



GLM-16 National Climate Assessment Analyses

GLM Science Meeting

Huntsville, AL

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Lightning MOnitor (LIMO)



- **Tool for monitoring lightning counts/attributes as related to changes in climate**
 - Written in the Wolfram Language (Mathematica 13.1.0.0)
 - Replaces & expands upon the older Lightning Analysis Tool (LAT) written in IDL
 - Puts Wolfram Knowledge Base “at your fingertips & ready for computation”
- **Ingests GLM-16 & NLDN datasets**
- **Continuously evolving to identify, analyze & monitor new/insightful parameters derived from the data.** *(also useful for GLM cal/val)*
- **Supports National Climate Assessment (NCA) ... so focus on CONUS primarily**
 - How does a changing climate affect US lightning?
 - What impact do changes in US lightning have on US infrastructure, economy, safety ...?
 - LNOx, wildfires, power-outages, deaths/injuries, crop/property damage, ...
 - What can changes in lightning tell us (i.e. “**indicate**”) about changes in climate?

Overview of LIMO Analyses



	GLM								NLDN									
	c	e	a	d	r	x	s	n/c	n	n-	n+	p	p-	p+	m	m-	m+	n+/n
num																		
max																		
ave																		
std																		
med																		
min																		

5x6 = 30 stats
Count = 1 type

5x6 = 30 stats
Count = 3 types

KEY:

Flash ...

- e = energy
- a = area
- d = duration
- r = # groups
- x = MGA
- s = ave group energy
- p = peak current
- m = multiplicity
- c = counts (GLM)
- n = counts (NLDN)
- + positive polarity
- negative polarity

6 basic plot types:

- HIS: histogram ... *fasap*
- MAP: geographical CONUS heat map ... *fasap*
- DIU: diurnal variation (0-24 hrs) *fasap*
- TIM: time evolution (day range) *fasap*
- TIM: time evolution (month range) *fasap*
- TIM: time evolution (year range) *fasap*

fasap: for a selected analysis period; i.e. day(s), month(s), year(s)

SUMMARY:

5x60 = 300 Statistics Plots (Max, Ave, Std, Med, Min)

5x4 = 20 Count Plots

4x2 = 8 Fraction (n/c, n+/n) Plots

1x12 = 12 Histogram Plots

= **340 possible plots!**

+ flash location plots (LOC)

+ 6!/(6-2)! + 6 = 36 covariation plots (COV)

Flash Energy a Proxy for LNO_x Production



LNO_x Production P in moles:

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

$Y \sim 10^{17}$ 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

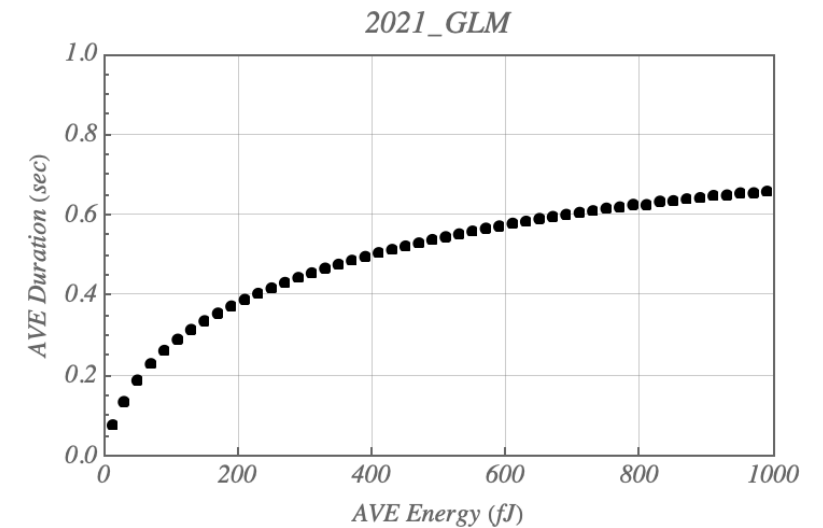
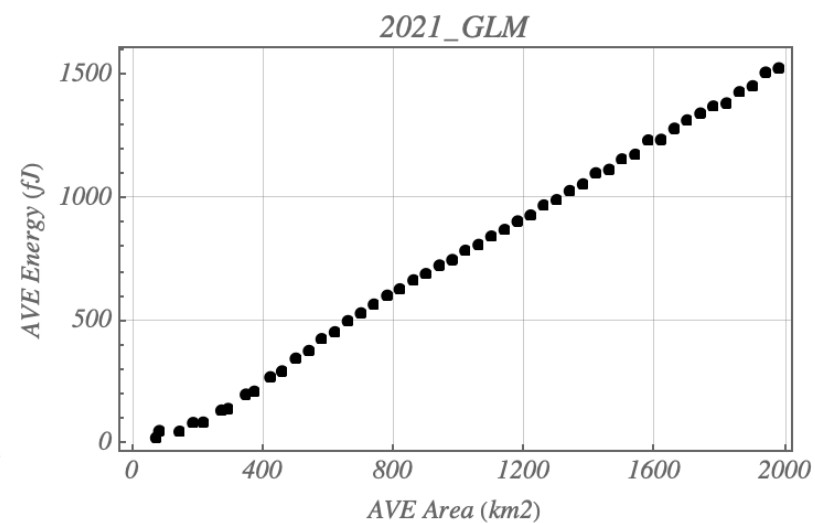
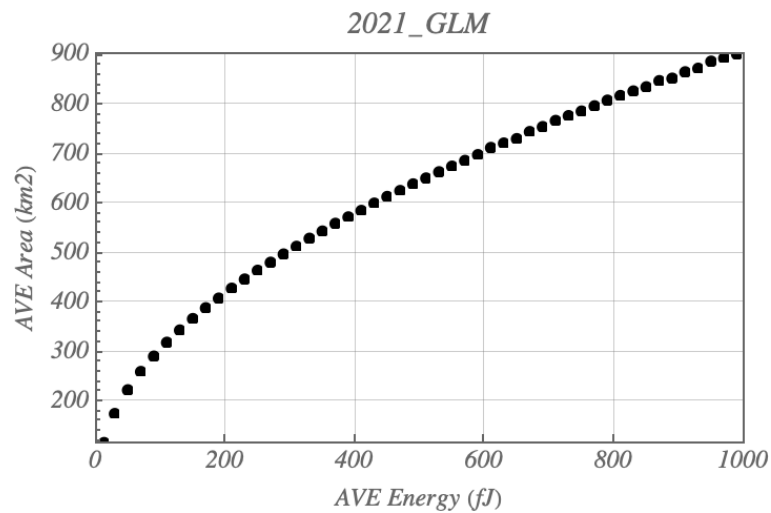
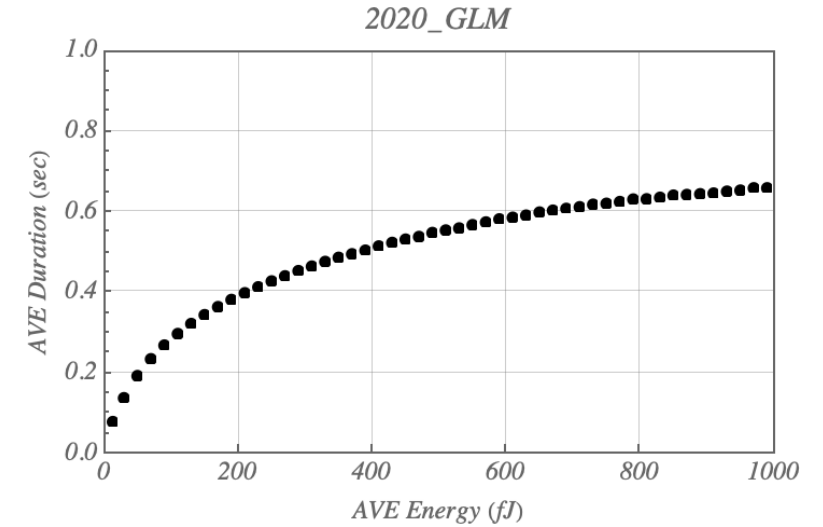
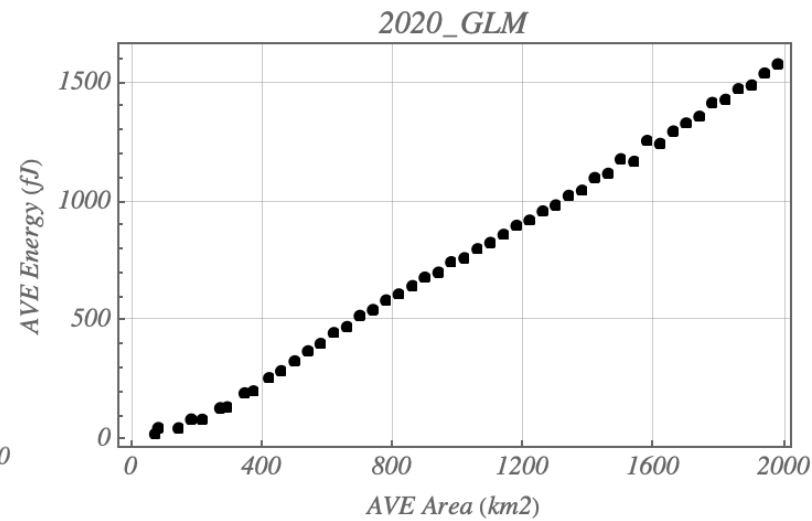
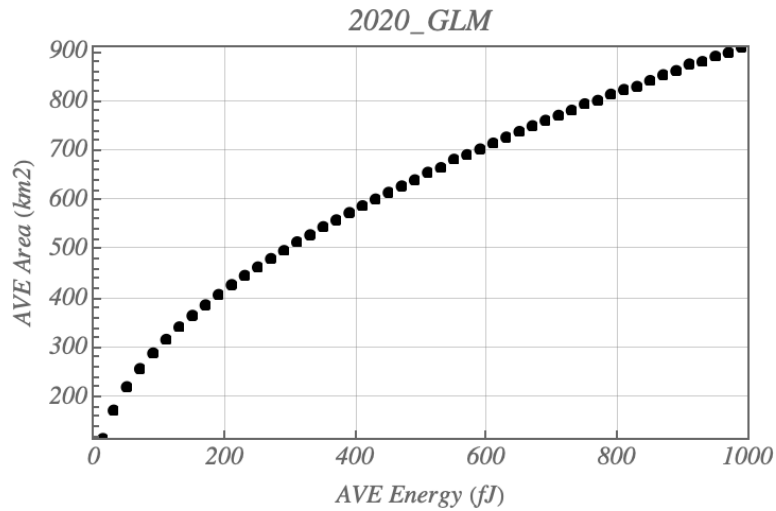
A more universal approach is to simply assign $\beta = (Y/N_A)(10^{-15} \text{ J/fJ}) = \mathbf{1.66058 \times 10^{-22}}$
which gives 1 mole of LNO_x per fJ of GLM flash optical energy; i.e. **$P = Q$, where Q is now in femtoJoules.**

For example, GLM flashes over CONUS are \sim couple hundred fJ ... so produce a couple hundred moles.

GLM-16 2020 & 2021 COVARIANCE INDICATORS



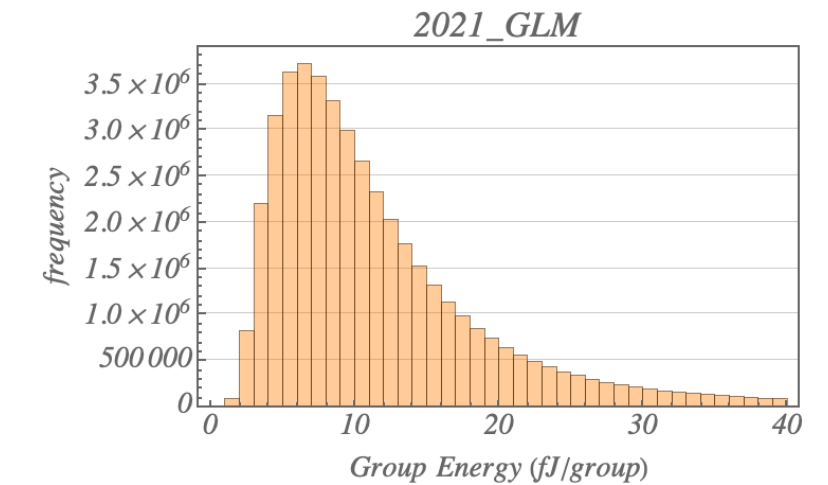
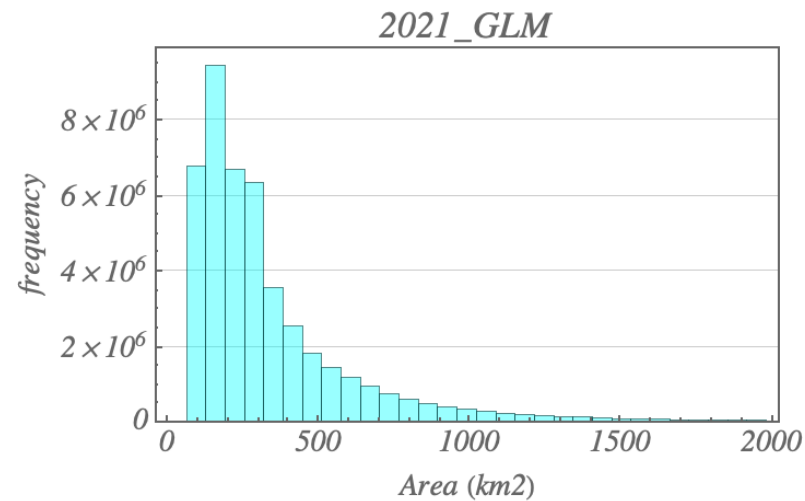
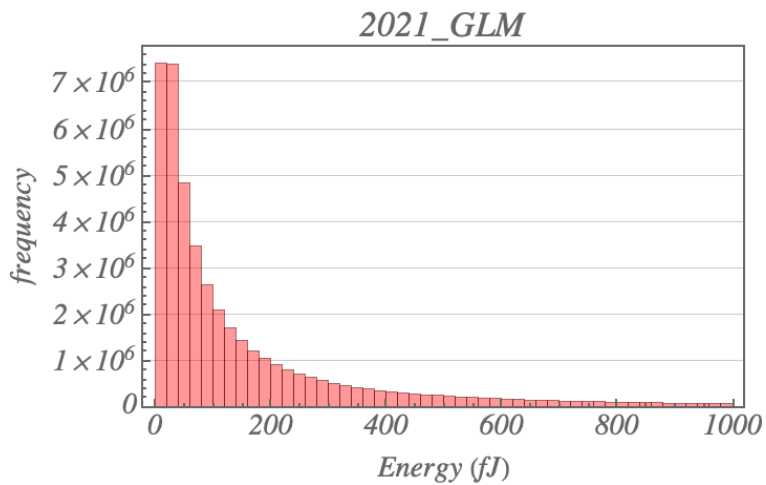
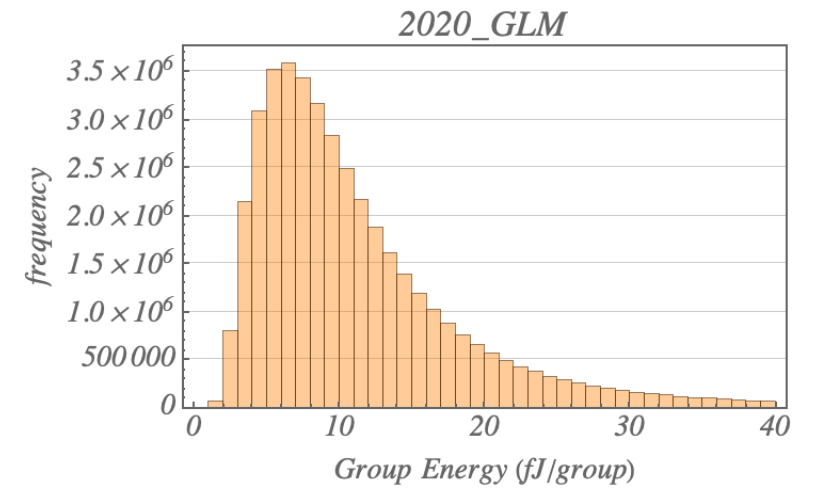
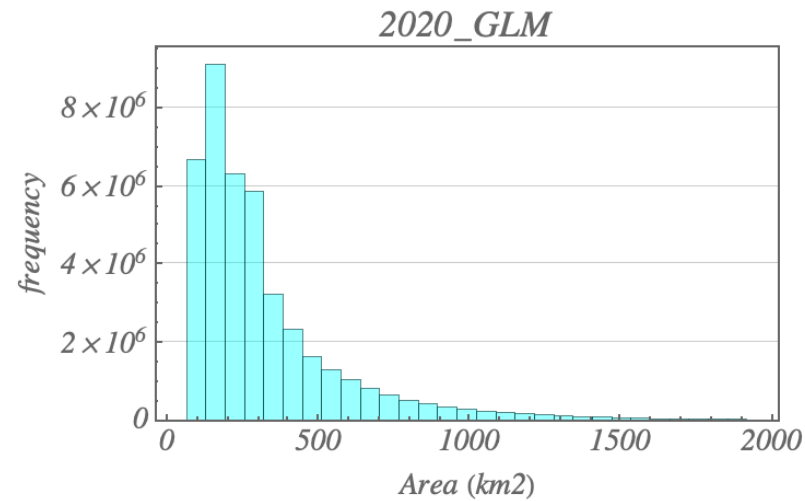
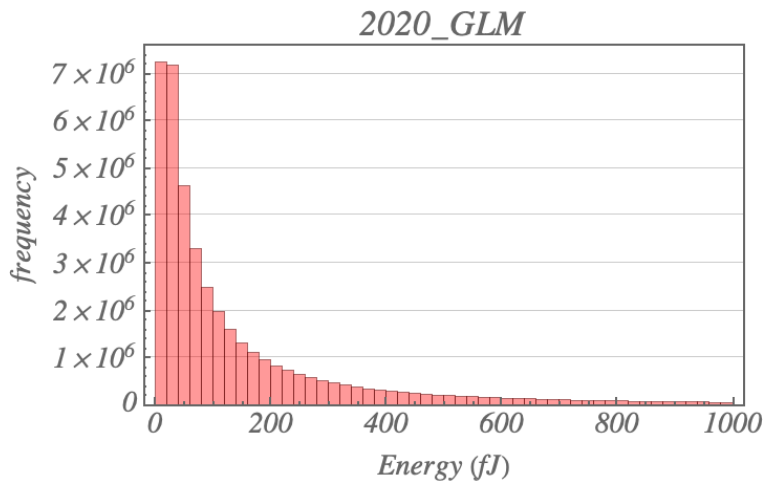
(Box-car Scanning Average of the Raw Scatter-Plots Along x-axis)



GLM-16 2020 & 2021 DISTRIBUTION INDICATORS



(flash energy in 1st column reasonable proxy to LNOx)

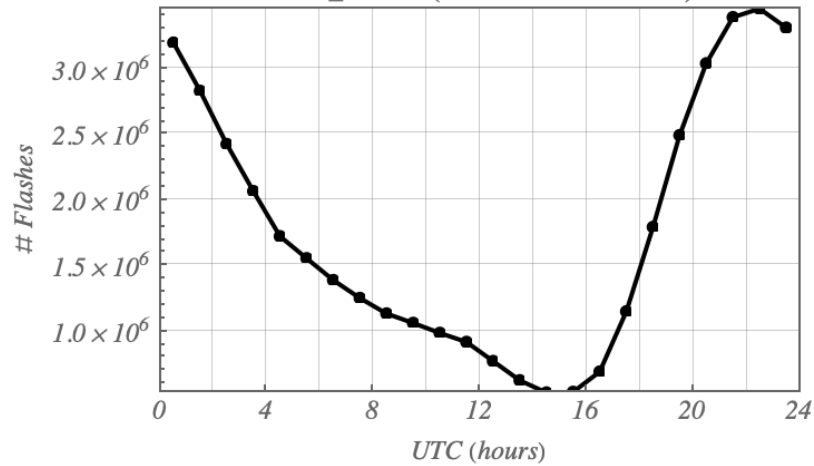


GLM-16 2020 & 2021 DIURNAL INDICATORS

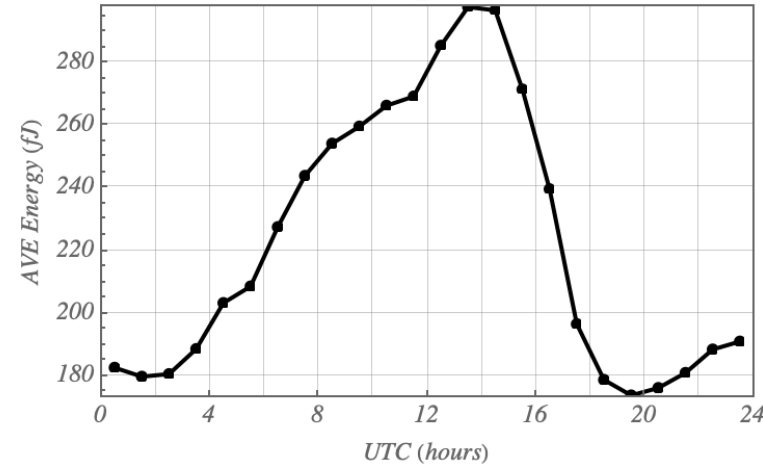
(also experimenting with other time-bases such as Solar Time, ...)



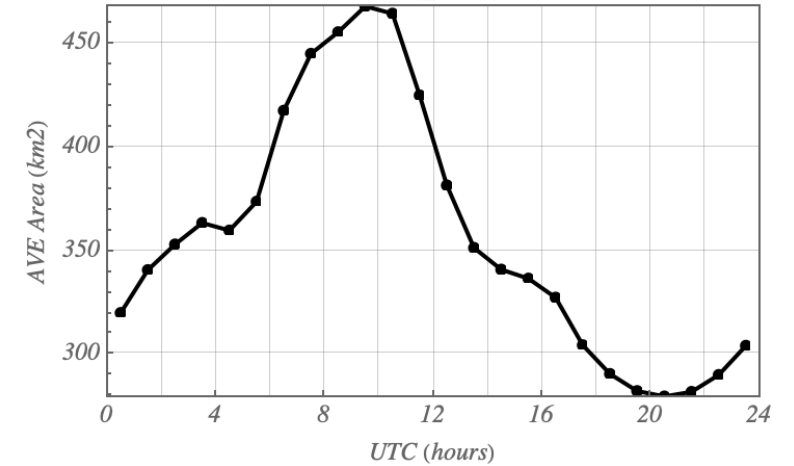
2020_GLM (Count = 42367955)



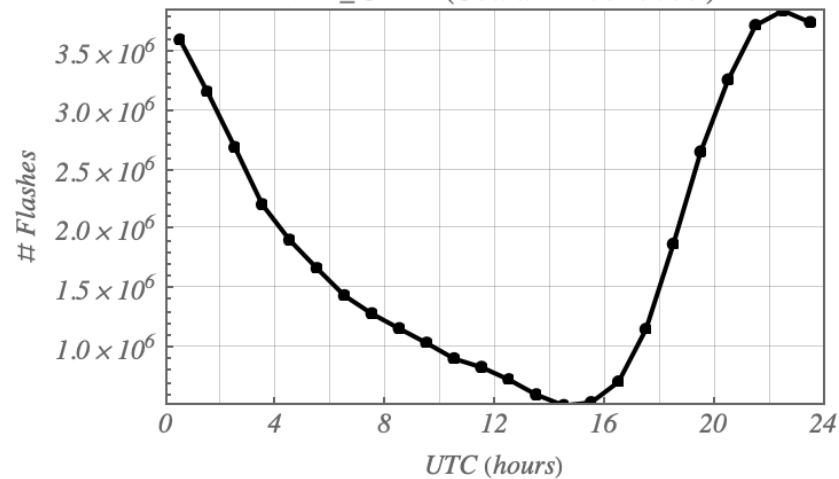
2020_GLM



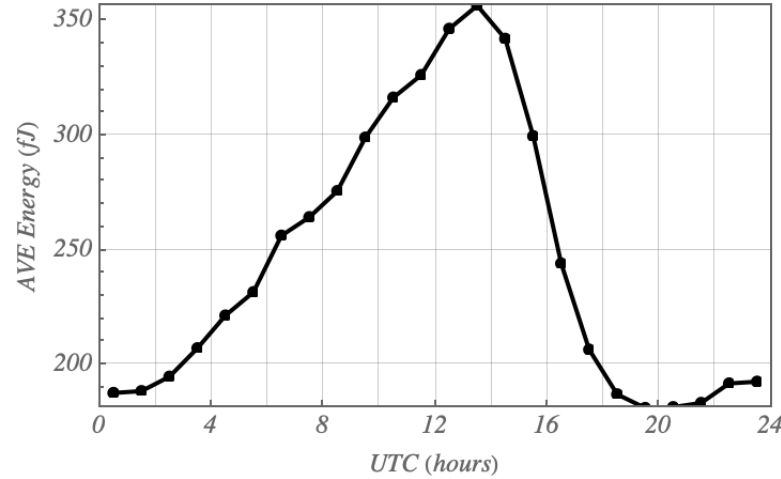
2020_GLM



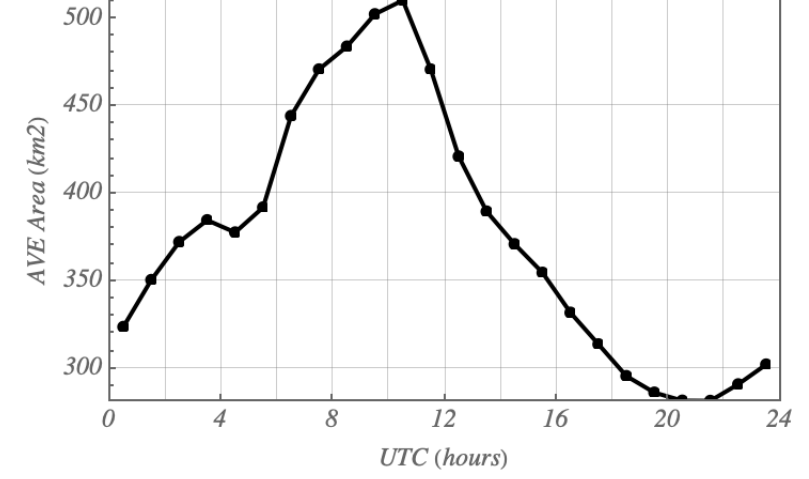
2021_GLM (Count = 45317537)



2021_GLM



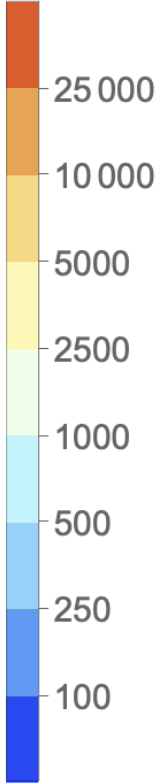
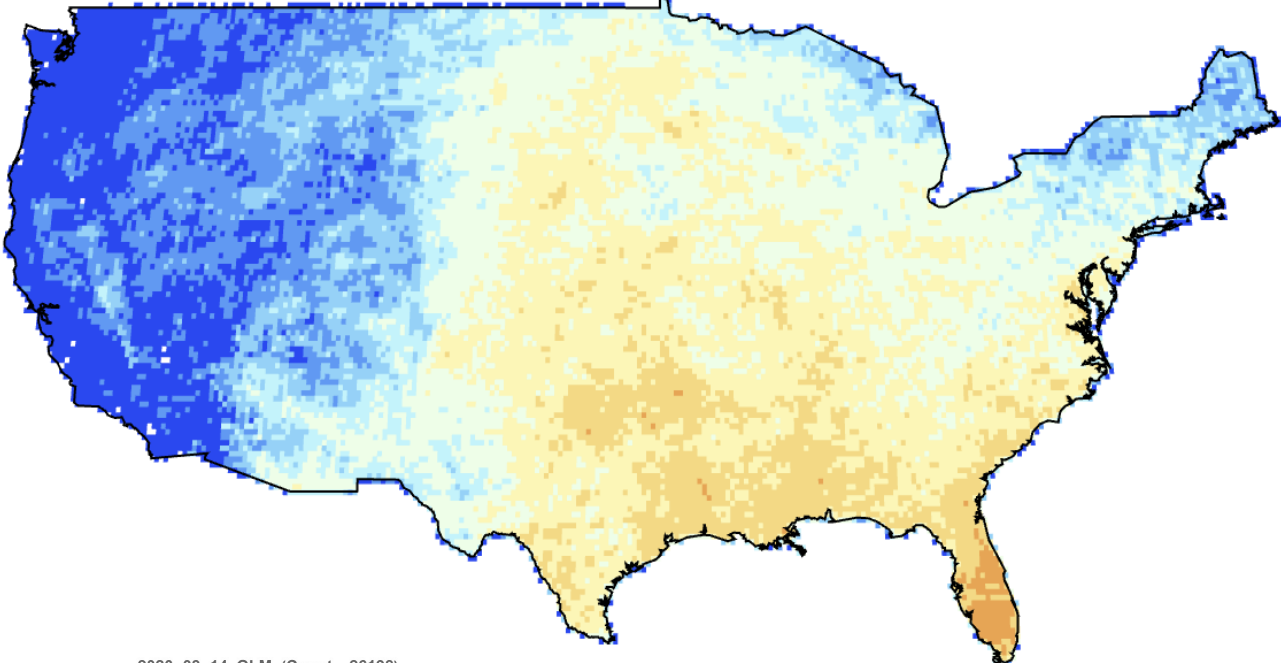
2021_GLM



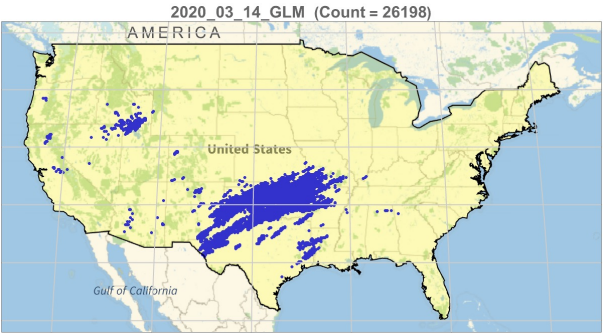
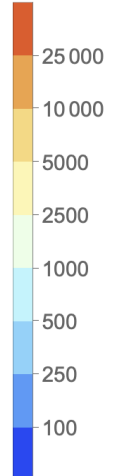
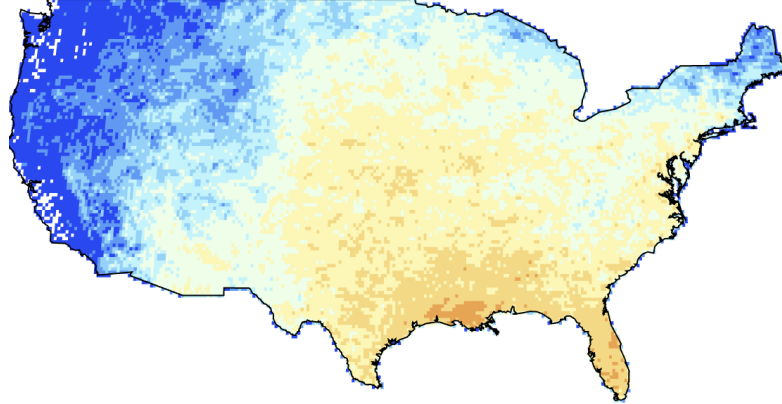
GLM-16 2020 & 2021 SPATIAL INDICATORS (Flash Counts)



2020_GLM (Count = 42368628)



2021_GLM (Count = 45318309)



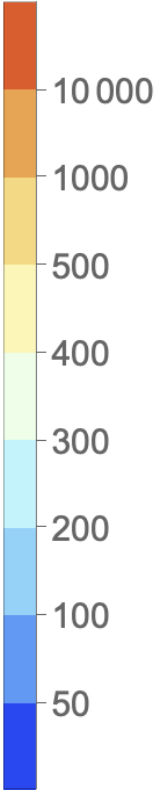
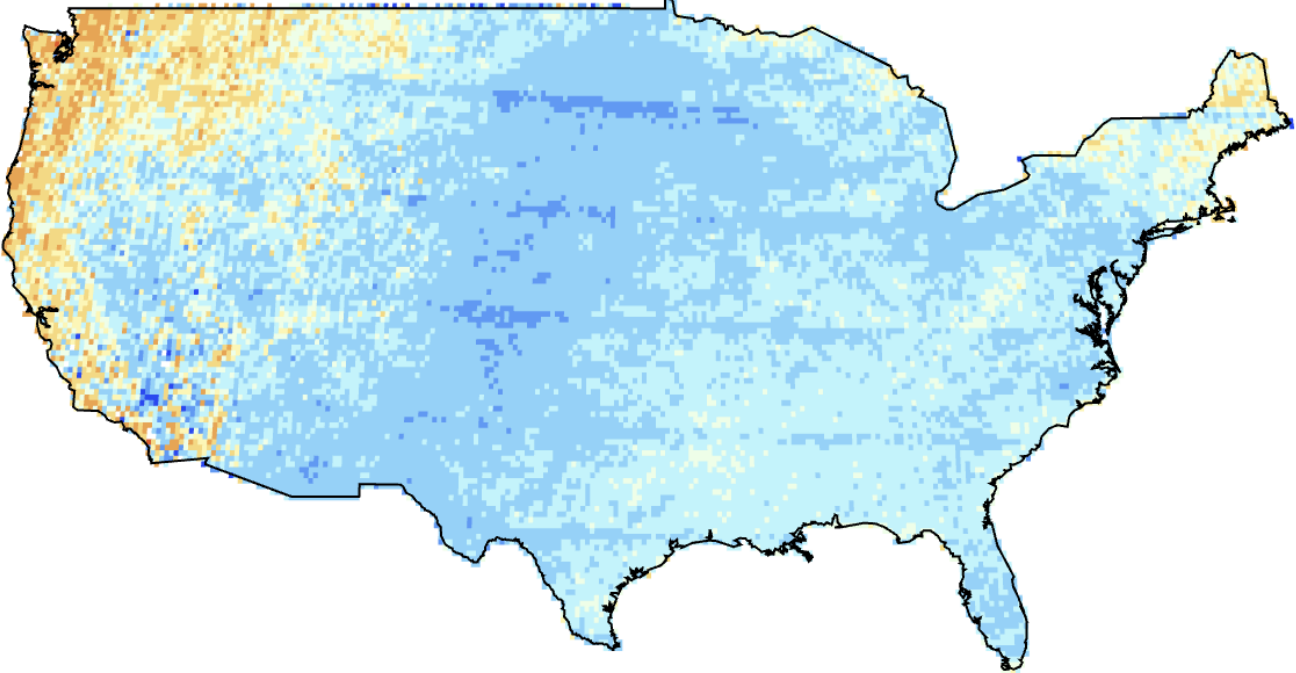
(also daily flash location plots)

GLM-16 2020 & 2021 SPATIAL INDICATORS

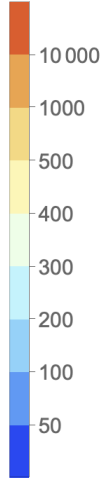
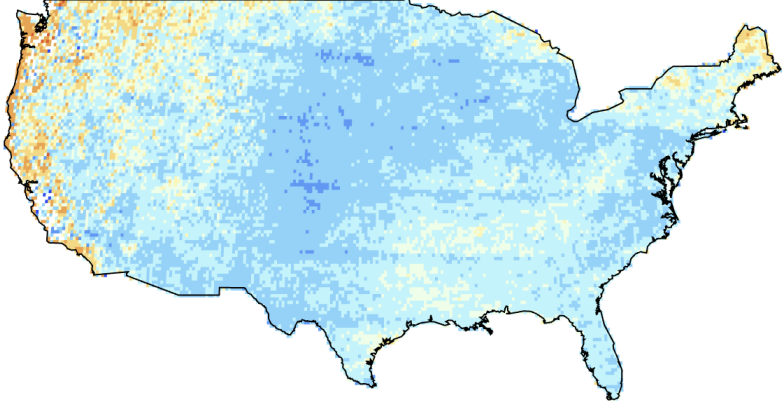


(Average Flash Energy)

2020_GLM AVERAGE Energy (fJ)



2021_GLM AVERAGE Energy (fJ)

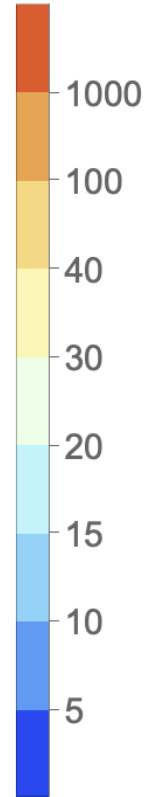
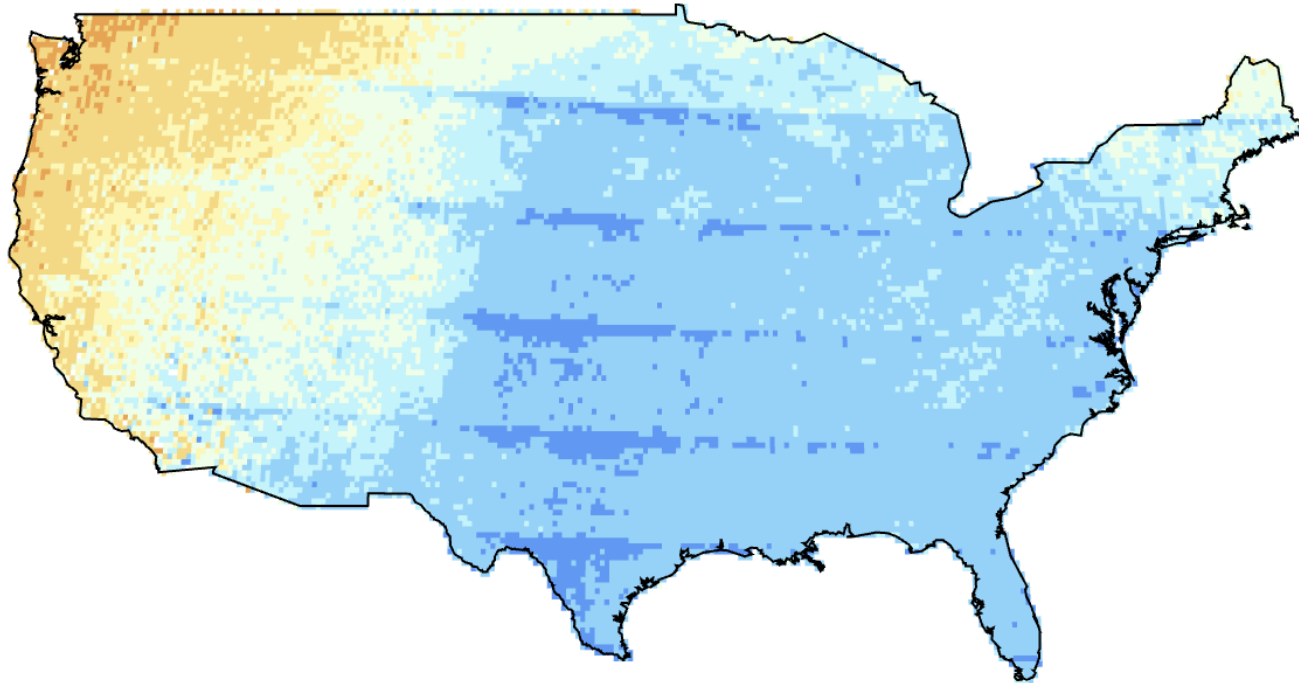


GLM-16 2020 & 2021 SPATIAL INDICATORS

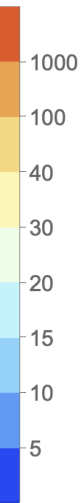
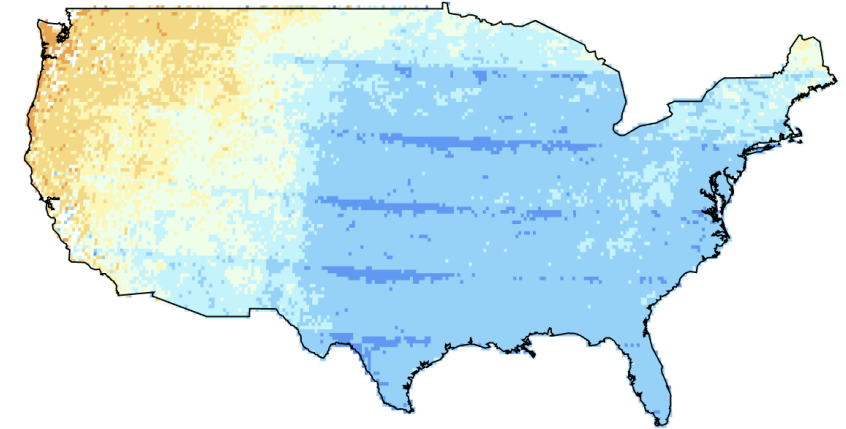
(Average Group Energy)



2020_GLM AVERAGE Group Energy (fJ/group)



2021_GLM AVERAGE Group Energy (fJ/group)

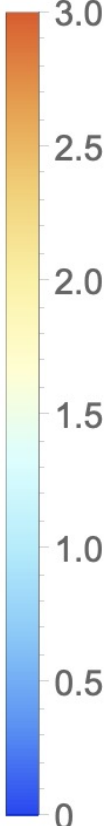
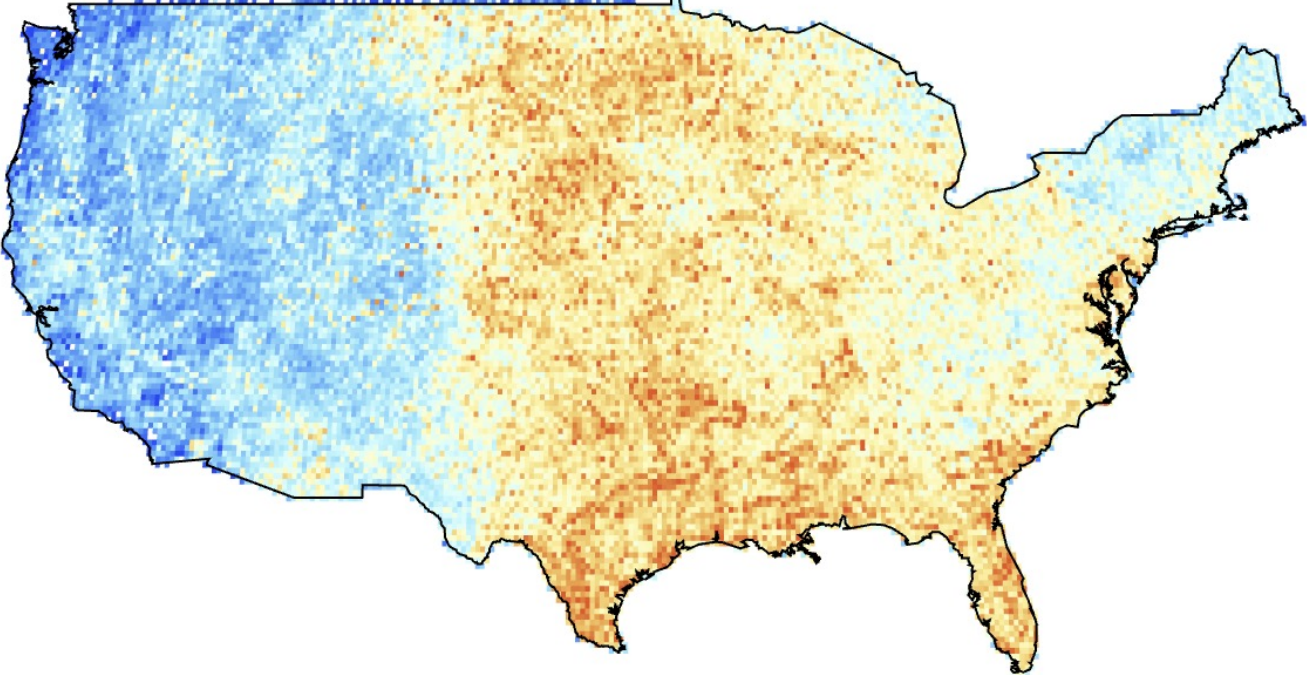


GLM-16 2020 & 2021 SPATIAL INDICATORS

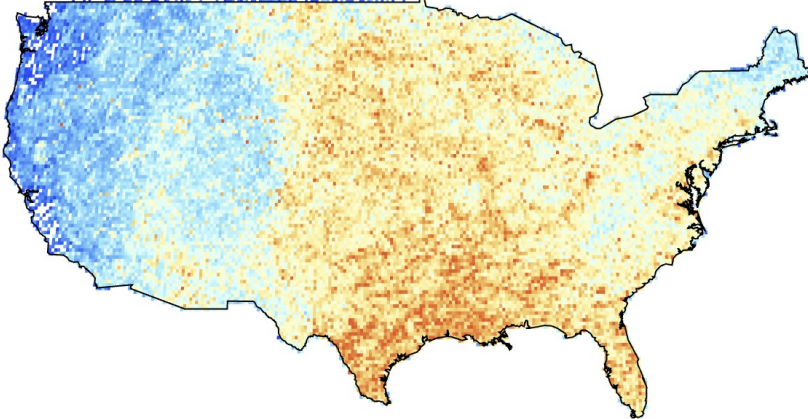
(Maximum Flash Duration)



2020_GLM MAX Duration (sec)

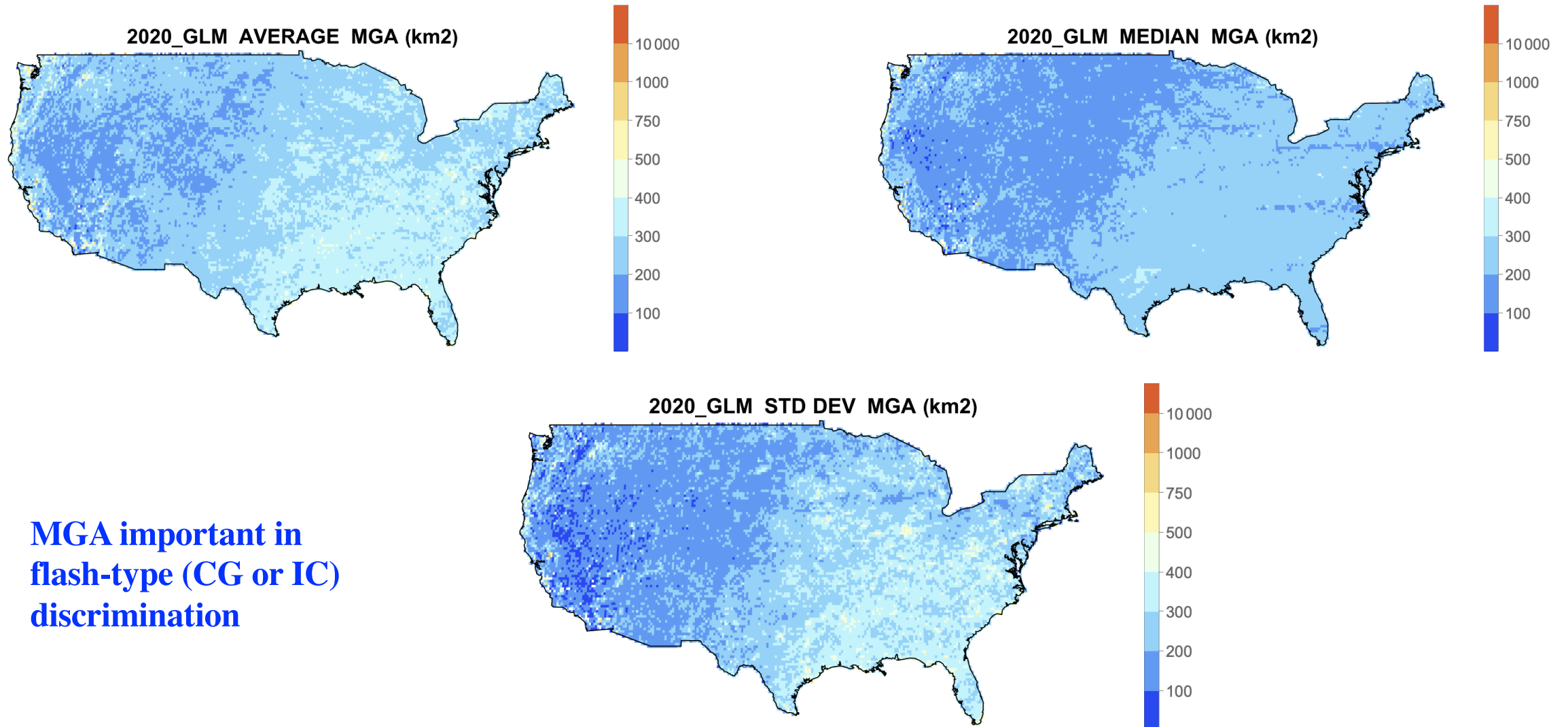


2021_GLM MAX Duration (sec)



GLM-16 2020 SPATIAL INDICATORS

(Maximum Group Area [MGA] Statistics)



**MGA important in
flash-type (CG or IC)
discrimination**



Thank You!