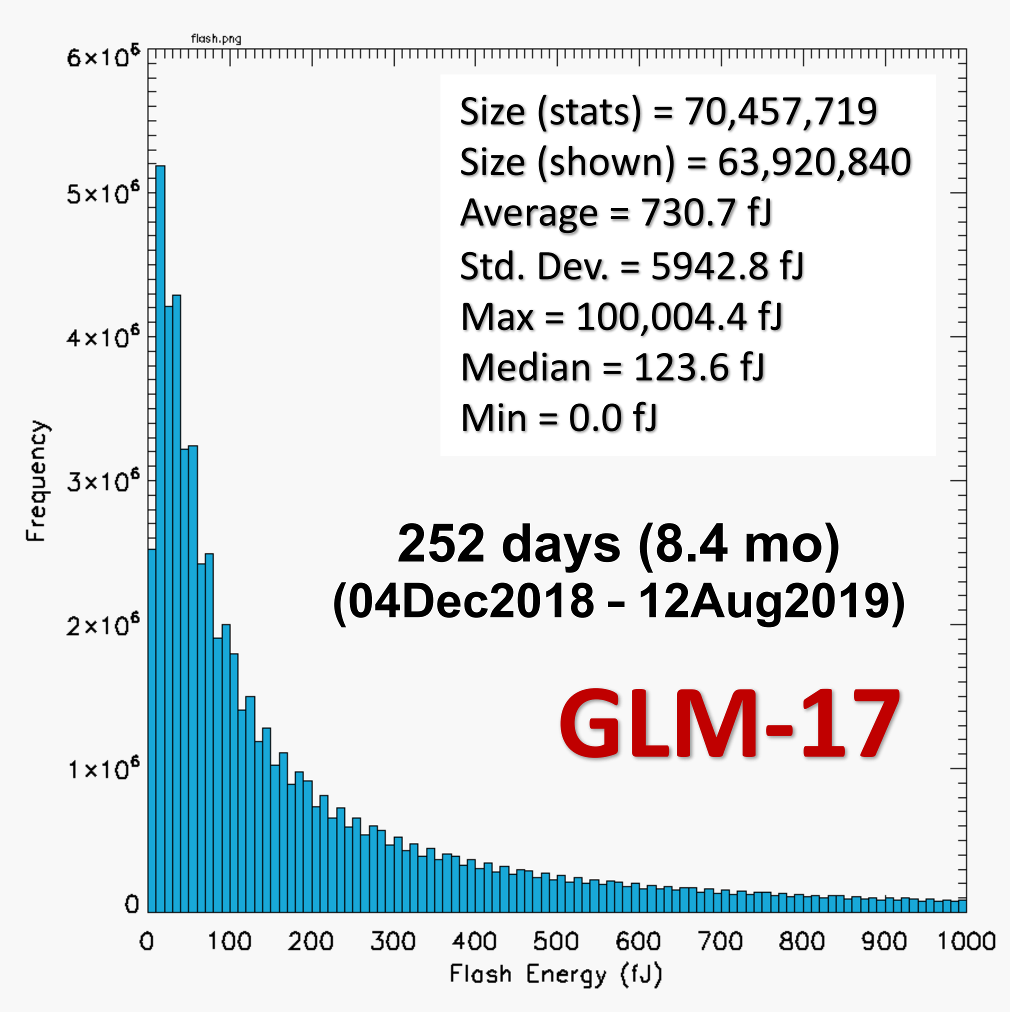
September 15, 2020
Huntsville, AL

- Flash Energy Variations
- Comparing Ground & Cloud Flashes
- Nuances & Practical Considerations

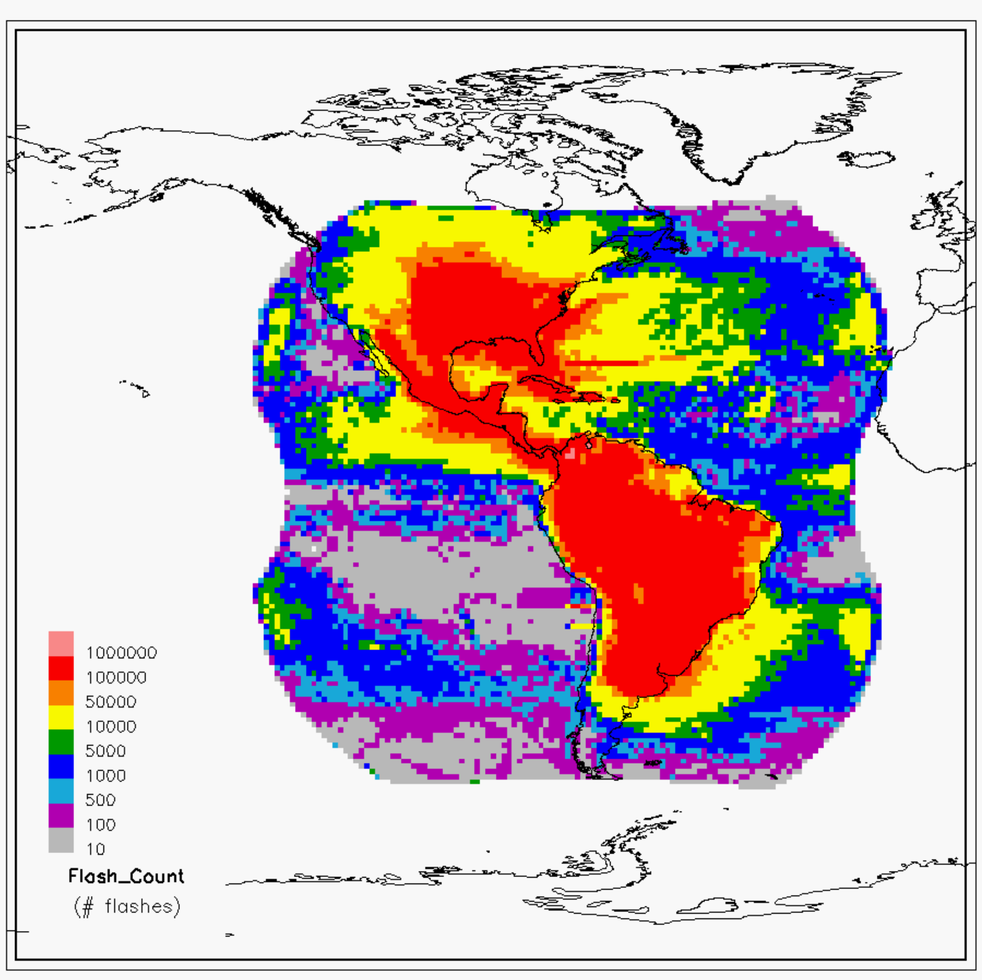
Flash Energy Distributions



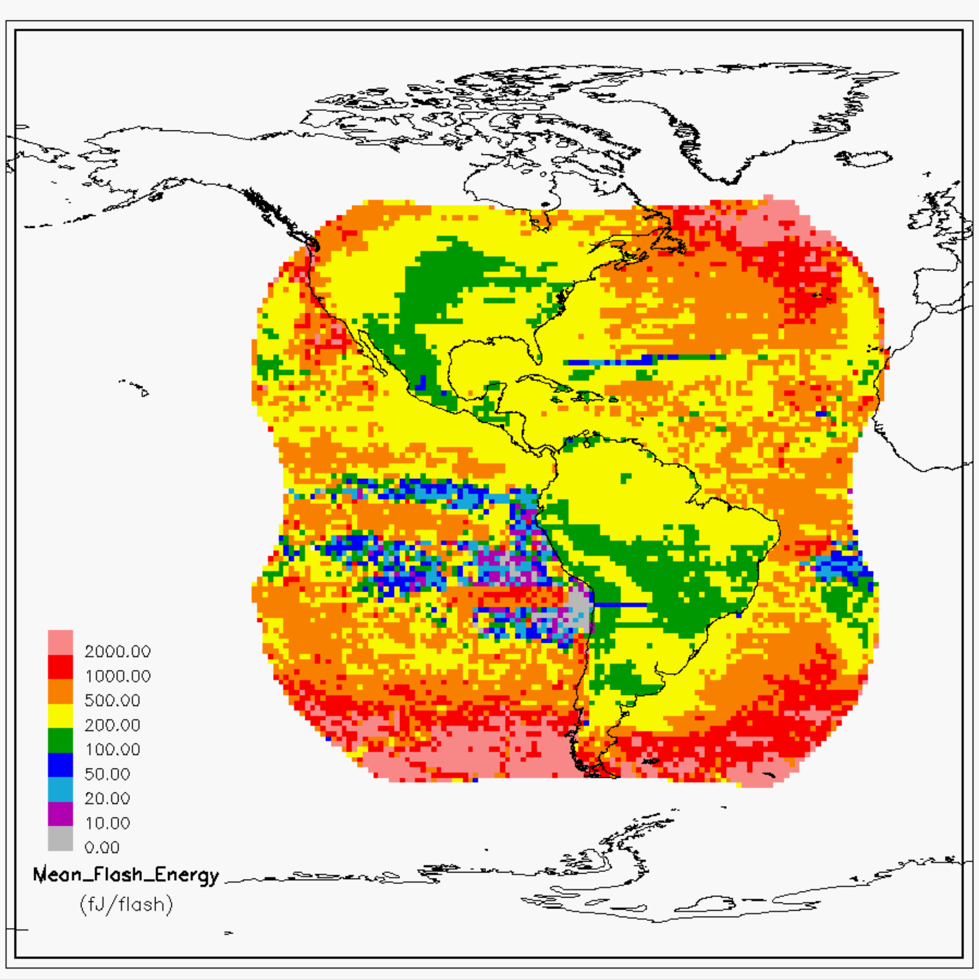


Spatial Variation

Flash Counts



Mean Flash Energy



GLM-16

589 days (1 yr 7.4 mo)
(01Jan2018 – 12Aug2019)

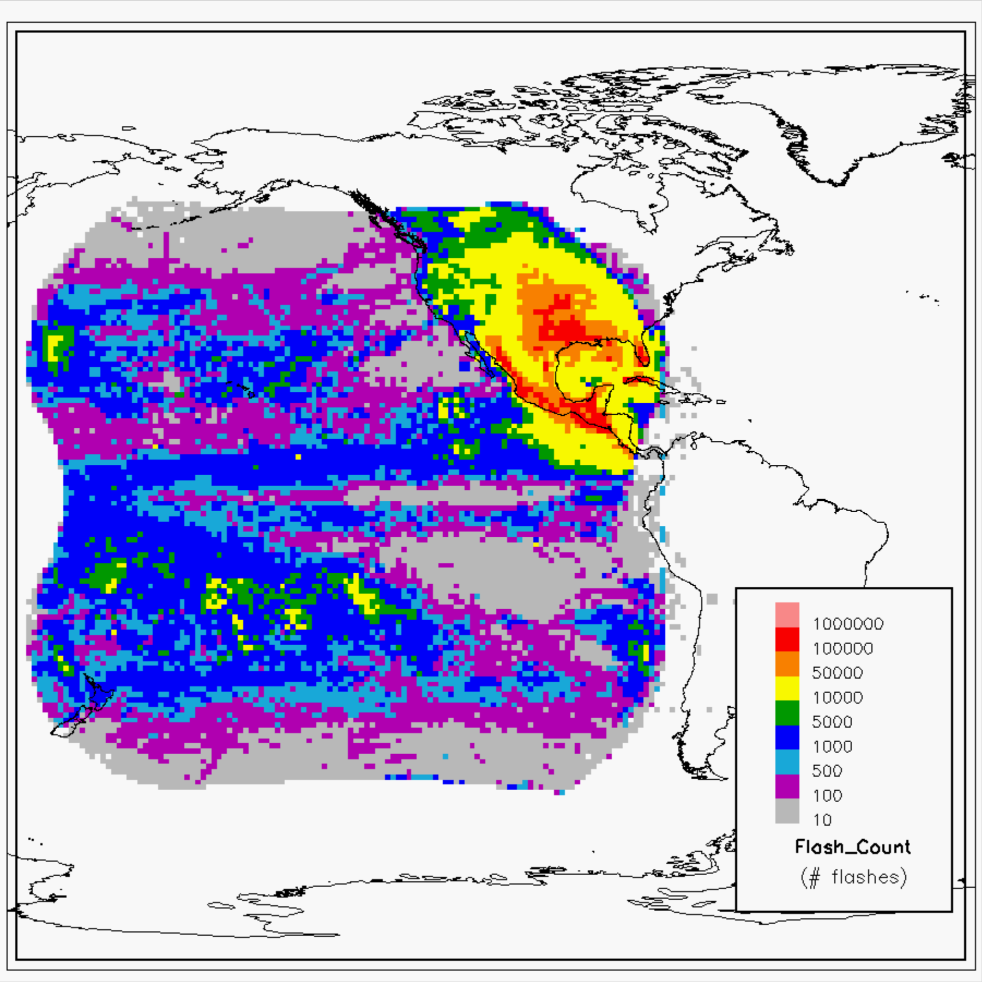
Flashes more energetic over oceans, for sufficient sample size. Agrees with TRMM/LIS findings in Beirle et al. (2014).

Flash energy increases towards limb since:

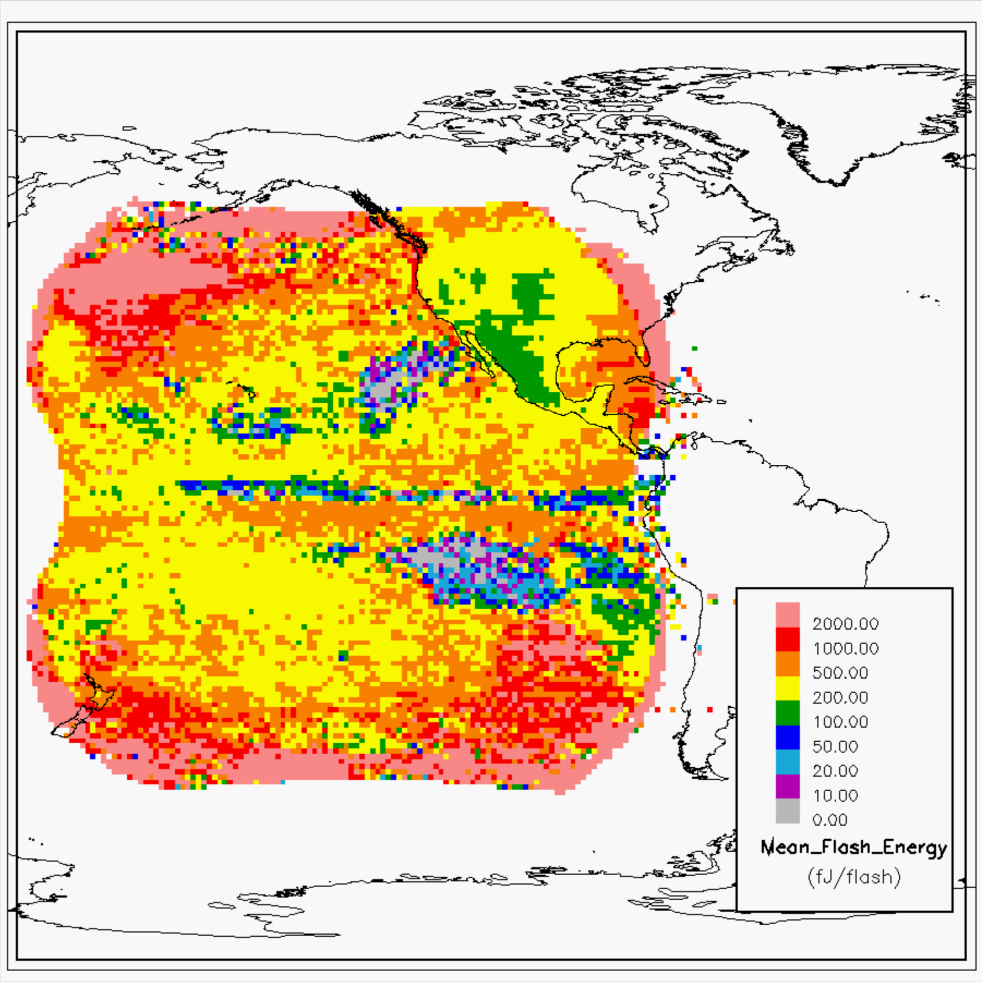
- beneath cloud bare channel detection suspected.
- Source stronger over ocean.
- Min detectable energy increases toward edge.

Spatial Variation

Flash Counts



Mean Flash Energy



GLM-17

252 days (8.4 mo)
(04Dec2018 - 12Aug2019)

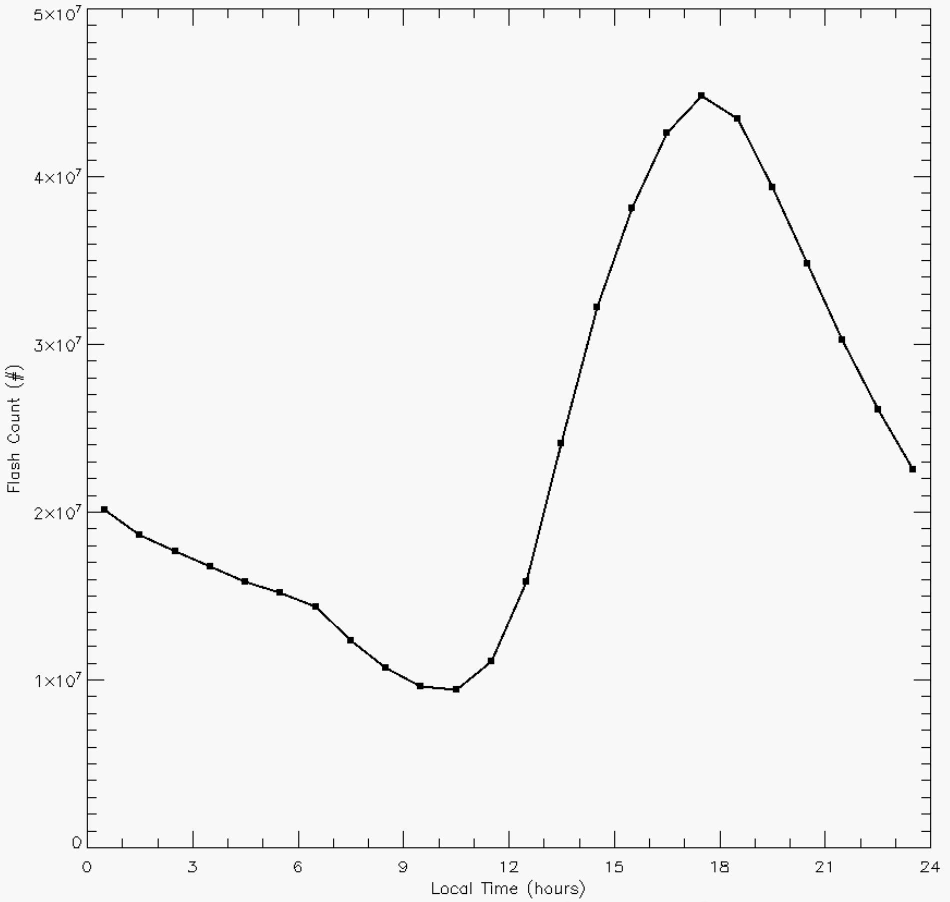
Flashes more energetic over oceans, for sufficient sample size. Agrees with TRMM/LIS findings in Beirle et al. (2014).

Flash energy increases towards limb since:

- beneath cloud bare channel detection suspected.
- Source stronger over ocean.
- Min detectable energy increases toward edge.

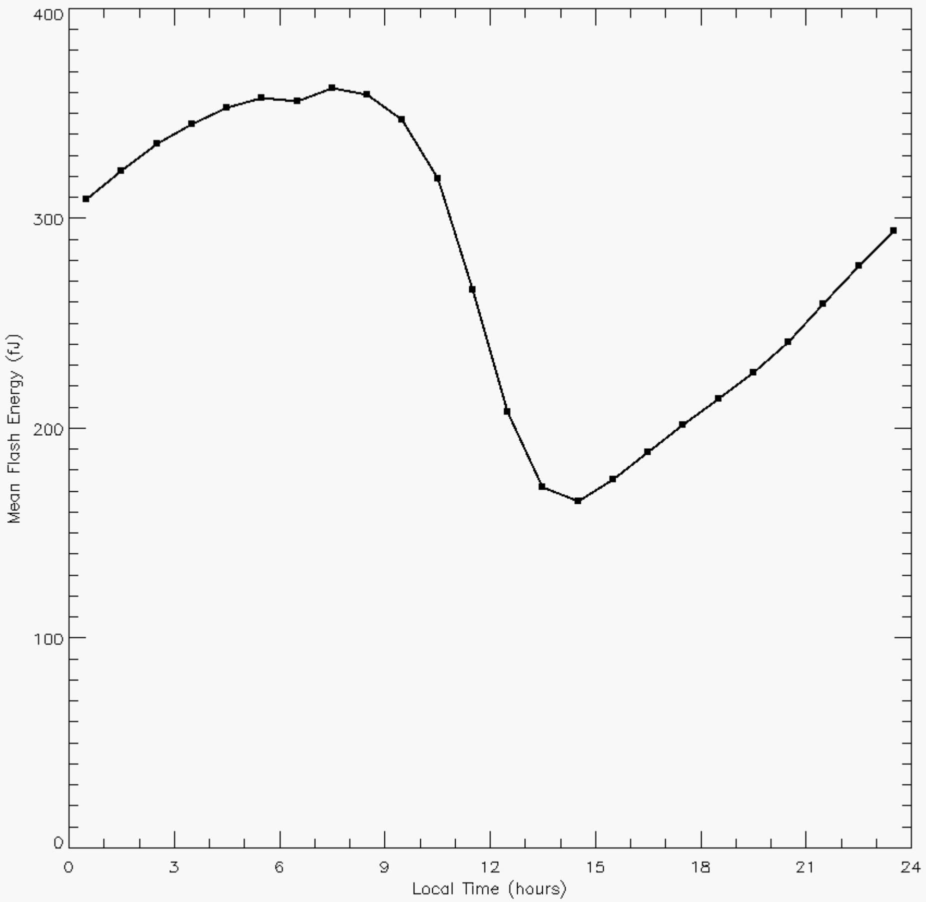
Diurnal Variation

Flash Counts



Local Time (hours)

Mean Flash Energy



Local Time (hours)

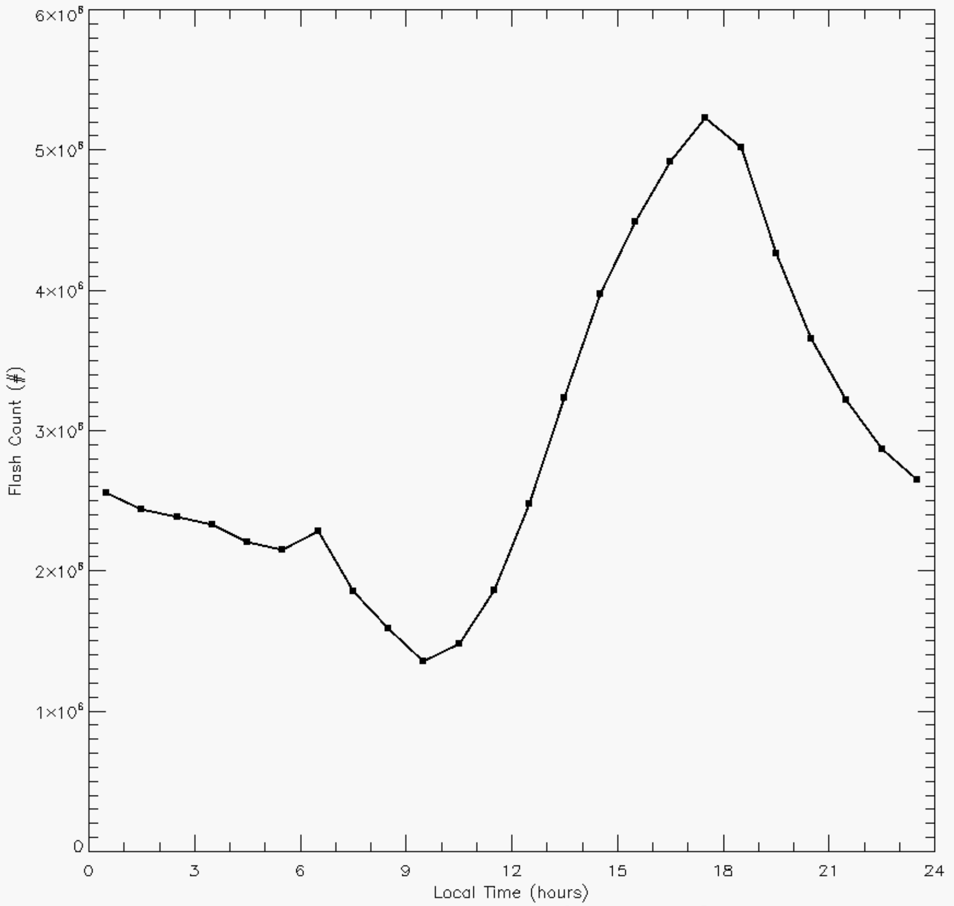
GLM-16

589 days (1 yr 7.4 mo)
(01Jan2018 – 12Aug2019)

Roughly an inverse relation between flash count and mean flash energy. Agrees with TRMM/LIS findings in Chronis and Koshak (2017).

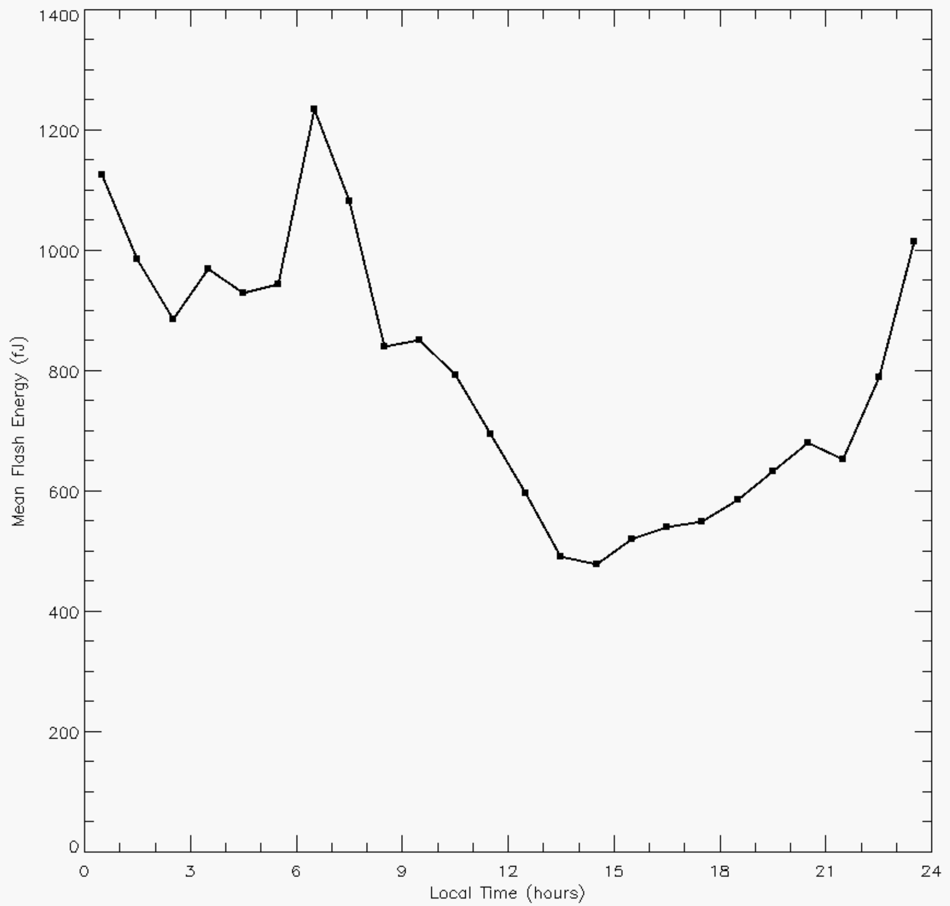
Diurnal Variation

Flash Counts



Local Time (hours)

Mean Flash Energy



Local Time (hours)

GLM-17

252 days (8.4 mo)
(04Dec2018 - 12Aug2019)

Roughly an inverse relation between flash count and mean flash energy, but oceanic results (G17) more erratic than land (G16) in agreement with TRMM/LIS findings in Chronis and Koshak (2017).

- Flash Energy Variations
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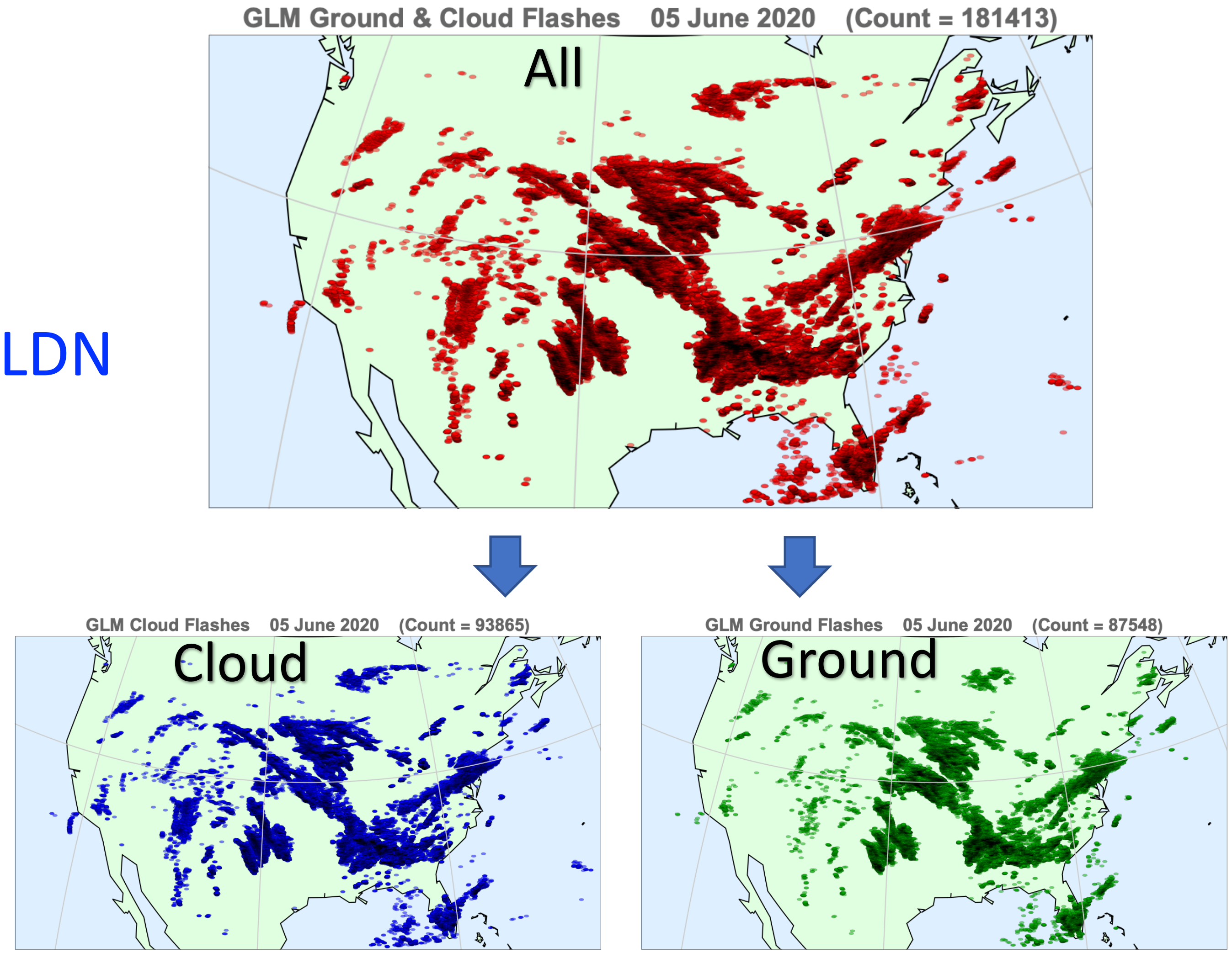
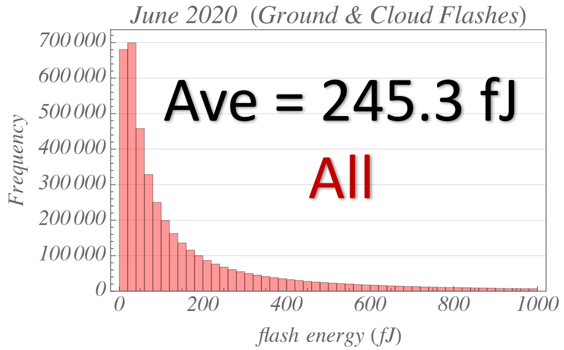
METHOD

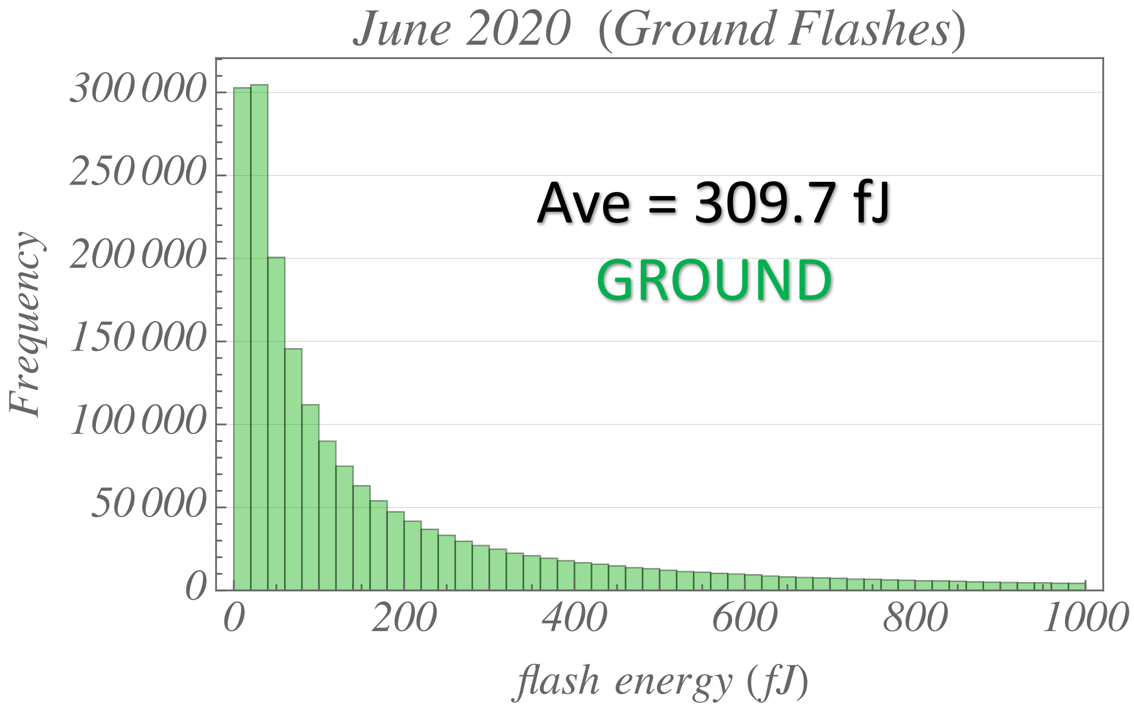
- **Mathematica v12.1.1**
- **Period:** June 2020 (entire month)
- **Region:** CONUS
- **Flash-typed:** GLM flashes using NLDN
  - **4,370,460 GLM flashes typed**
  - 2,077,872 typed Ground
  - 2,292,588 typed Cloud
- **Removed:** Ambiguous type
- **Compared:**
  - Q, for Ground & Cloud
  - Q, MGA, i_{peak} for Ground

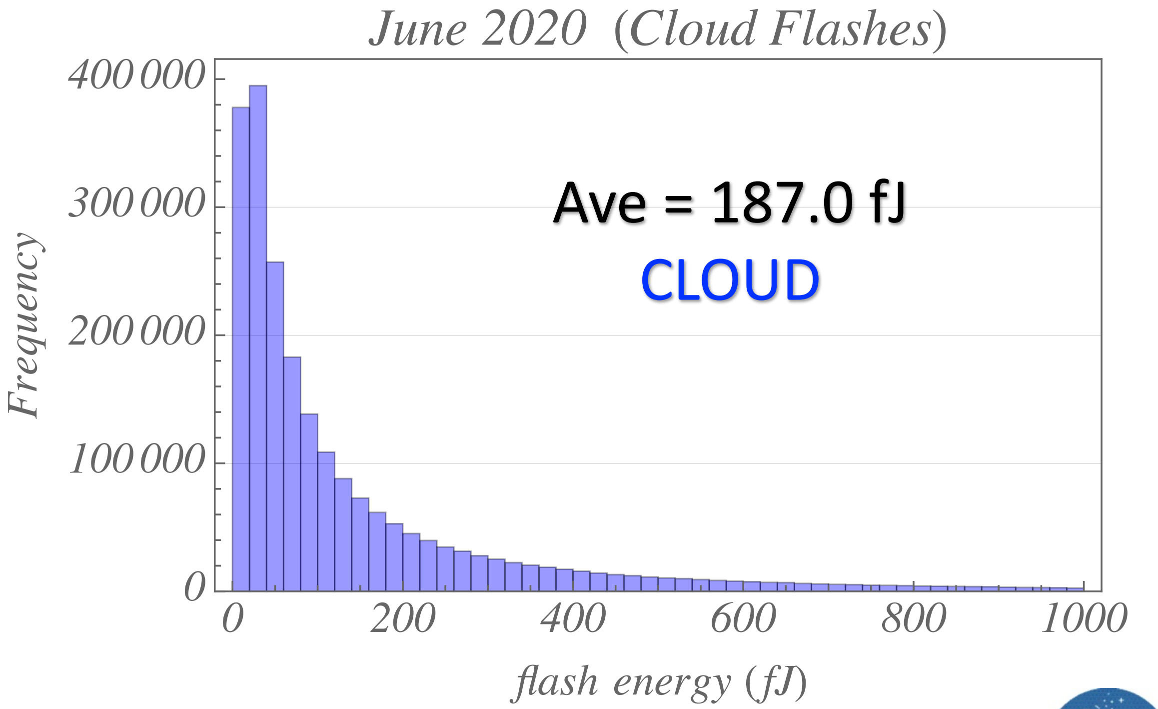


Ground Flashes are More Optically Energetic

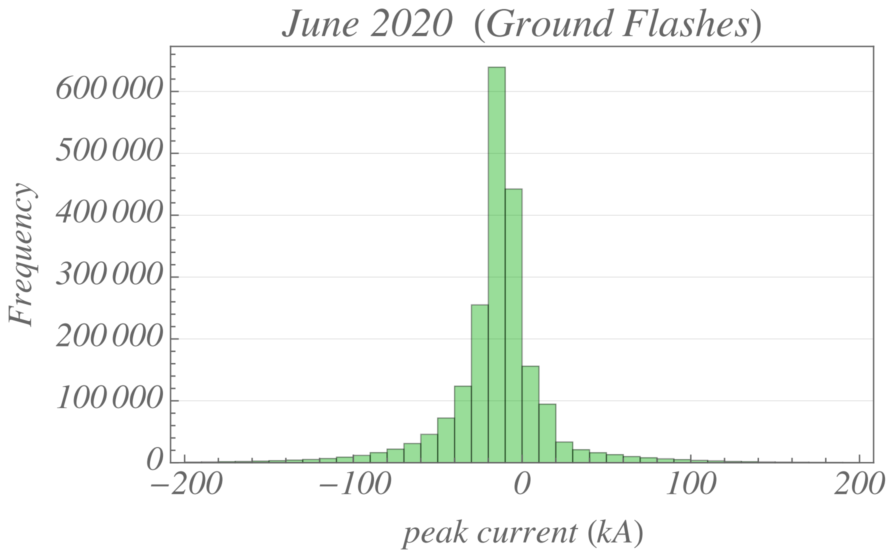
GLM ground flashes optically more energetic than GLM cloud flashes, on average:

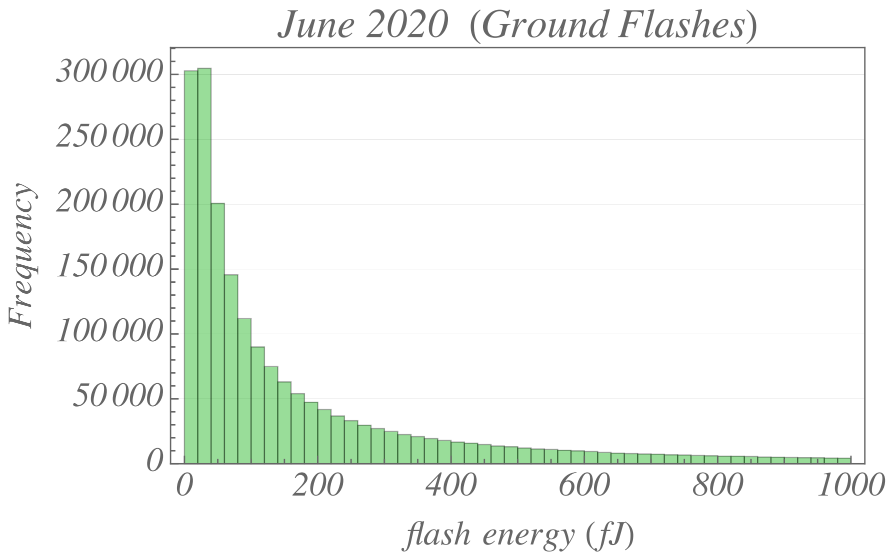


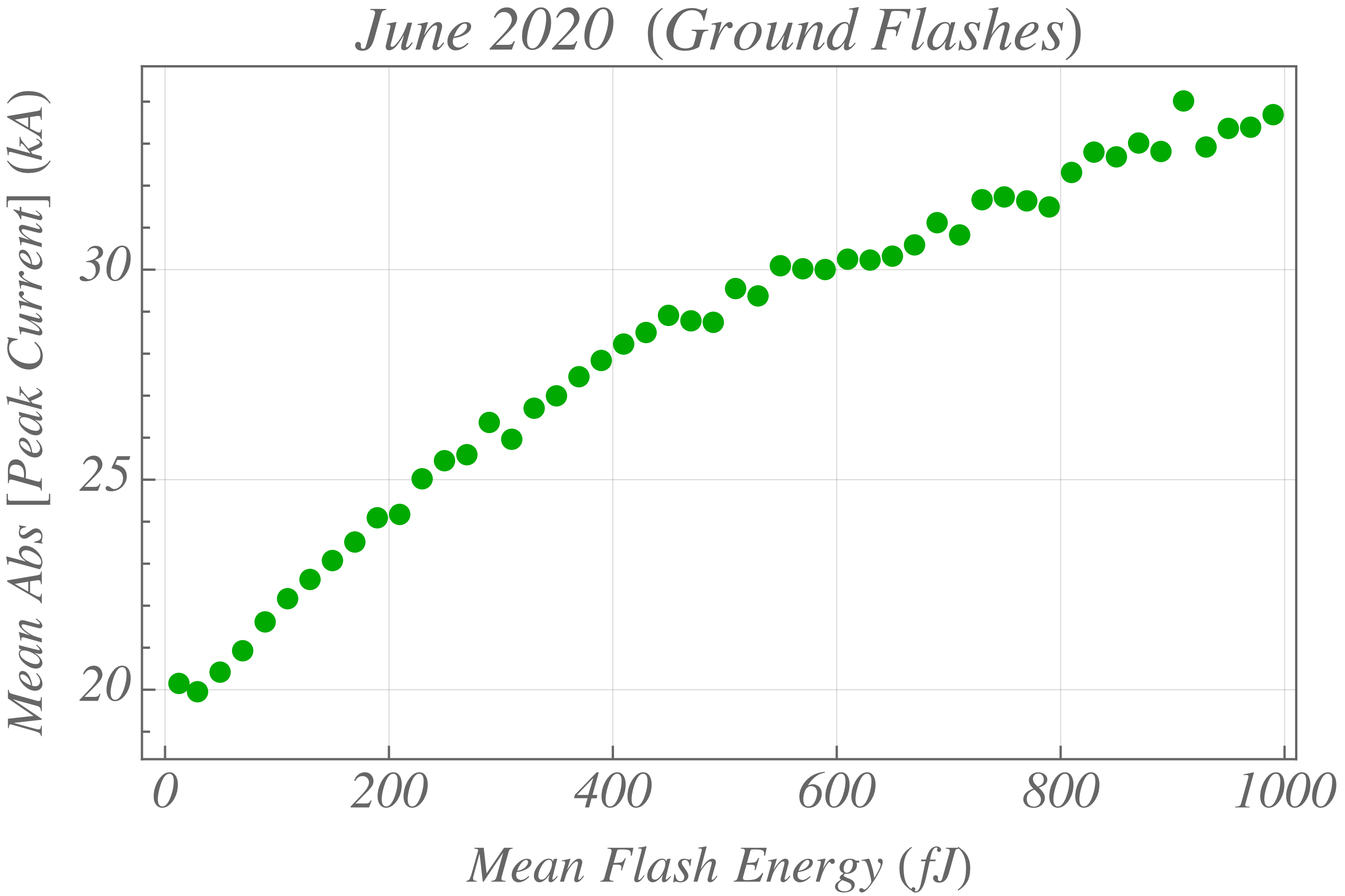




Correlation with Ground Flash Peak Current







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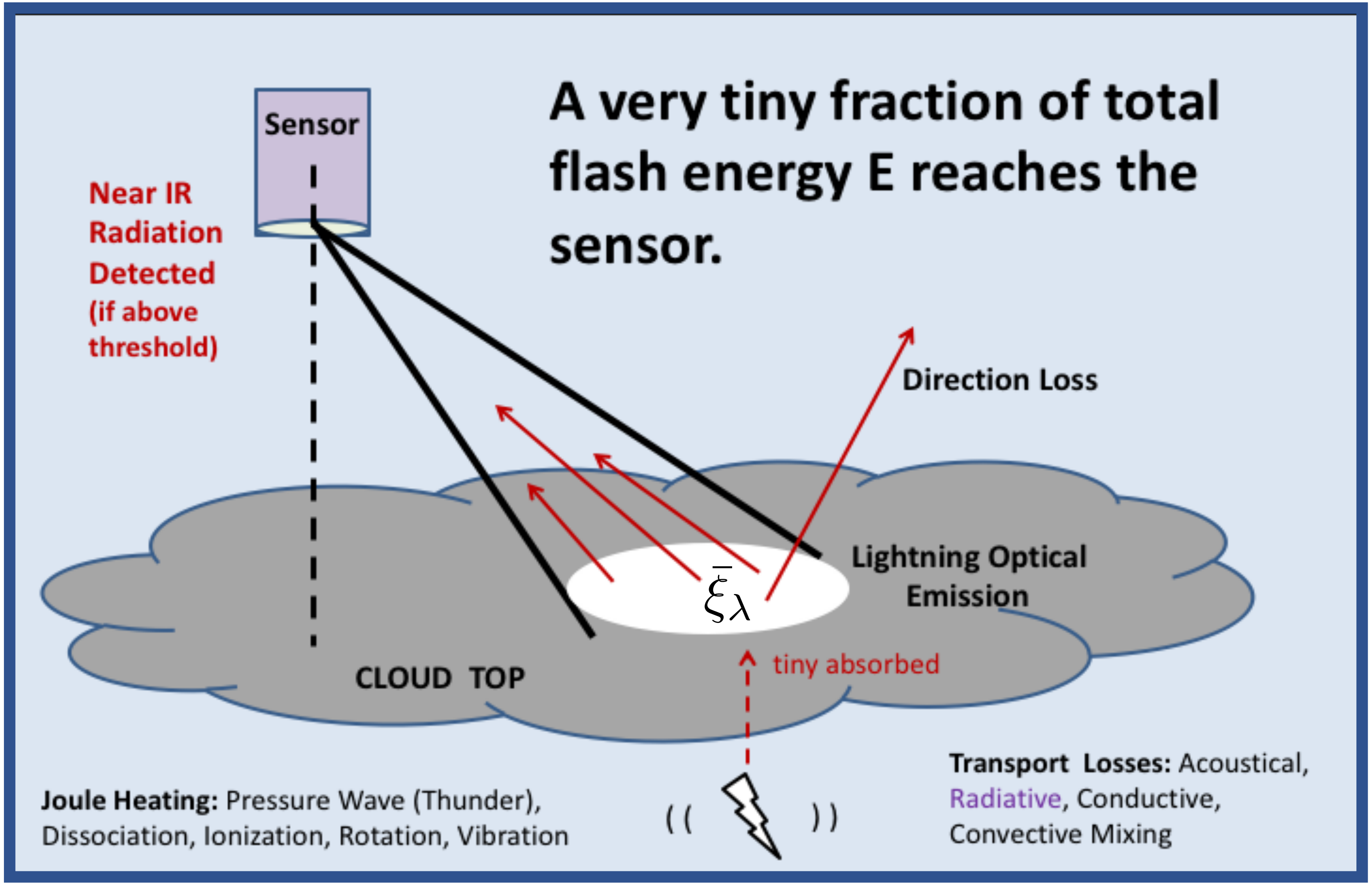
Energy Flow



Flash Energy

- Typically GigaJoules

Flash Optical Energy

- 100s of femtoJoules

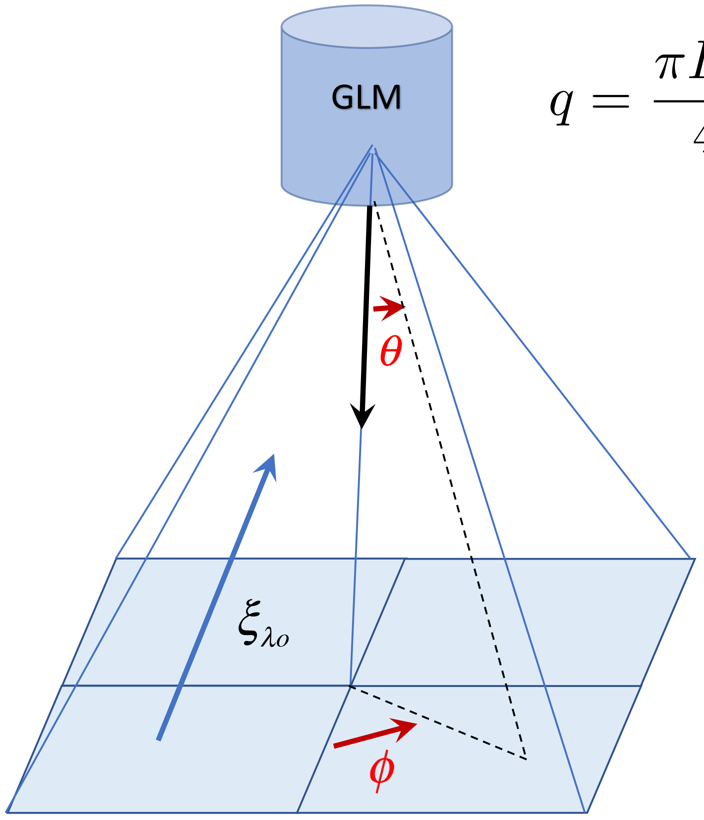
Energy Intercepted by Pixel:

$$q = \frac{\pi D^2}{4} \bar{\xi}_\lambda \Delta\lambda \Delta\omega$$

- GLM pixel solid angle small, but D large.

Pixel Sub-Filling

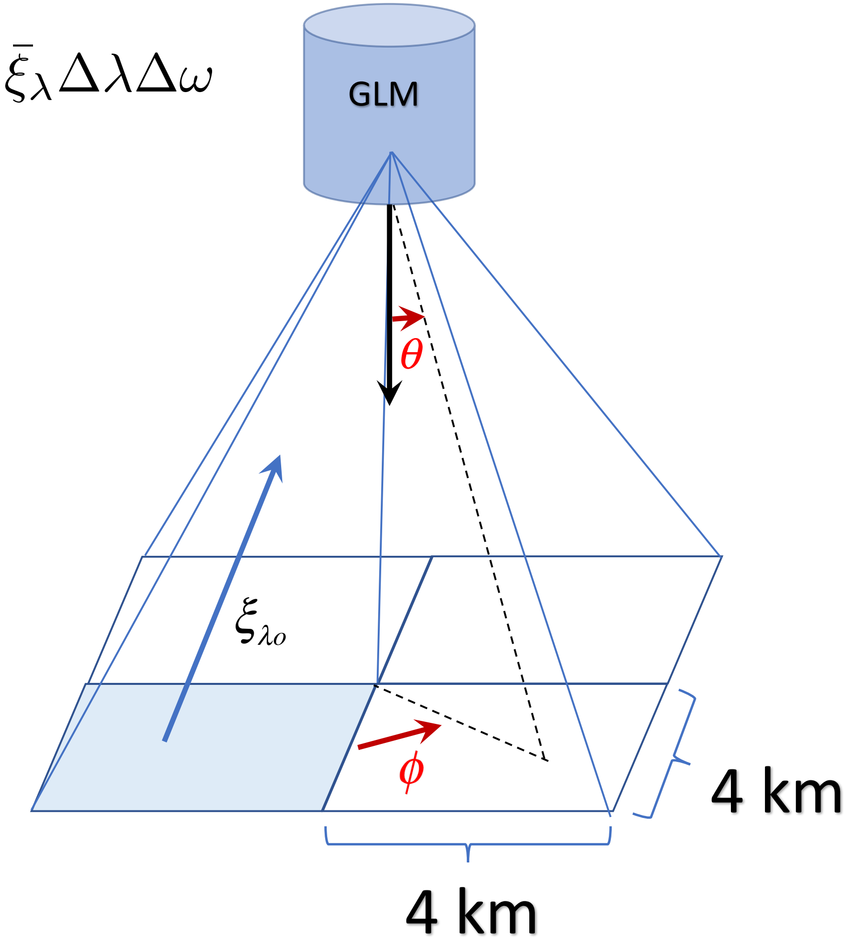
Case A



$$q = \frac{\pi D^2}{4}\bar{\xi}_\lambda \Delta\lambda\Delta\omega$$

$$\bar{\xi}_\lambda = \frac{1}{\Delta\omega}\int_{\Delta\omega} \xi_\lambda(\hat{\Omega}(\theta,\phi))d\Omega$$

Case B



Nadir Resolution

- LIS (4km)^2
- GLM (8km)^2

Case B:

- GLM pixel gets ¼

$$\bar{\xi}_\lambda = \frac{1}{4}\xi_{\lambda o}$$

Sub-filling hurts!

- 1 LIS pixel gets it all

(3 LIS pixels get nothing):

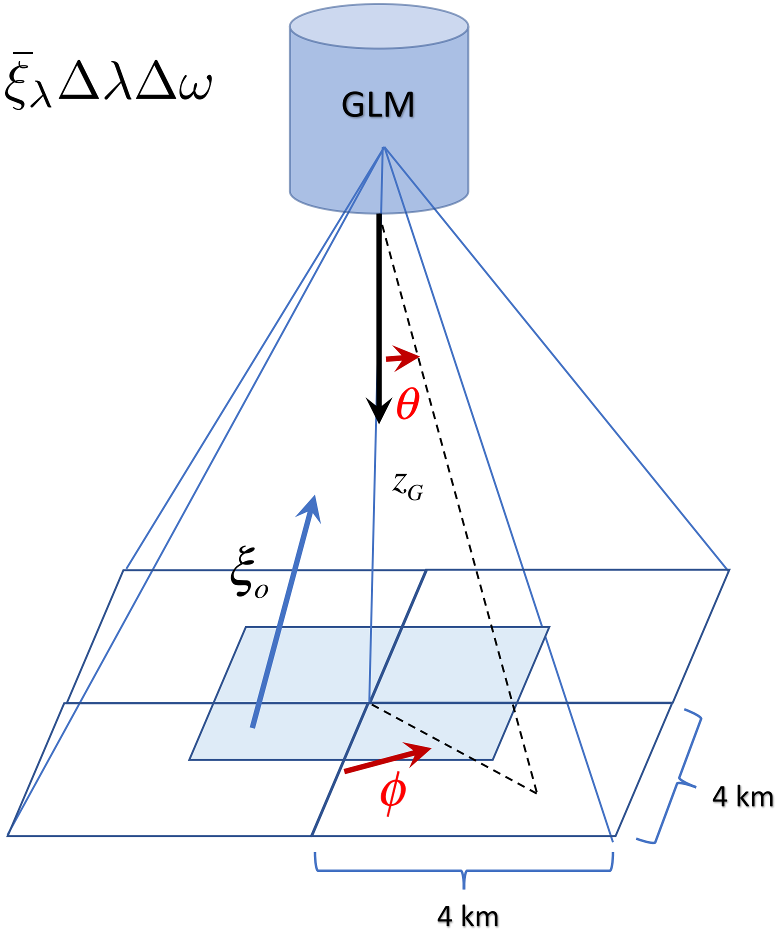
$$\bar{\xi}_\lambda = \xi_{\lambda o}$$

Pixel Splitting

$$q = \frac{\pi D^2}{4} \bar{\xi}_\lambda \Delta\lambda\Delta\omega$$

Imaging by one GLM
Pixel Footprint at Nadir
with Sub-Filling

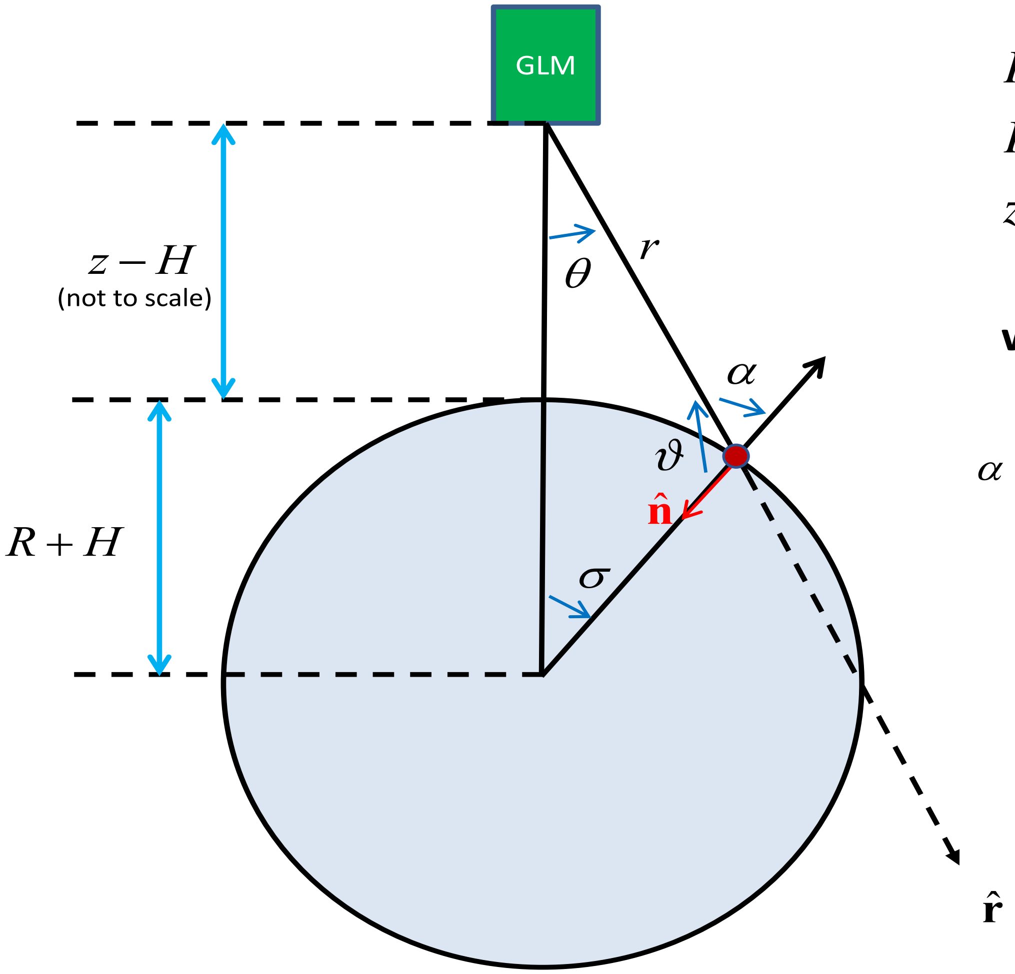
(not to scale)



- GLM pixel still gets ¼ the energy density
- Now each of the 4 LIS pixels get only ¼ too

Splitting hurts!
(creates sub-filling here)

Secant Effect for Scattering Length



$R =$ Earth Radius ~ 6371 km

H = Cloud-Top Height ~ 12 km

z = Orbital Altitude ~ 35,786 km

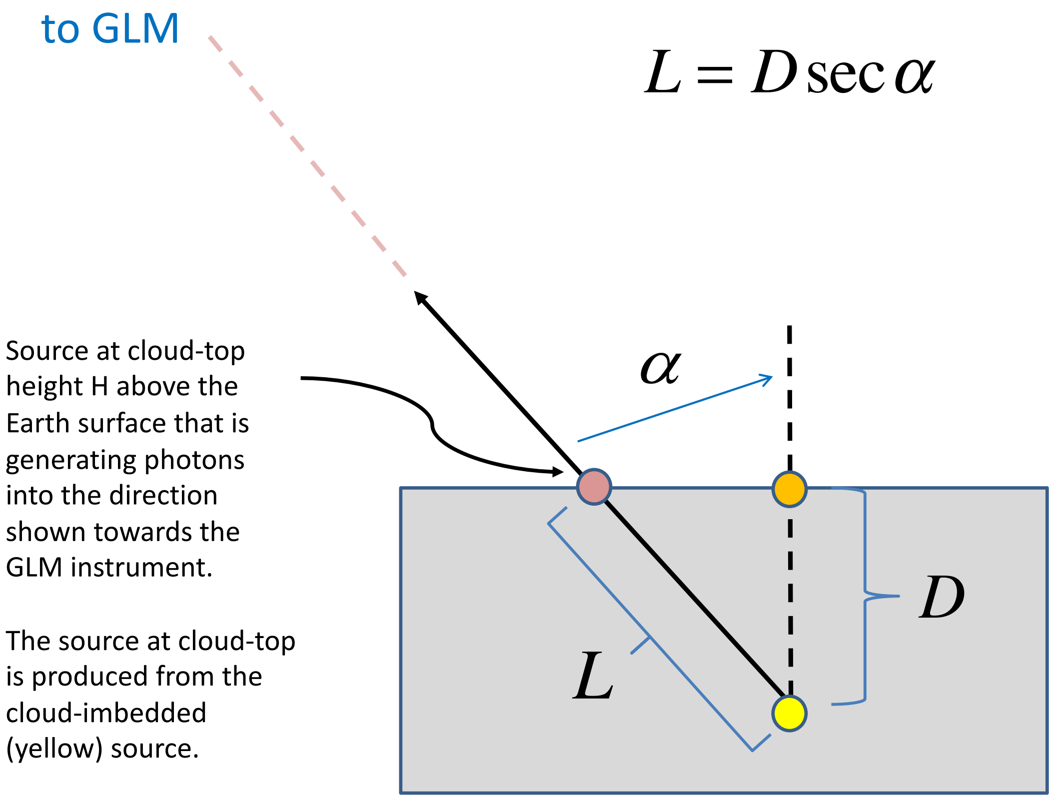
where Law of Sines & geometry gives:

$$\alpha = \sin^{-1}\left[\left(\frac{R+z}{R+H}\right)\sin\theta\right] = \text{foreshortening angle}$$

$$L = D\sec\alpha$$

(see next slide)

Secant Effect (cont.)

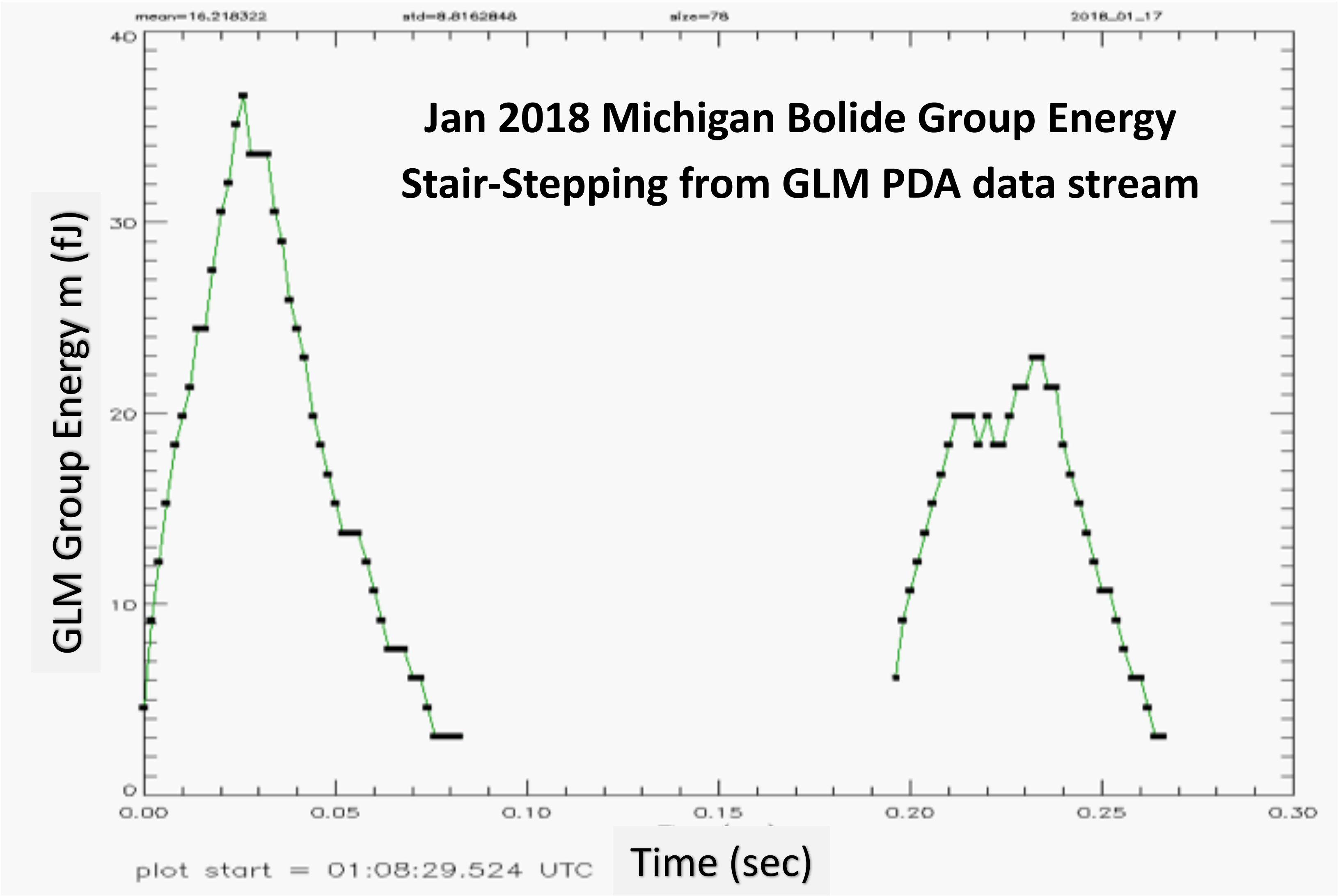


The cloud-top height H varies as a function of latitude according to the ellipsoid model employed, but H=12 km is assumed here for quick & dirty results:

θ (deg)	α (deg)	D (km)	L (km)
0	0	2	2.0000
2	13.3263	2	2.0553
4	27.4331	2	2.2534
6	43.6591	2	2.7645
8	66.8064	2	5.0782

Even though GLM half angle is 8 degrees, note how the Earth Curvature amplifies the secant effect so that alpha varies from 0 to almost 67 degrees (given the 12 km cloud-top height assumption). The 67 degrees is larger than the (almost) 50 degrees of LIS.

Low-End "Stair-Stepping" Fixed



Scale_Factor & Add_Offset Report

- Completed 8-21-2019

GS Fix Implemented

- ADR 738/739
- PR.08.03.04
- Into OE 10-2-2019

Min Detectable:

- GLM16 0.61 fJ
- GLM17 0.53 fJ
- NOT EVERY PIXEL (Depends on BG & distance from nadir)