First Applications of GLM Data for National Climate Assessment (NCA) Studies

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National Climate Assessment (NCA) Program

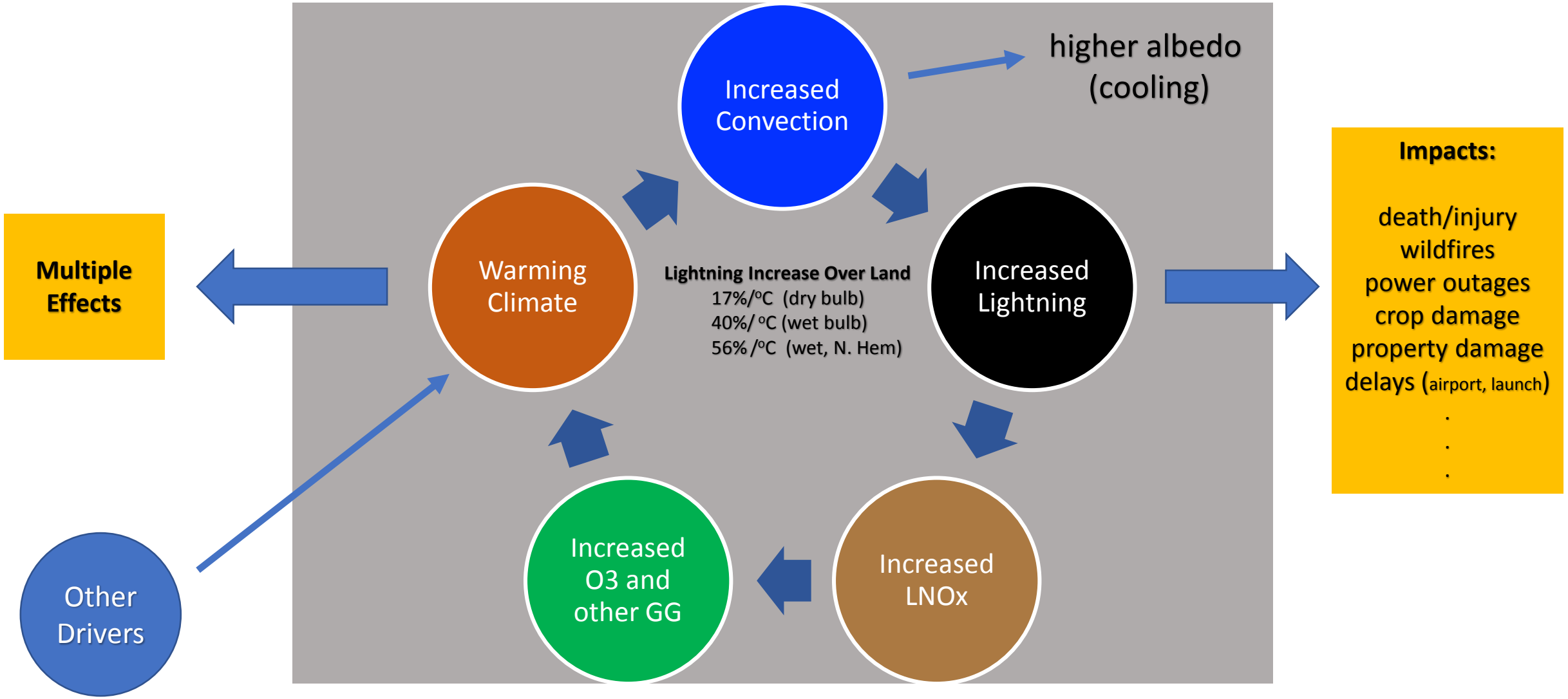
- ✓ **Congressionally Mandated: Global Change Research Act (1990)**
- ✓ **Vision:**

> To advance an inclusive, broad based, and sustained process for assessing and communicating scientific knowledge of the impacts, risks, and vulnerabilities associated with a changing global climate in support of decision-making across the US.

- ✓ **USGCRP Oversees the NCA Process**
  - o 13 Federal Depts/Agencies Involved
- ✓ **Culminates in regular NCA Assessment Reports**
  - o NCA1 completed in 2000
  - o NCA2 completed in 2009
  - o NCA3 completed in 2014
  - o NCA4 completed in 2018

WMO recently added **lightning** to the Global Climate Observing System (GCOS) list of Essential Climate Variables (ECVs)

Lightning/Climate Interaction



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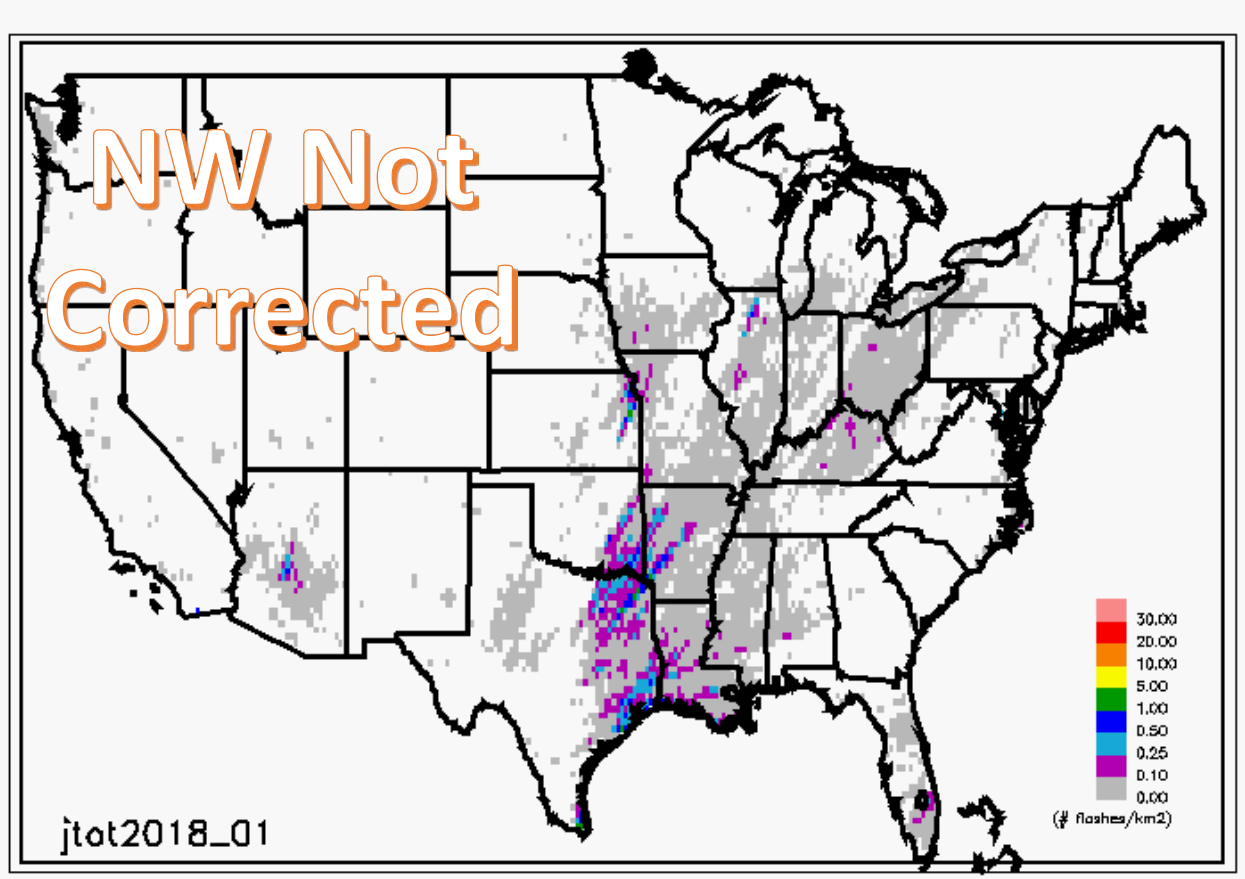
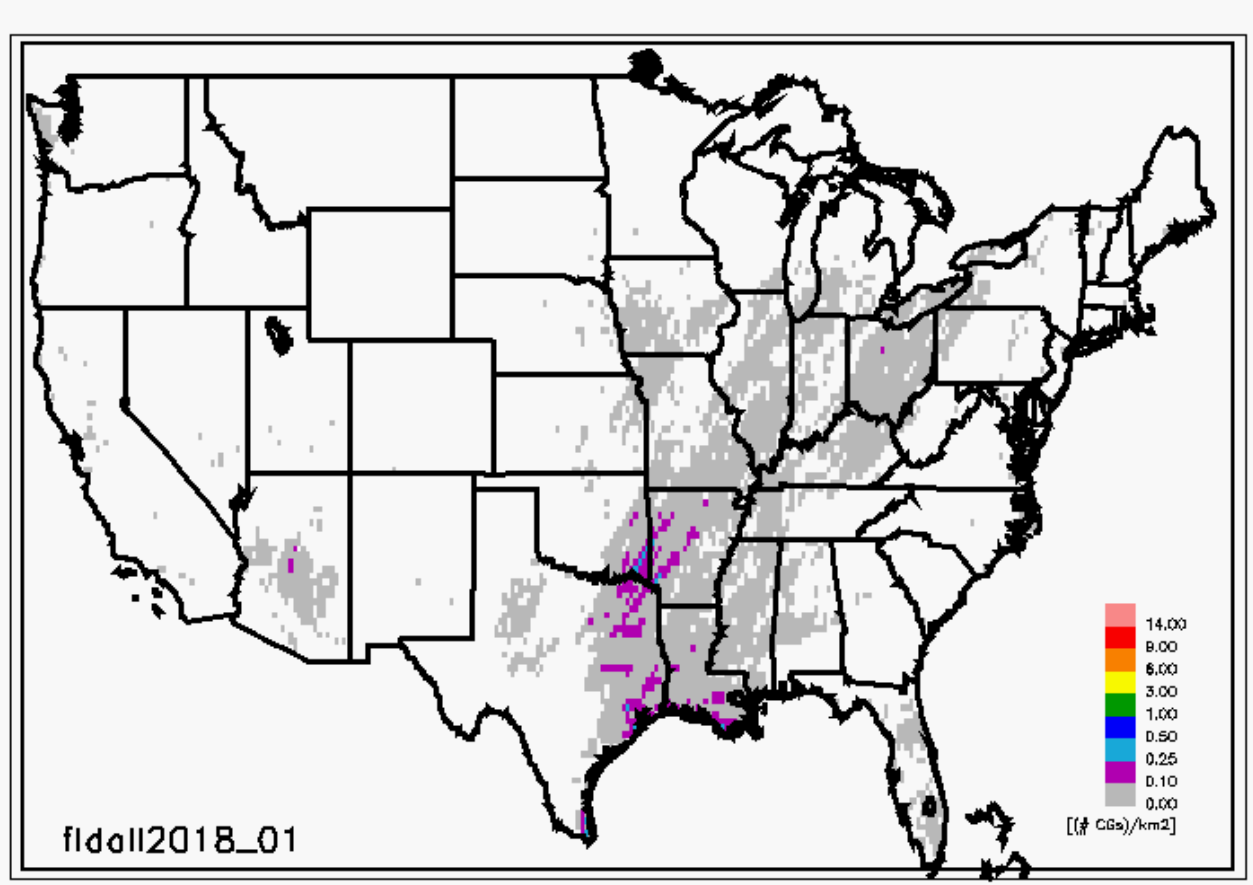
10 mo Trend (Jan-Oct, 2018) CONUS Flash Density

GLM-16



NLDN



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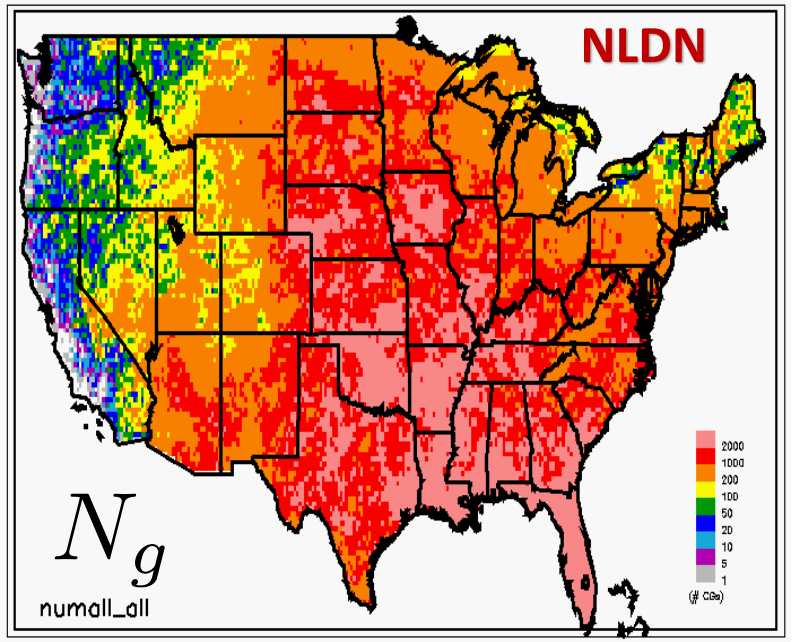
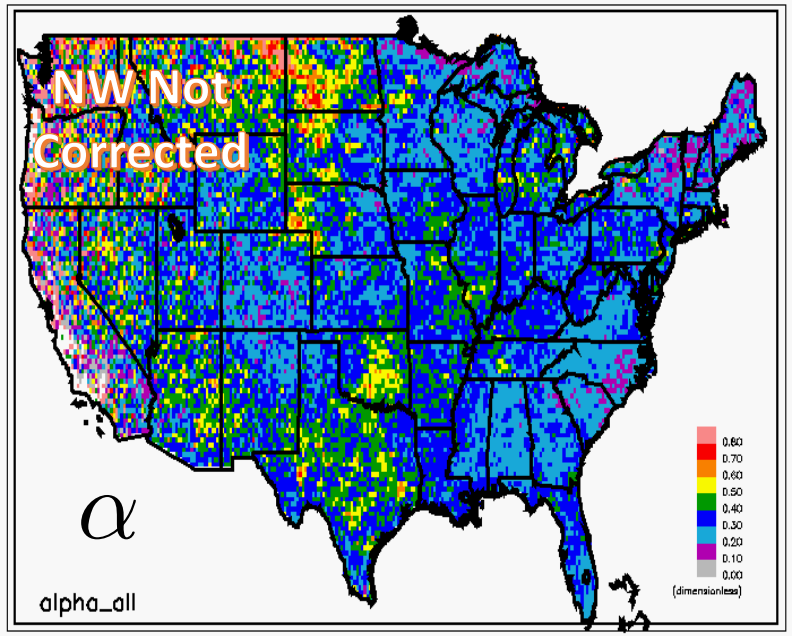
10 months (Jan-Oct, 2018)



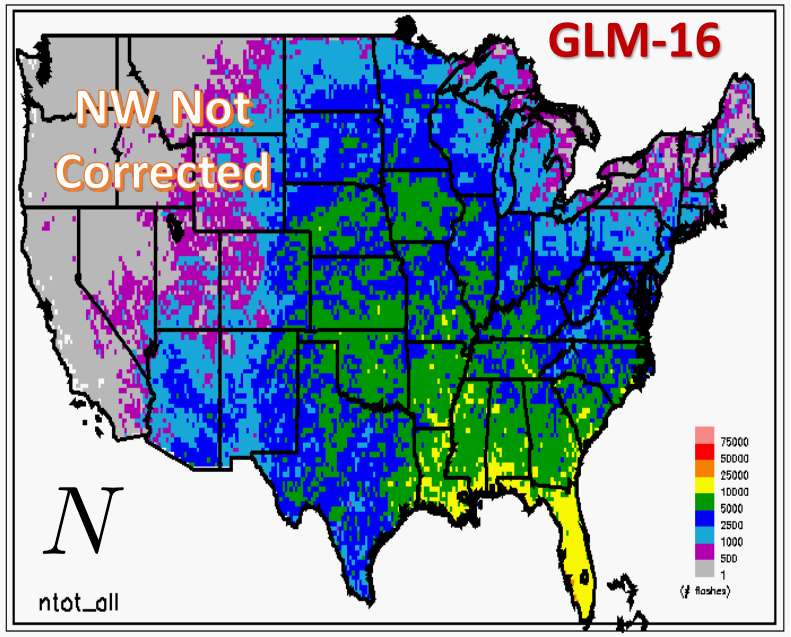


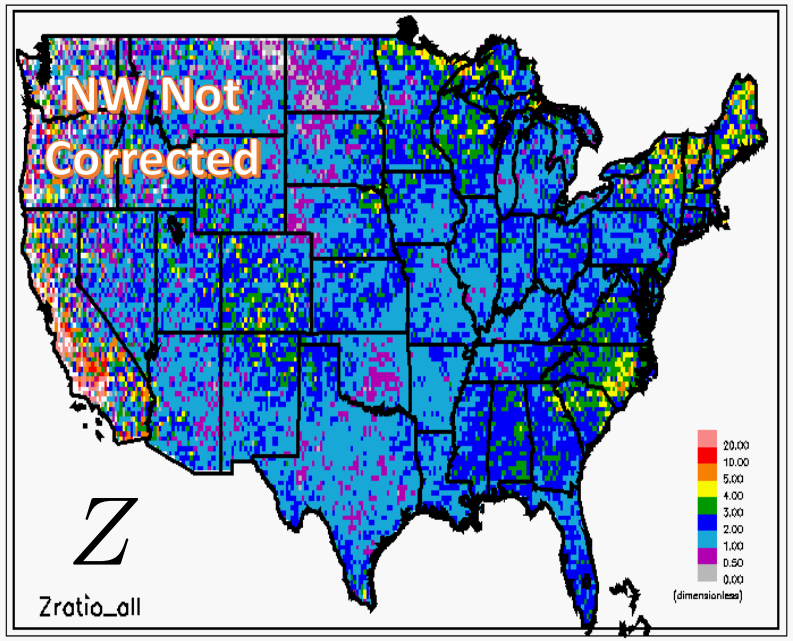
Ground Flash Fraction:

$$\alpha = \frac{N_g}{N} = \frac{N_g}{N_g + N_c} = \frac{1}{1+Z}$$

Cloud Flash to Ground Flash Ratio:

$$Z = \frac{1}{\alpha} - 1$$





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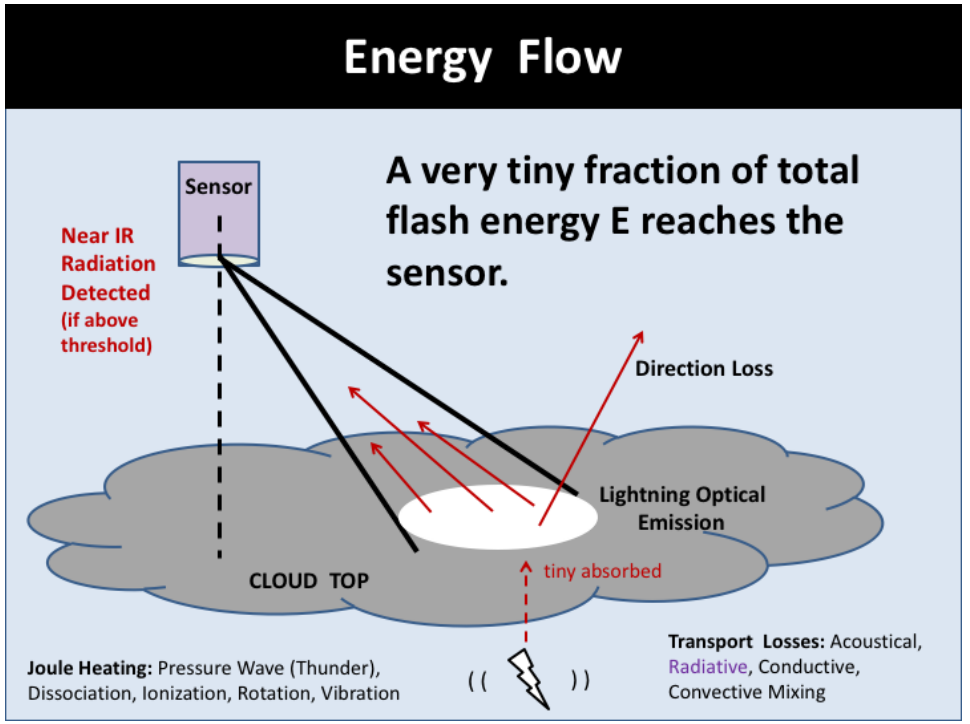
Two Optical Energy Metrics

Sensor-Intercepted Energy

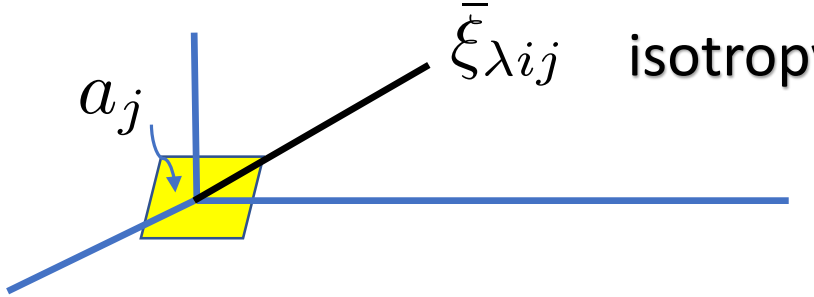
$$Q = \sum_{i=1}^{m}\sum_{j=1}^{n} A_j \Delta\lambda_j \Delta\omega_j \bar{\xi}_{\lambda ij} \qquad (\text{in fJ}) \qquad [GLM]$$

Total Upward Energy (from cloud-top surface)

$$\Gamma_\lambda = \sum_{i=1}^{m}\sum_{j=1}^{n} \pi \bar{\xi}_{\lambda ij} a_j \qquad (\text{in mJ } nm^{-1}) \qquad [LIS]$$



sum upward flux from each event



isotropy assumed

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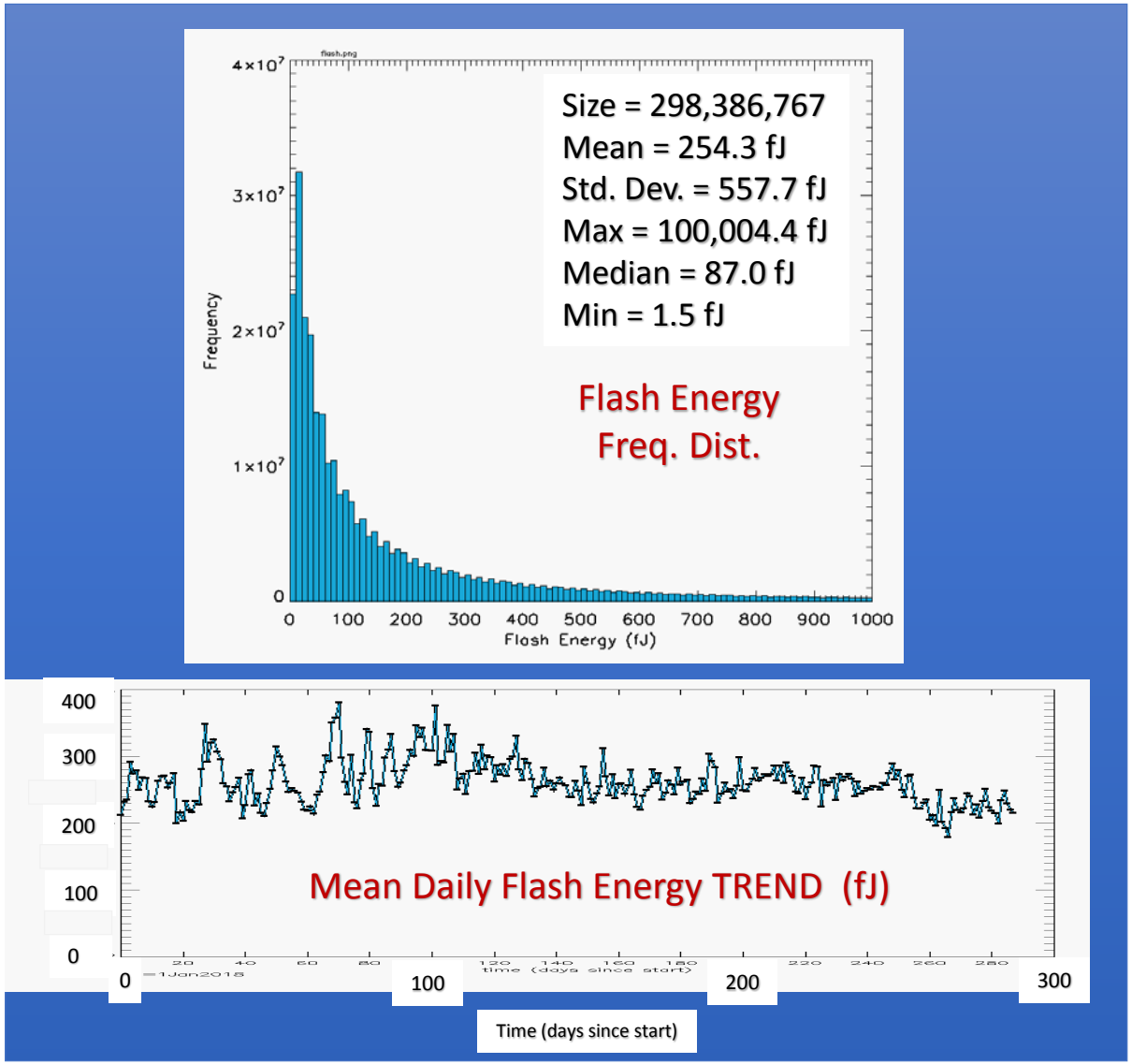
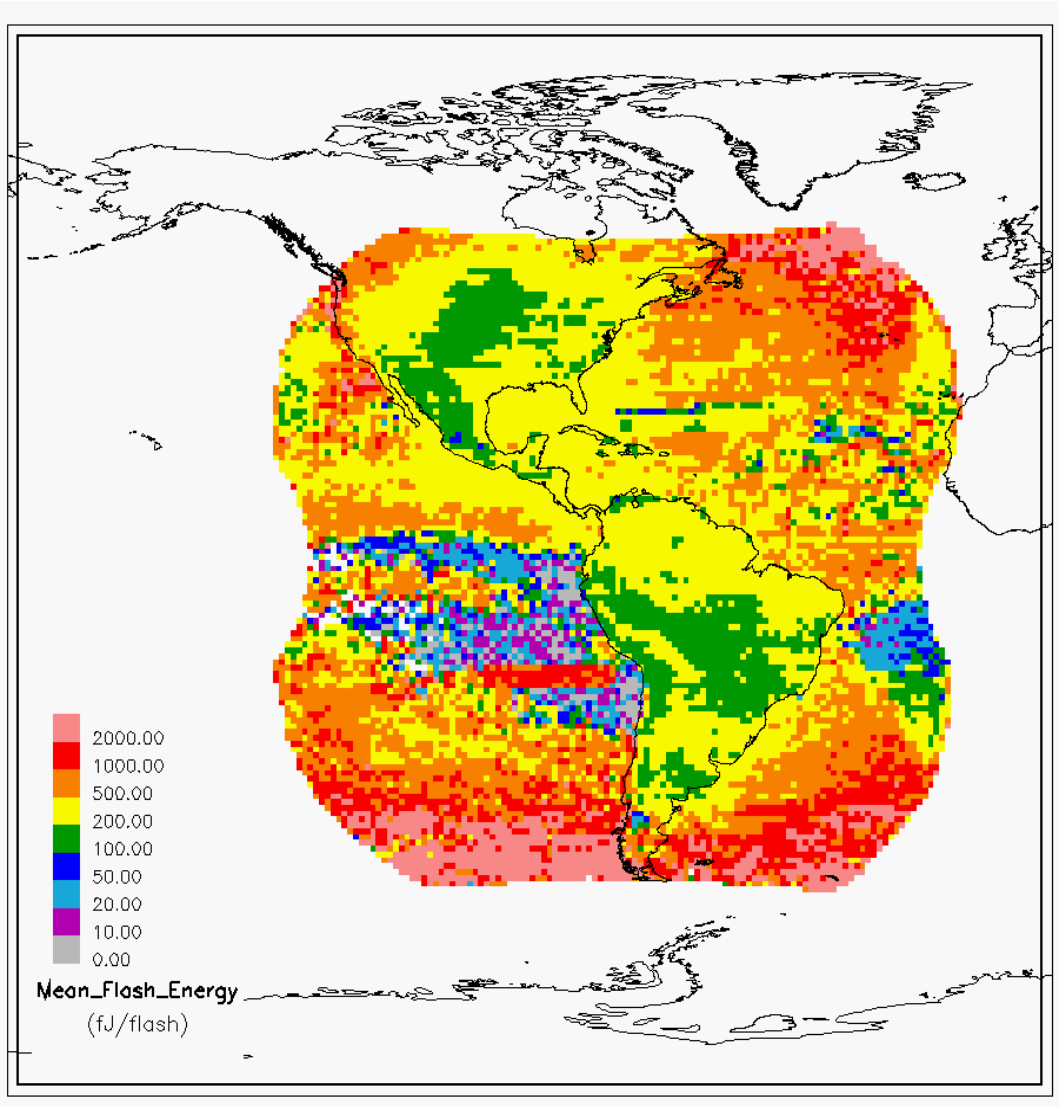
Flash Optical Energy Q (Broad View):

9.5 mo (2018: Jan 1 – Oct 15); ~ 300 M flashes





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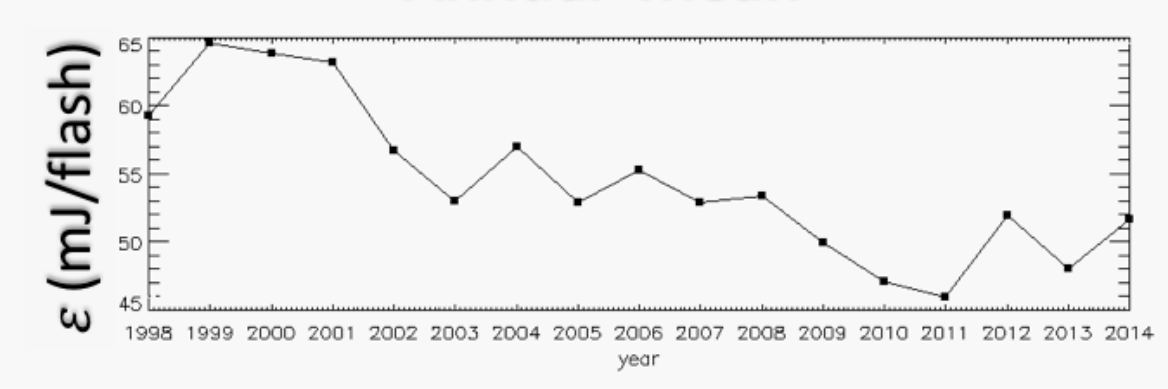
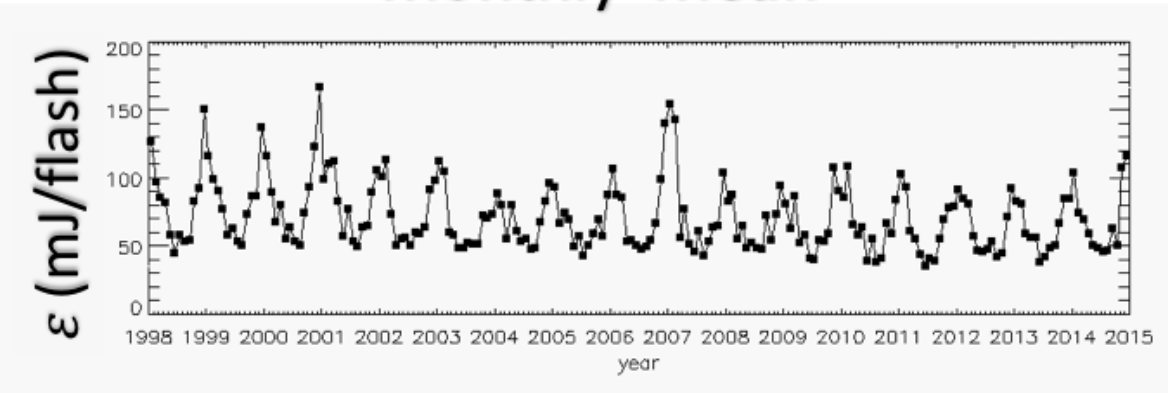
Long-Term Trend of TRMM/LIS Mean CONUS Upward Flash Optical Energy ε

Annual Mean



Monthly Mean



➡ Trends down to 2011, then trends up.

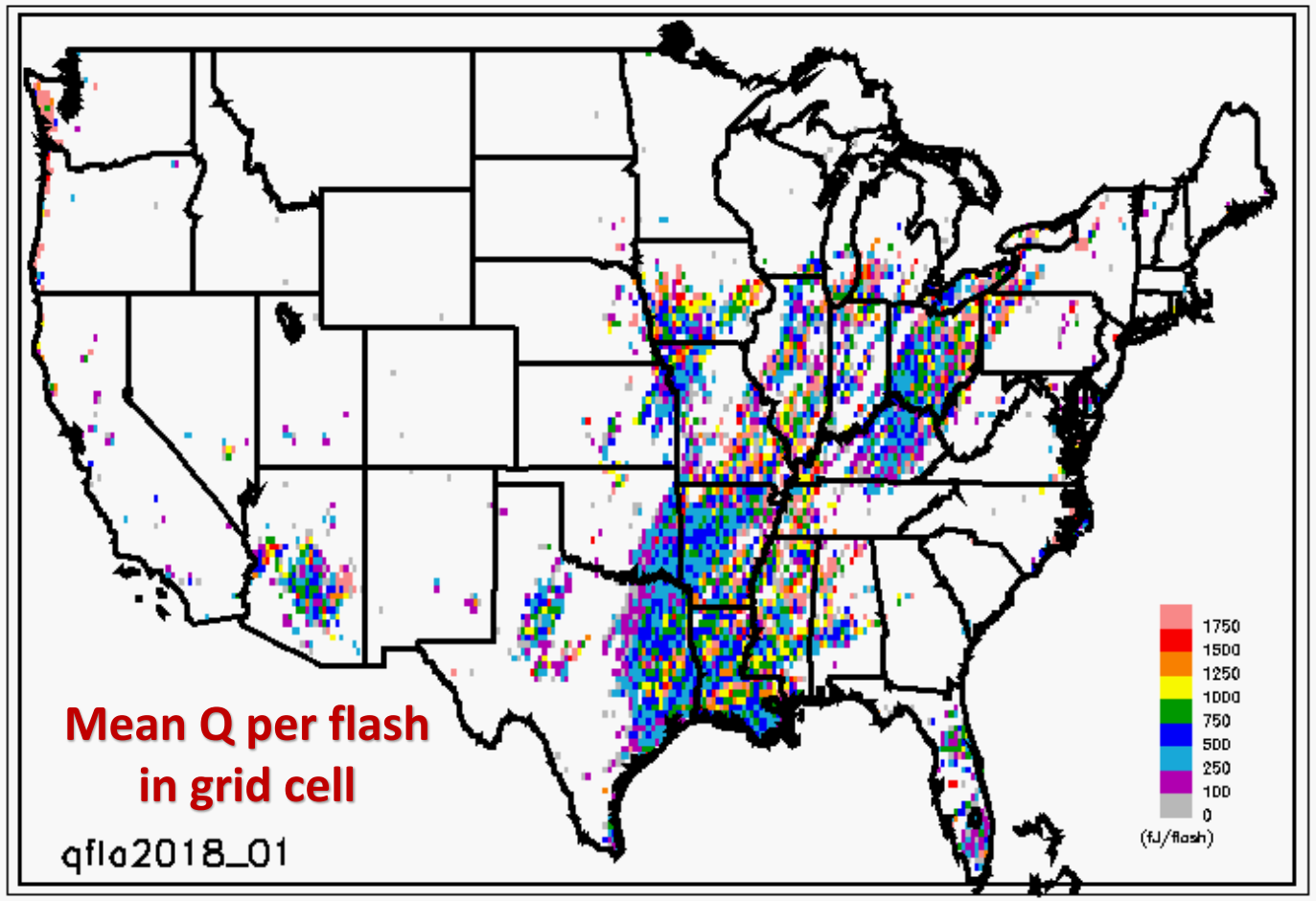
$$\varepsilon = \frac{1}{N_o} \sum_{k=1}^{N_o} \Gamma_{\lambda k} \Delta\lambda$$

➡ Oscillates! ... with peak in Winter.

Koshak, W. J, Lightning NOx estimates from space-based lightning imagers, 16th Annual CMAS Conference, Chapel Hill, NC, October 23-25, 2017

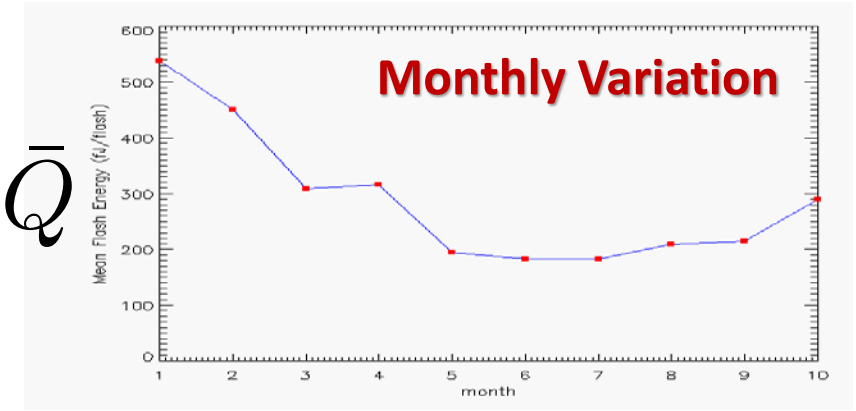
10 mo Trend (Jan-Oct, 2018) of GLM-16 CONUS Incident Flash Optical Energy Q

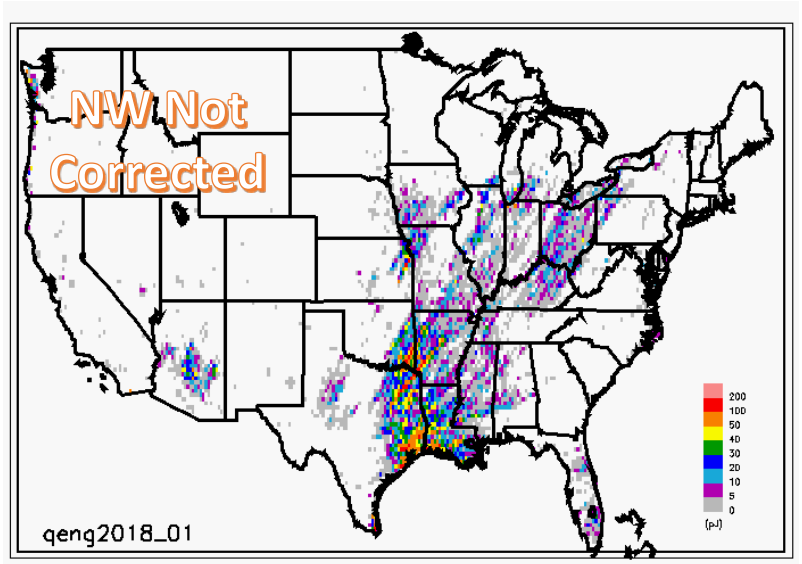
$$Q = \sum_{i=1}^{m}\sum_{j=1}^{n} q_{ij} = \sum_{i=1}^{m}\sum_{j=1}^{n} A_j \Delta\lambda_j \Delta\omega_j \bar{\xi}_{\lambda ij} \qquad (\text{in fJ})$$



Mean Q per flash in grid cell

$\bar{Q}$





Total Q from all flashes in grid cell

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LNO_x Production P in moles:

$$P = \left[\frac{Y}{N_A}\right] E = \left[\frac{Y}{\beta N_A}\right] Q \,, \qquad\qquad Q \text{ in Joules}$$

$Y \sim 10^{17}\ molecules\ J^{-1}$ (Thermochemical Yield)

$N_A = 6.022 \times 10^{23}\ molecules\ mol^{-1}$ (Avogadro's Number)

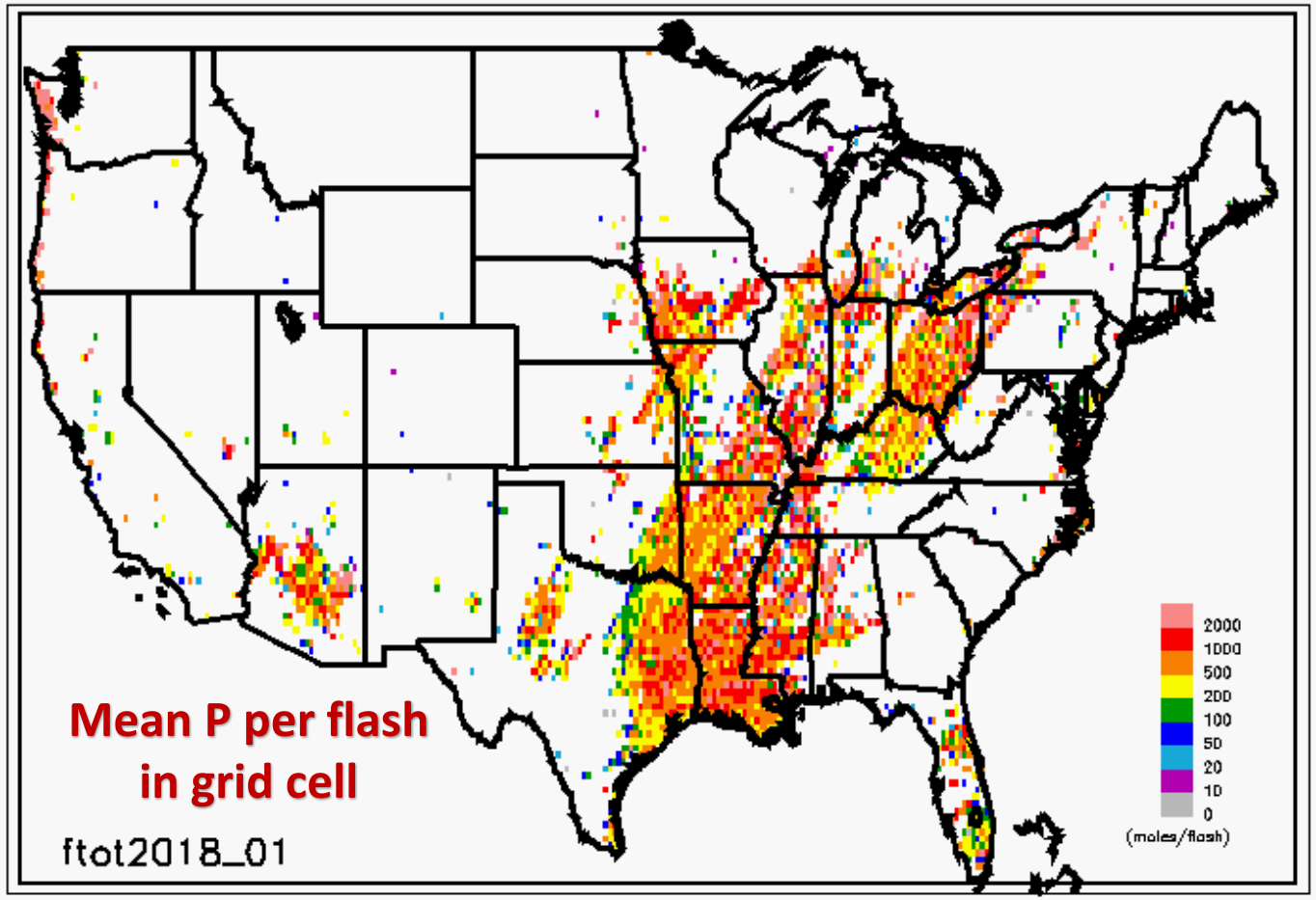
$\beta \sim 1.35997 \times 10^{-22} \Rightarrow$ ave $P = 250$ moles/flash over 1st 10 mo of 2018 reference year

Flash Energy E when $P = 250$ moles is:

$$E = \frac{N_A P}{Y} = 1,505,500,000\ J \sim 1.5\ GJ$$

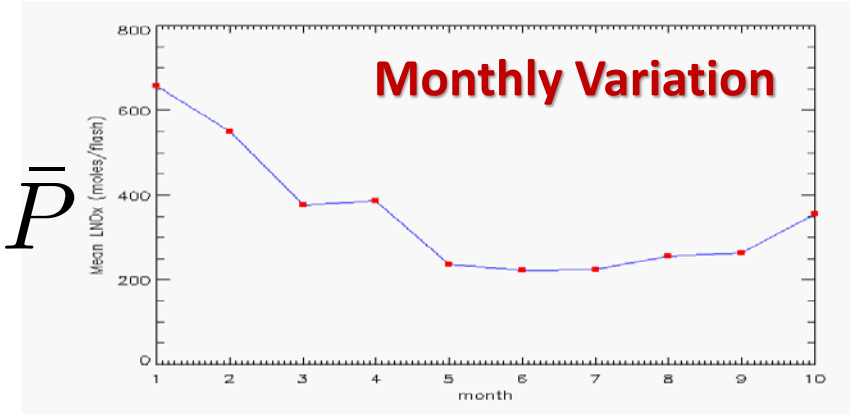
10 mo Trend (Jan-Oct, 2018) of GLM-16 CONUS LNOx Production P Estimate

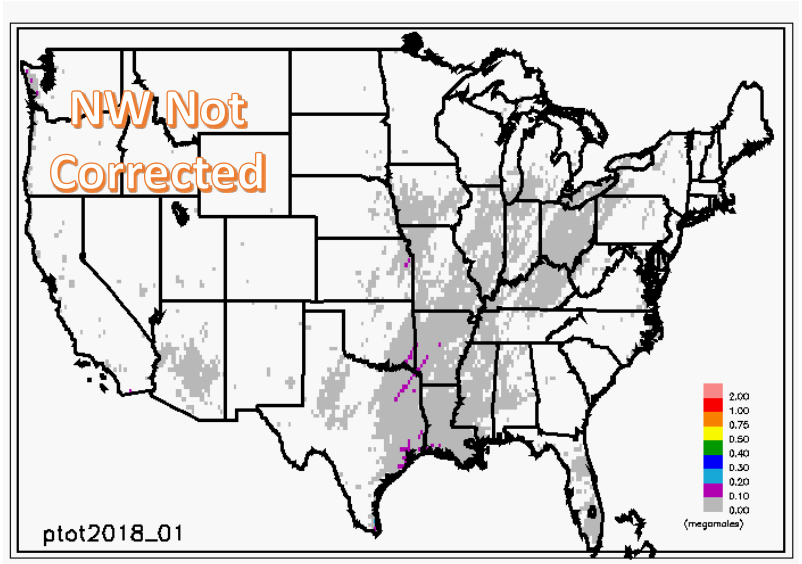
$$P = \left[\frac{Y}{\beta N_A}\right] Q \qquad \text{(in moles)}$$



Mean P per flash in grid cell

$\bar{P}$





Total P from all flashes in grid cell

Koshak, NASA/MSFC

Summary

- GLM is a new effective tool for probing lightning/climate relations for NCA program, and for improving air quality modeling.
- Major benefits: 24/7 continuous monitoring, & total lightning detection.
- Allows for continuous monitoring of Z ratio when GLM combined with NLDN data.
- GLM trending of flash optical energy, Q, has begun which is a proxy to flash LNOx production (and which directly affects greenhouse gas concentrations, such as ozone).