Ongoing GLM16/NLDN National Climate Assessment Analyses

GLM Science Meeting, Huntsville, AL
15 November 2023

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LIghtning MOnitor (LIMO)

- **Research Tool for monitoring lightning attributes as related to changes in climate**
  - Written in the Wolfram Language (Mathematica 13.2.1.0) by Koshak
  - 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,** ***and now produces PRATIO & ALPHA plots***

- **Continuously evolving to identify, analyze & monitor new/insightful parameters derived from the GLM/NLDN 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

18 Flash Parameters:
(NLDN, GLM)

1. p = CG peak current
2. m = CG multiplicity
3. p- = -CG peak current
4. m- = -CG multiplicity
5. p+ = +CG peak current
6. m+ = +CG multiplicity
7. e = energy … proxy for LNOx
8. a = area
9. d = duration
10. r = # groups
11. x = MGA
12. s = e/r = ave group energy

13. PRATIO = Ng+/Ng
14. ALPHA = Ng/N (hybrid)

15. Ng = # NLDN CGs
16. Ng- = # NLDN -CGs
17. Ng+ = # NLDN +CGs
18. N = # GLM flashes

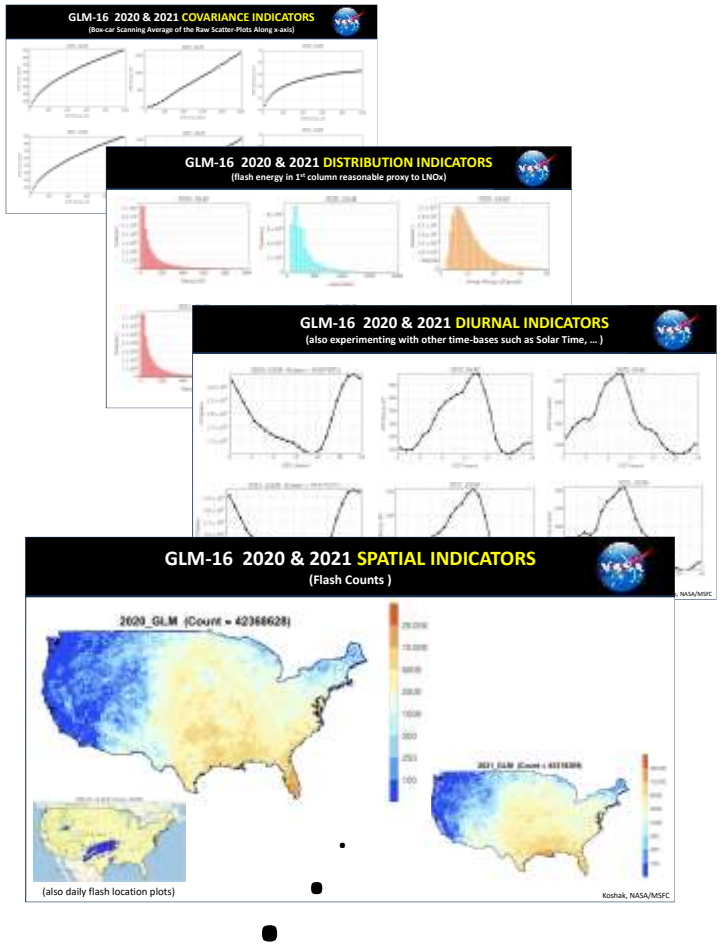
Z = (N-Ng)/Ng = 1/ALPHA -1

Plot Types:
- HIS: histogram
- MAP: geographical CONUS heat map
- DIU: diurnal variation
- TIM: time evolution
- LOC: flash location
- COV: ave(VAR1) vs ave(VAR2)

Statistics:
- Size, Max, Mean, Std Dev, Median, Min

Analysis Periods:
- Single Day
- Multiple Days in a Month
- Single Month
- Multiple Months in a Year
- Single Year
- Multiple Years

Many Plots!



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Reclassified NLDN

- **NLDN "type classification" (IC vs. CG) has changed/evolved over the years**
  - 2015, 2018, 2022: See Murphy et al. (2021, JTECH-A) for details
- **Therefore, "Normalization" is required to minimize effects of these changes on long-term trends in CONUS CG flash counts for NLDN reports since August 2015**
- **Our Approach: "reclassify" all NLDN strokes and flashes using "pre-2015" classification**
  - Re-classify NLDN ***sensor reports*** as IC or CG using the classification algorithm and parameters employed before August 2015 (uses peak current, polarity, and waveform peak-to-zero time)
  - Re-classify ***located strokes***/***cloud pulses*** using two nearest sensors >50 km from discharge location
  - Re-classify ***located flashes*** based on member strokes / cloud pulses
    - If a flash includes any CG strokes, it is classified as a CG flash

20 yr NLDN Flash Counts (2003 – 2022)

Table 1. Summary of NLDN CG lightning count, and +CG fraction (PRATIO) for the 20 yr period 2003 - 2022. Note that the Standard NLDN product is used for 2003 - 2014, and the Reclassified NLDN product is used for 2015 - 2022. The few years of GLM-16 total CONUS lightning count and ground flash fraction ALPHA (= NLDN/GLM-16) also shown. GLM Blooming Filter not implemented until 25 July 2019.

Year	NLDN	PRATIO	GLM-16	ALPHA
2003	25,214,012	0.044	-	-
2004	26,393,510	0.051	-	-
2005	25,587,278	0.053	-	-
2006	25,010,419	0.056	-	-
2007	23,289,999	0.059	-	-
2008	22,754,220	0.069	-	-
2009	22,152,380	0.068	-	-
2010	22,725,216	0.073	-	-
2011	23,619,517	0.079	-	-
2012	18,134,904	0.084	-	-
2013	18,661,357	0.082	-	-
2014	22,809,502	0.072	-	-
2015	23,869,712	0.069	-	-
2016	24,769,395	0.067	-	-
2017	21,916,029	0.072	-	-
2018	21,821,645	0.069	-	-
2019	21,013,962	0.074	-	-
2020	15,350,478	0.081	42,368,490	0.362
2021	16,579,429	0.077	45,318,145	0.366
2022	17,477,559	0.069	46,438,720	0.376

(17,477,559-25,214,012)/25,214,012 = -30.7% drop

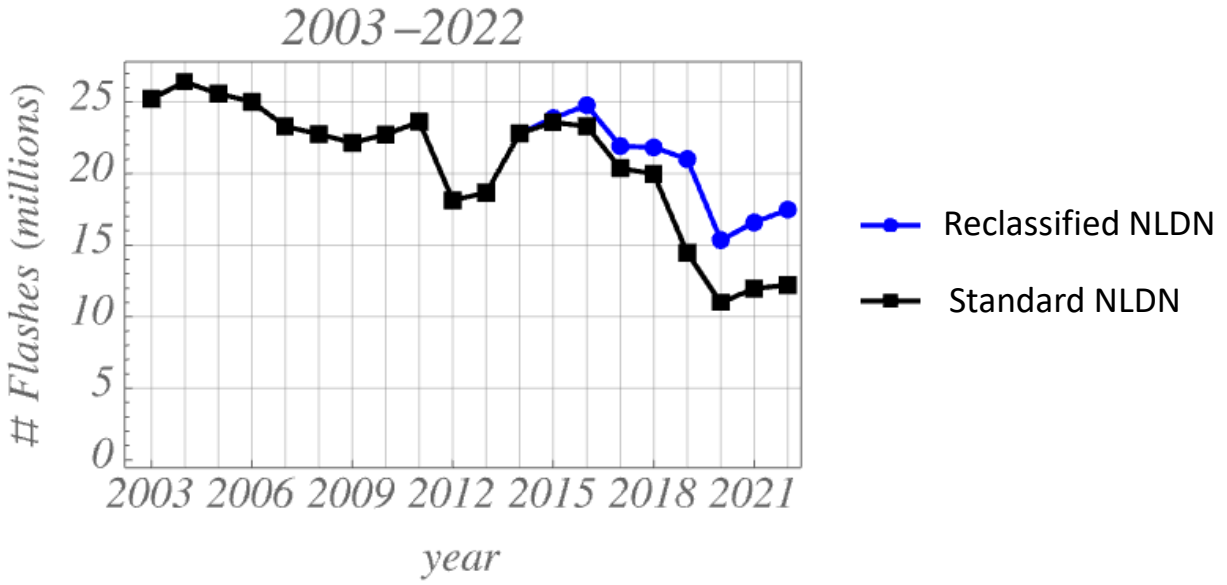

Table 2. Percent change [i.e., 100(Reclassified-Standard)/Standard] in the CG lightning count for the period 2015 - 2022.

Year	NLDN (Reclassified)	NLDN (Standard)	% Change
2015	23,869,712	23,581,122	1.22
2016	24,769,395	23,293,049	6.34
2017	21,916,029	20,376,025	7.56
2018	21,821,645	19,964,236	9.30
2019	21,013,962	14,458,981	45.34
2020	15,350,478	10,977,886	39.83
2021	16,579,429	11,967,164	38.54
2022	17,477,559	12,205,845	43.19

- Blooming Filter not implemented until **25 July 2019** … so ”clean” GLM-16 annual results start in 2020.
- Upticks in NLDN & GLM-16 occur coming out of COVID
- GLM-16 flash counts not DE-corrected

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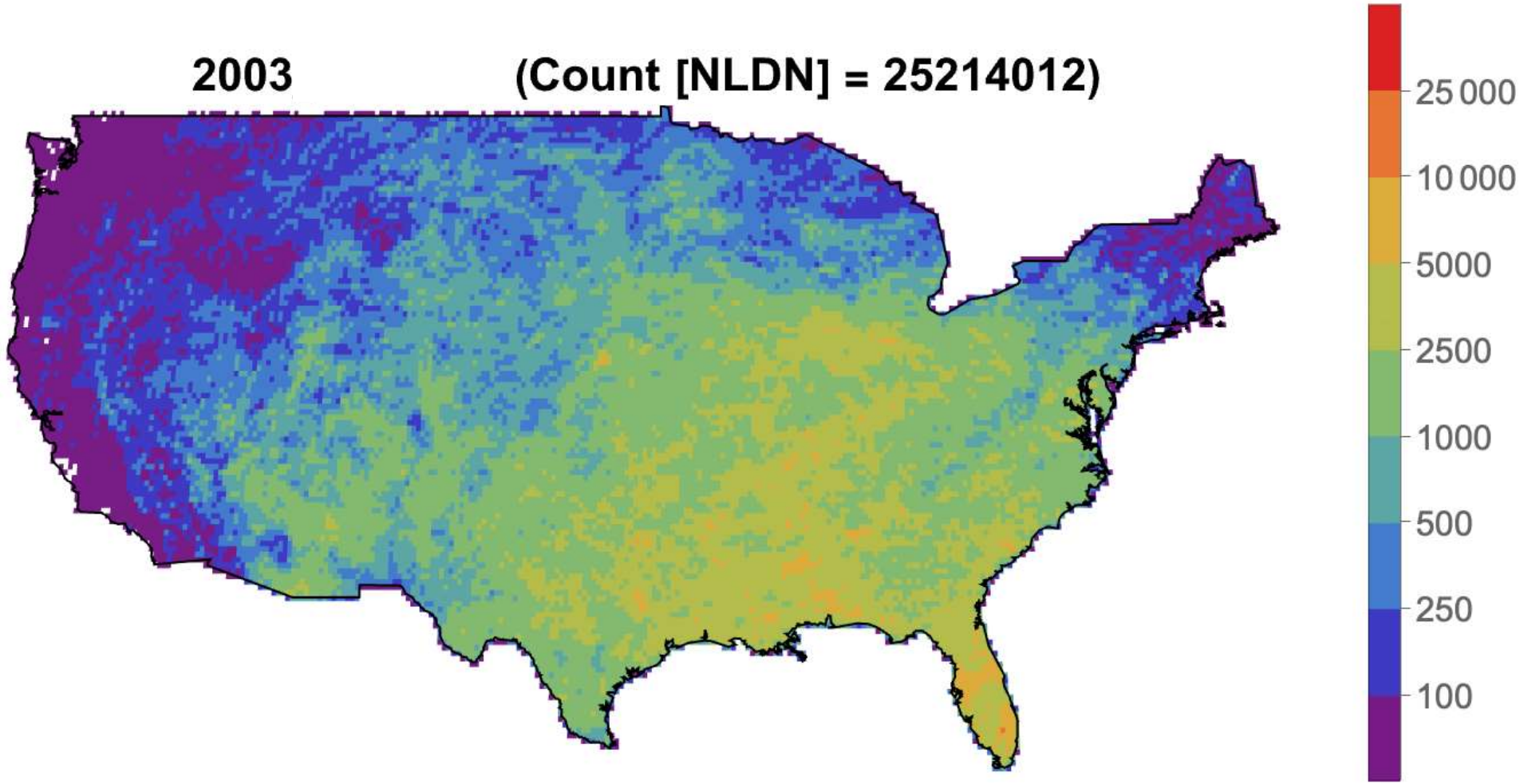
20 yr NLDN CG Flash Counts (2003 – 2022)



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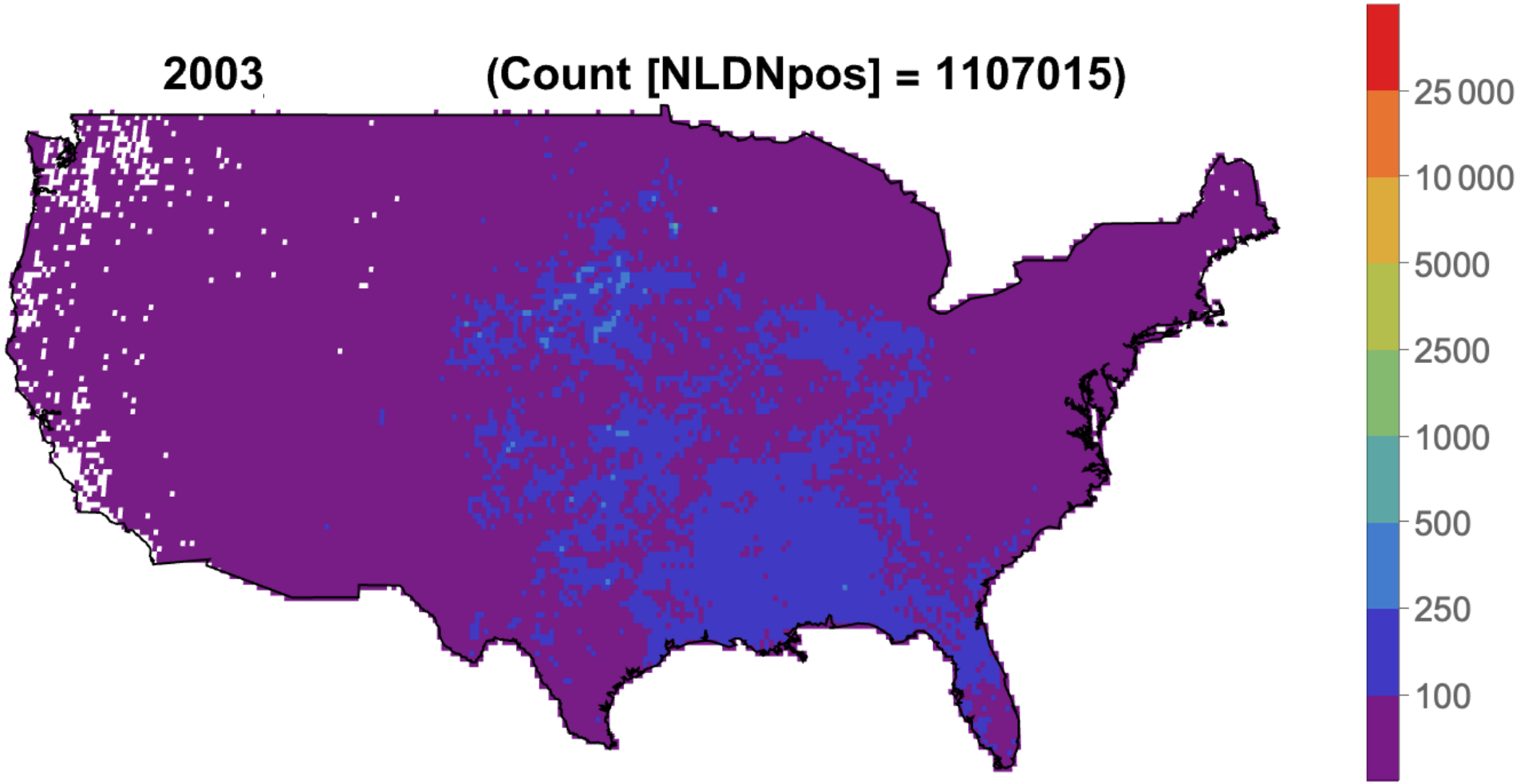
20 yr NLDN +CG Flash Counts (2003 – 2022)



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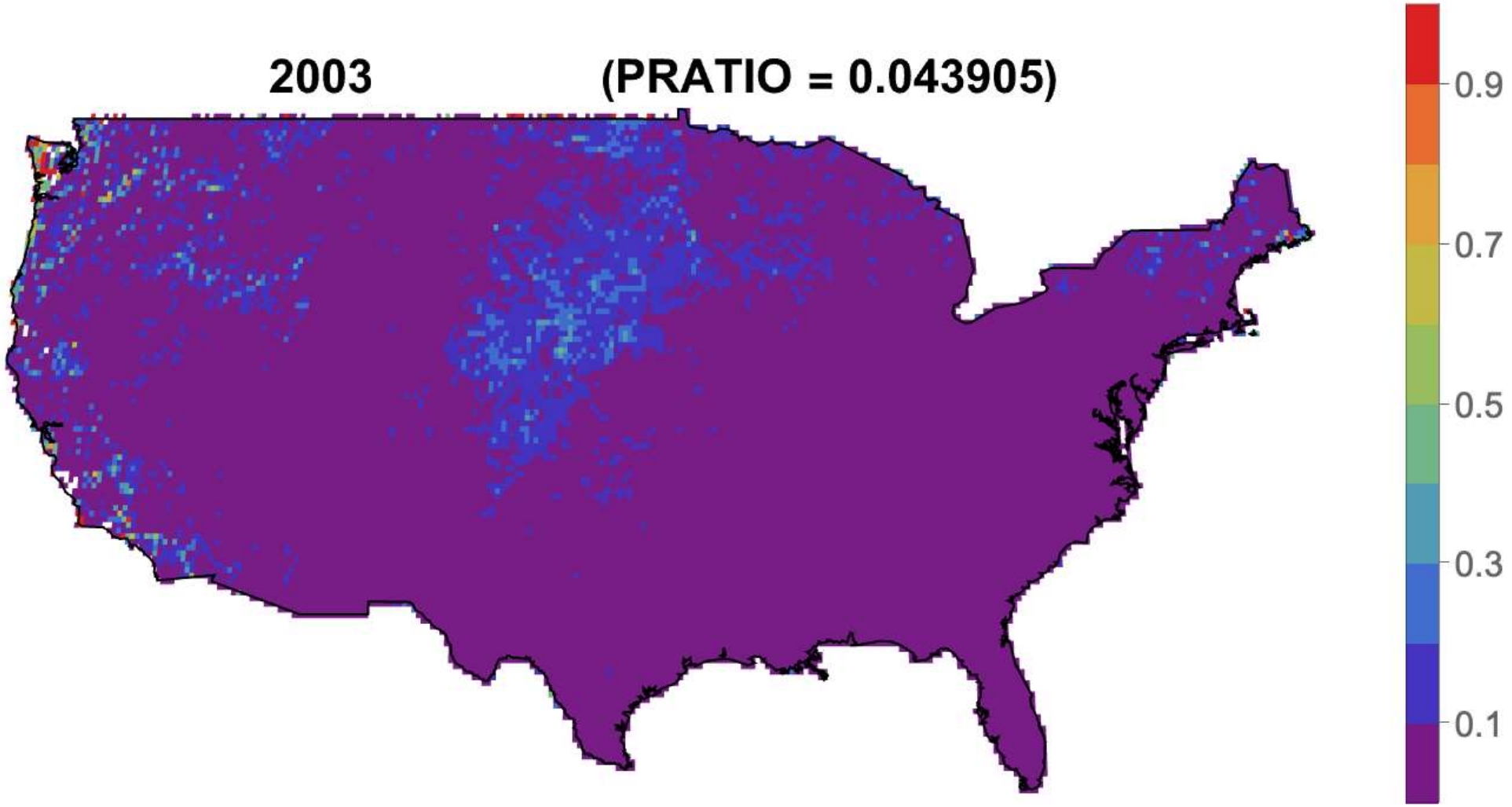
20 yr PRATIO = +CG/CG (2003 – 2022)



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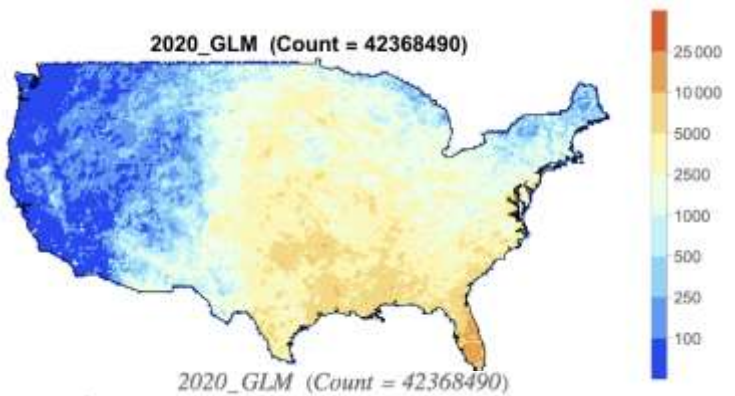
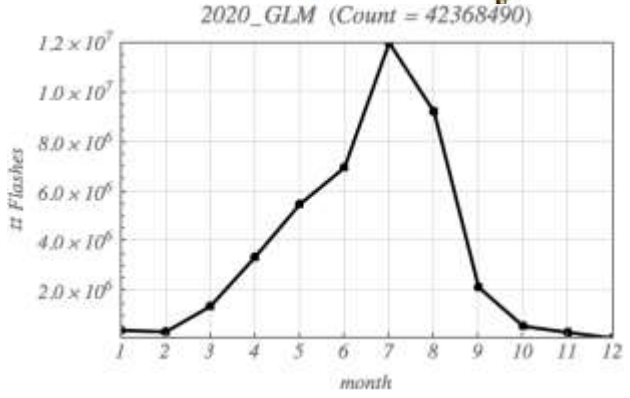
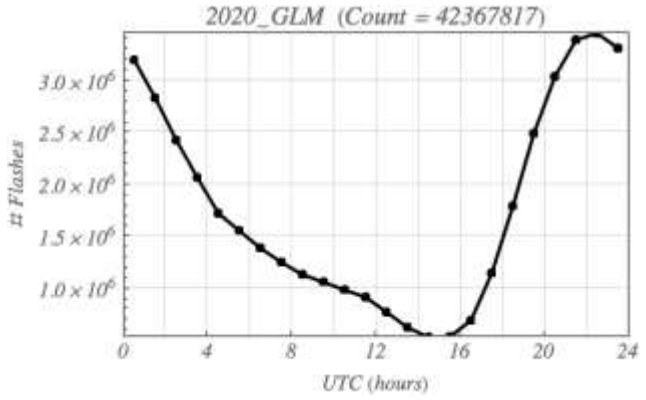
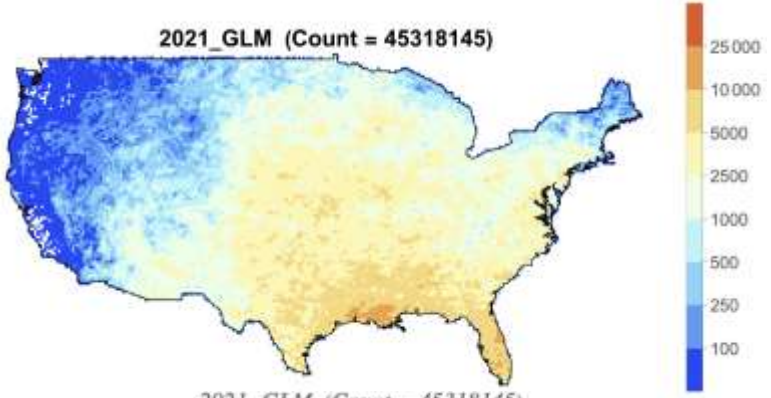
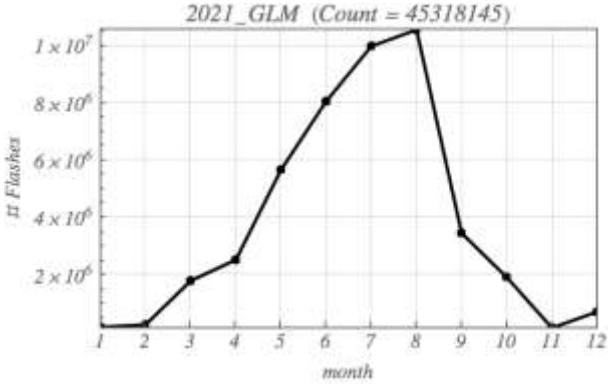
GLM-16 Flash Counts (2020 – 2022)

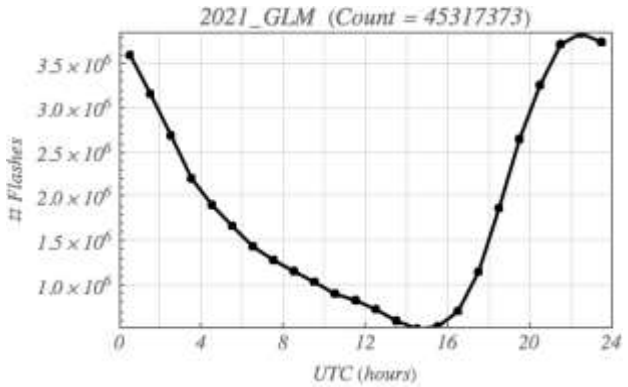


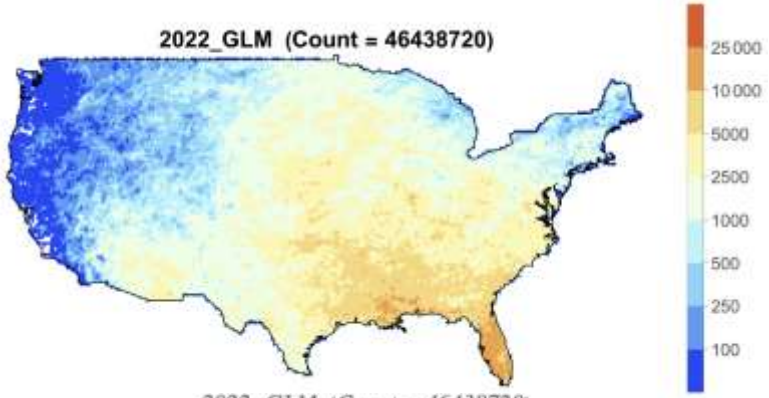


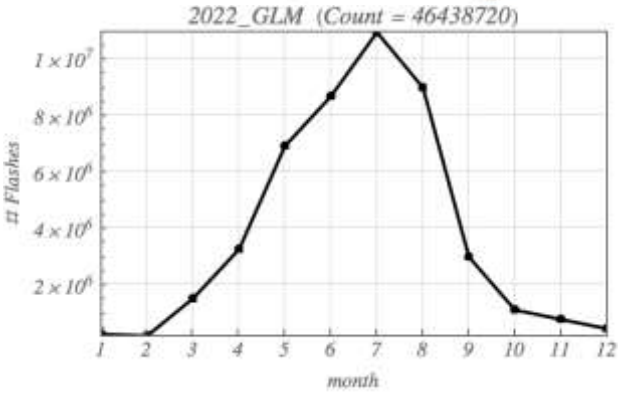


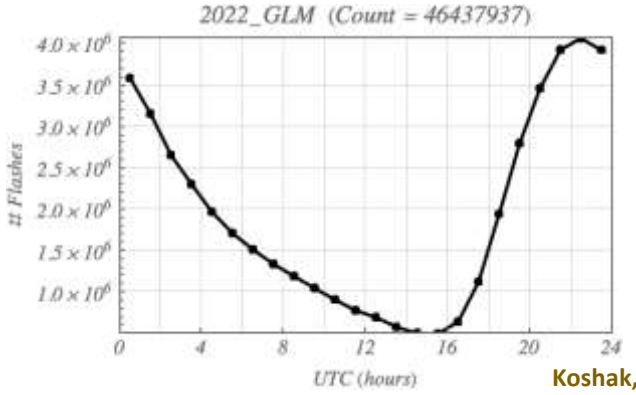












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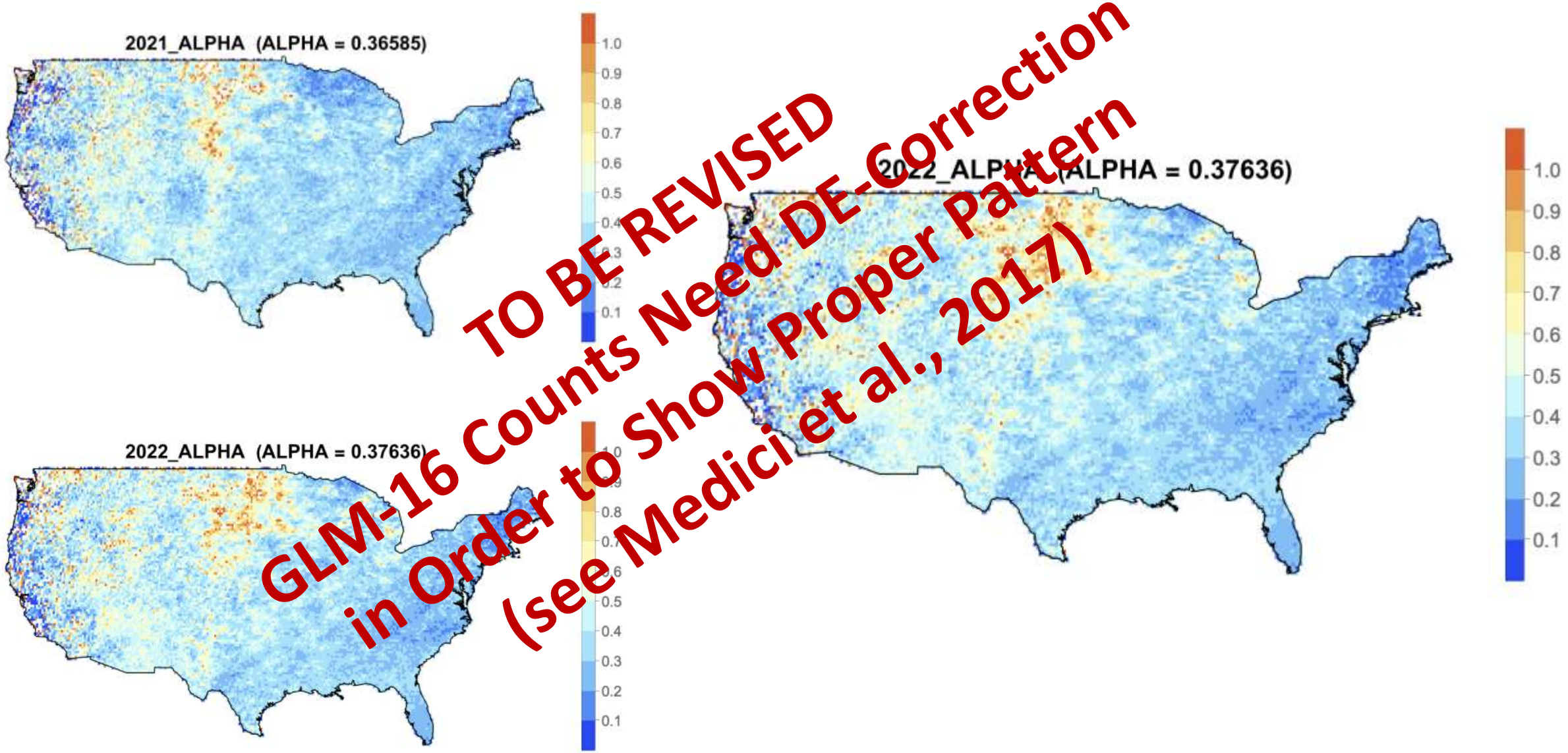
NLDN/GLM-16 Ground Flash Fraction (2020 – 2022)



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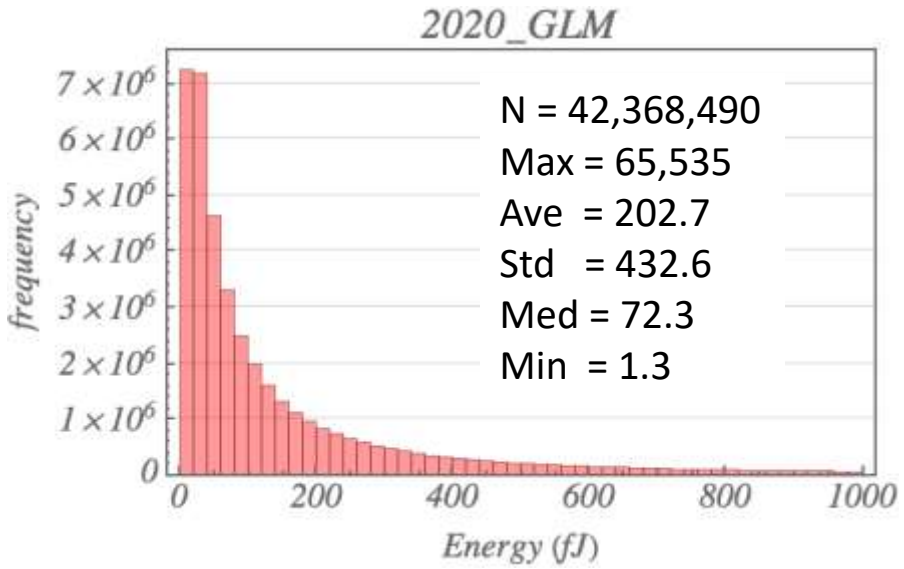
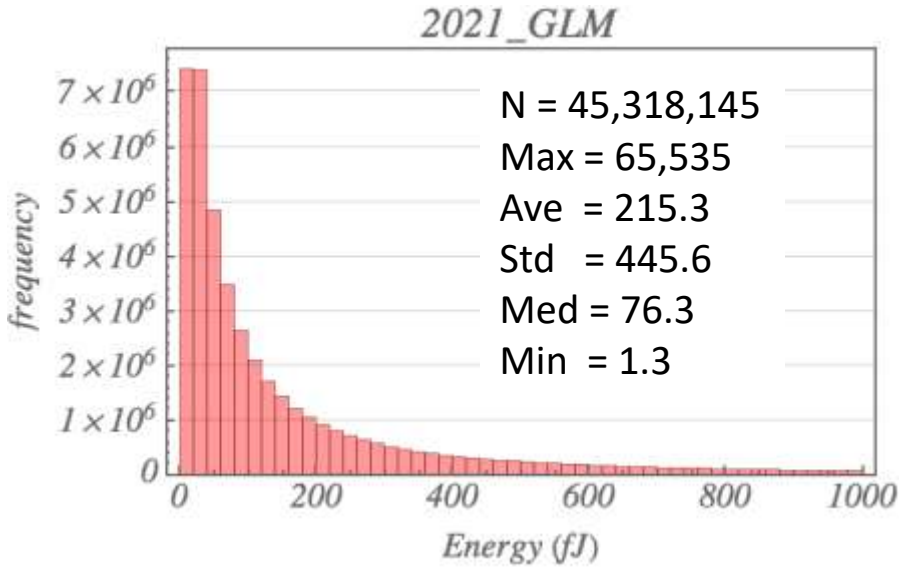
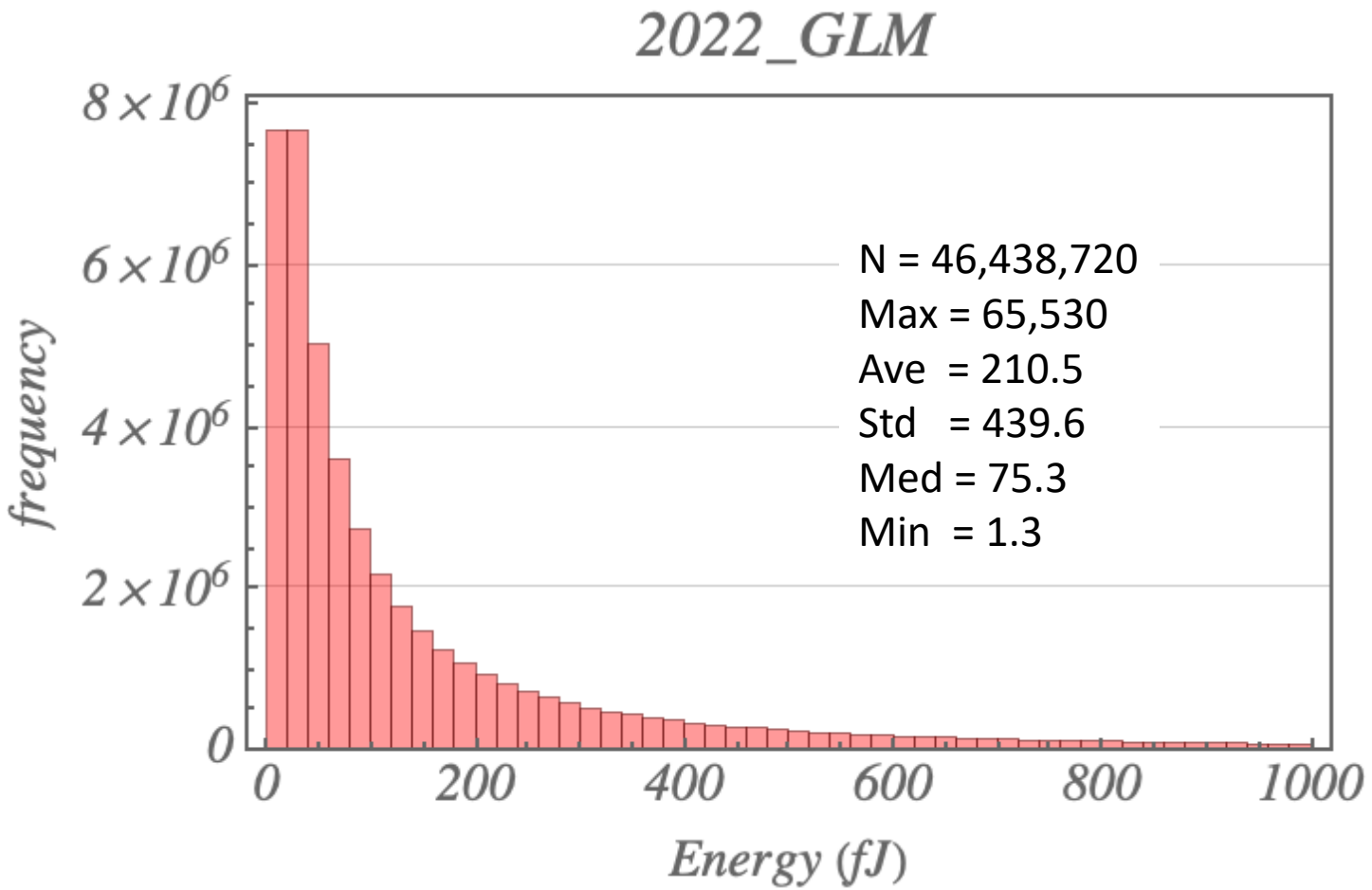
GLM-16 Flash Energy (2020 – 2022)







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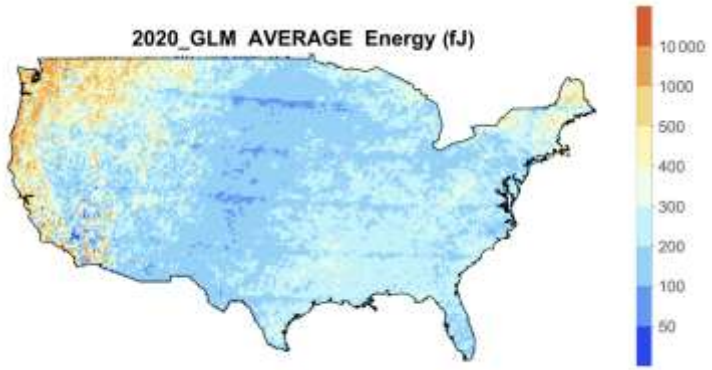

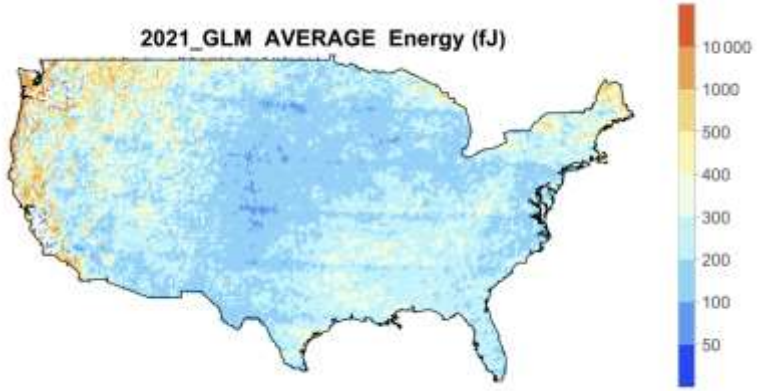

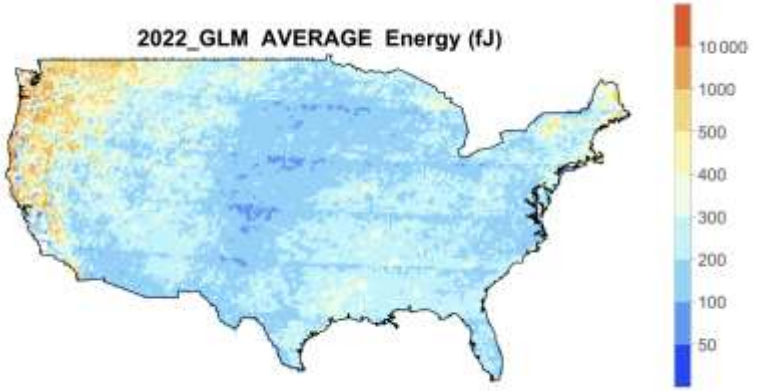

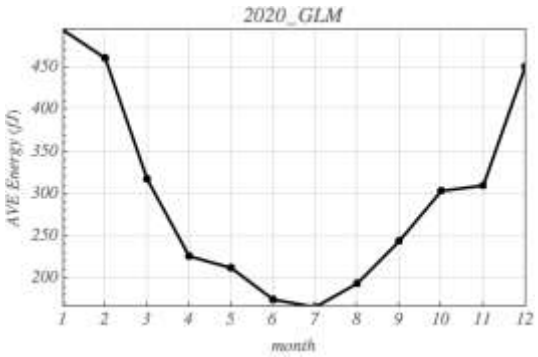

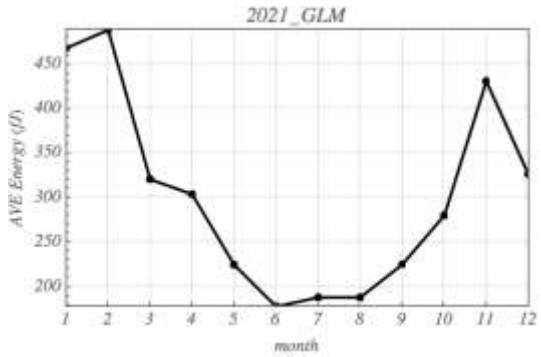

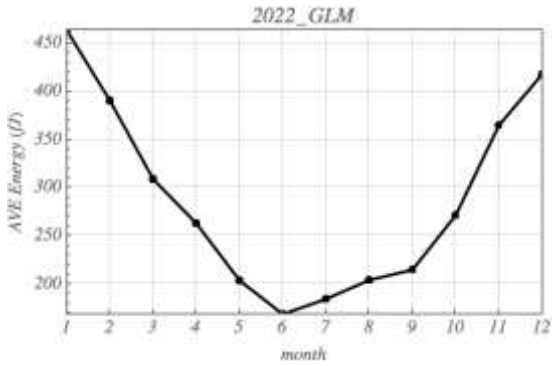

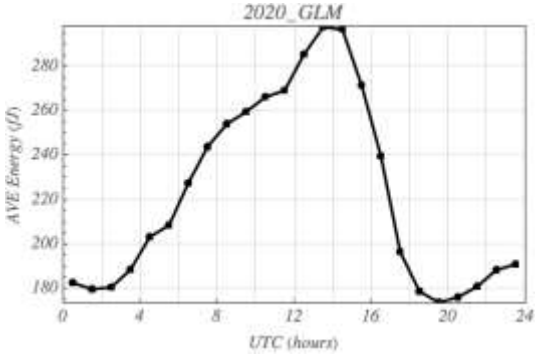

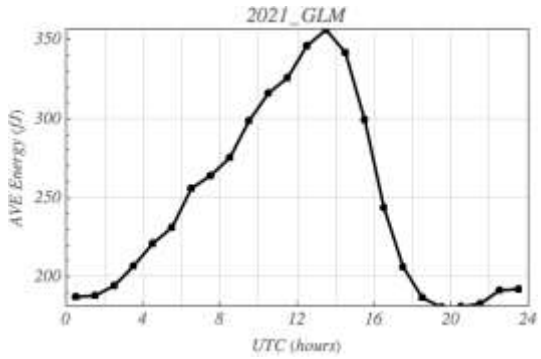

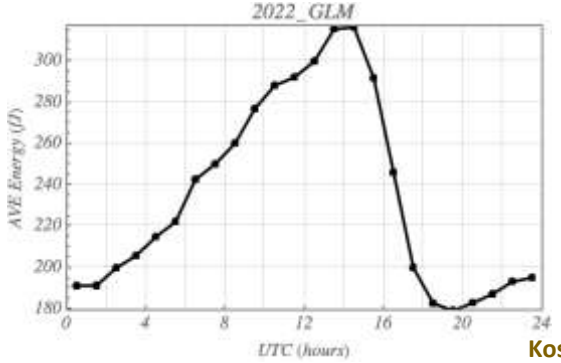

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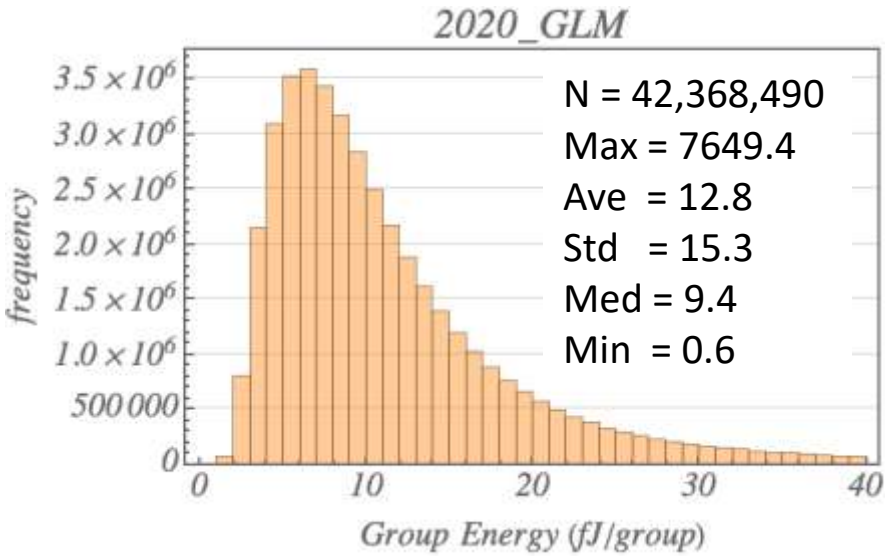
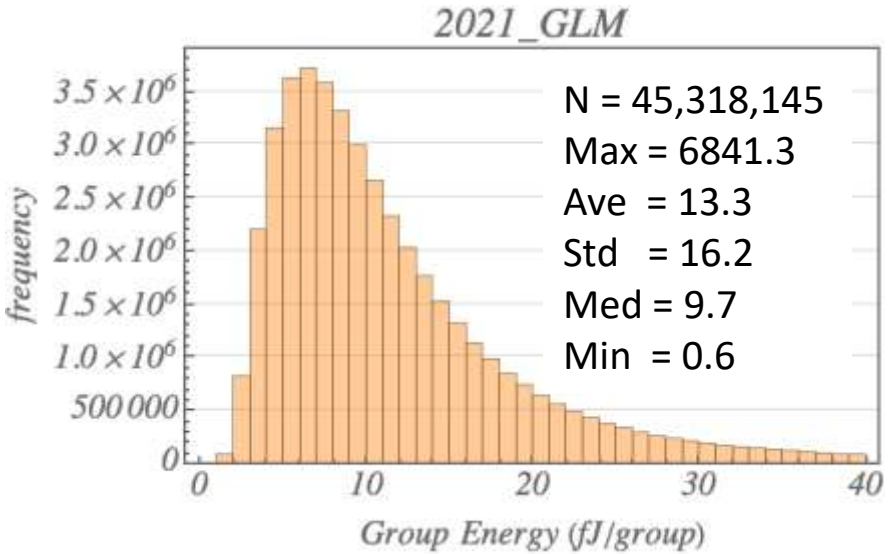
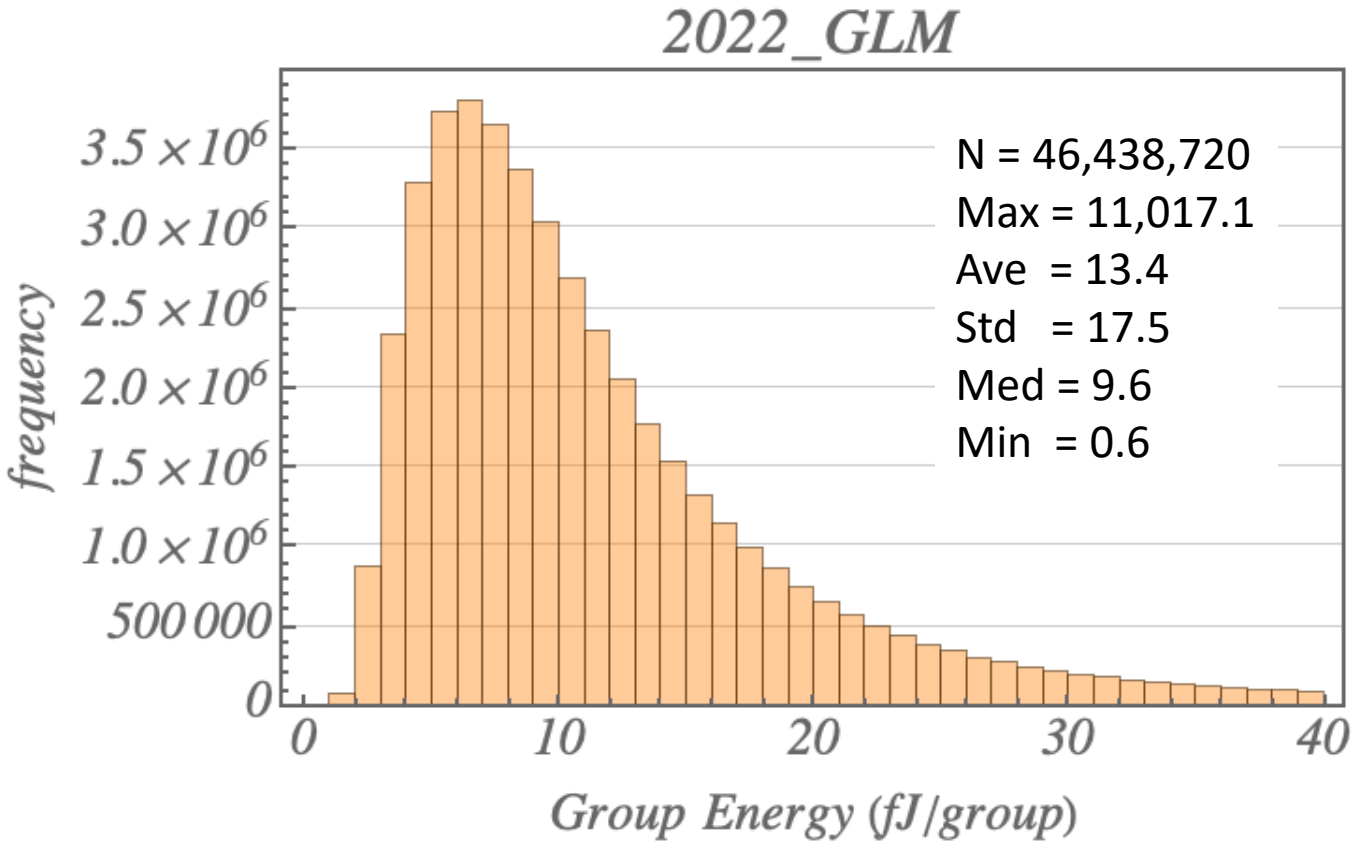
GLM-16 Group Energy (2020 – 2022)







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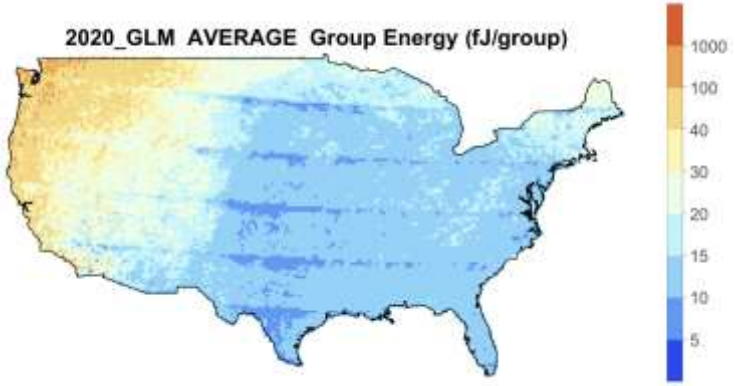

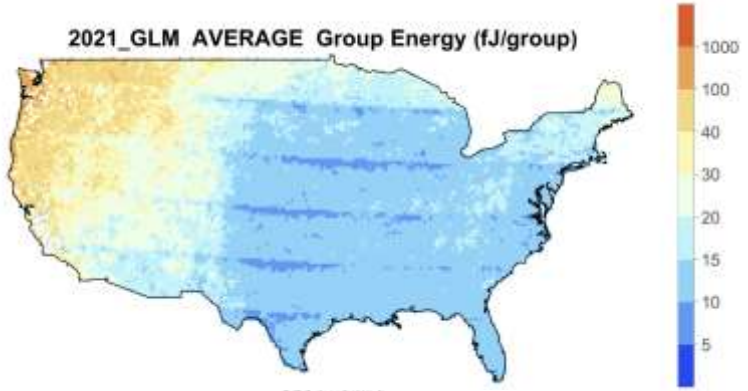

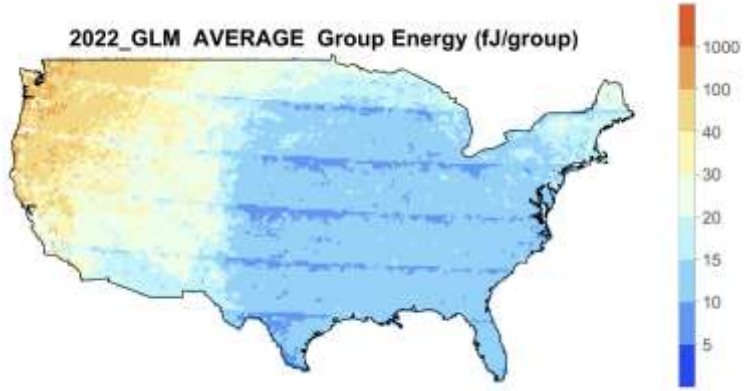

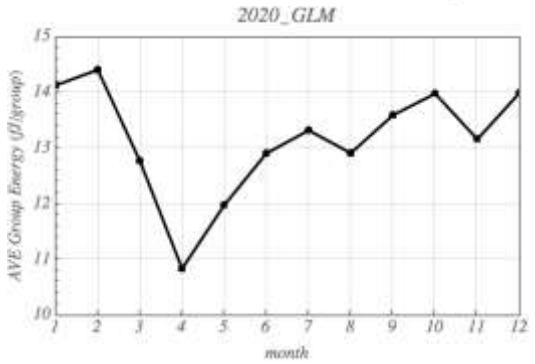

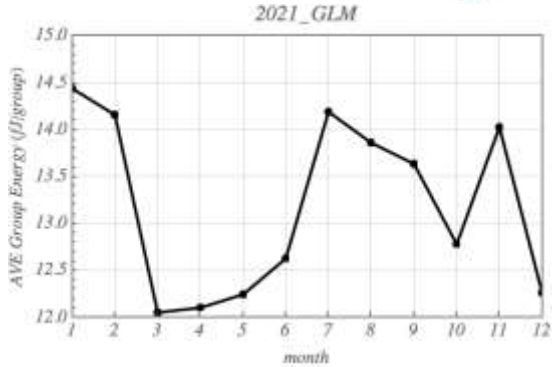

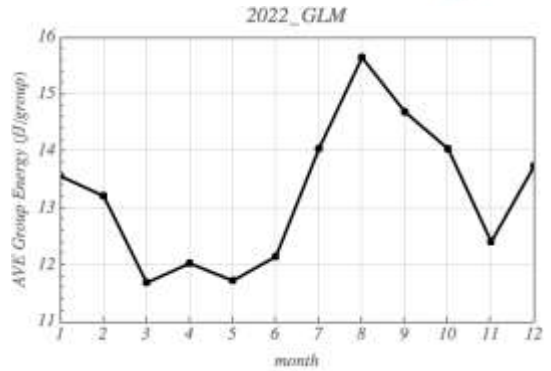

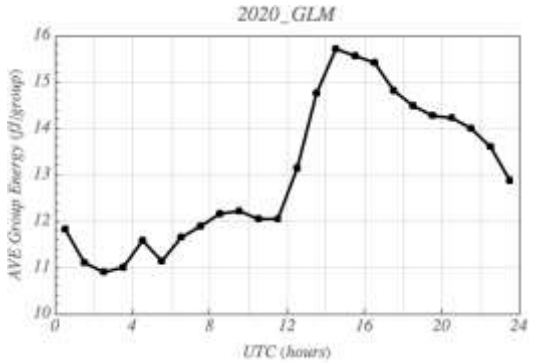

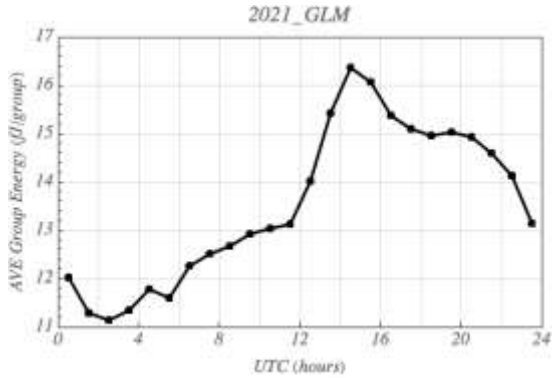

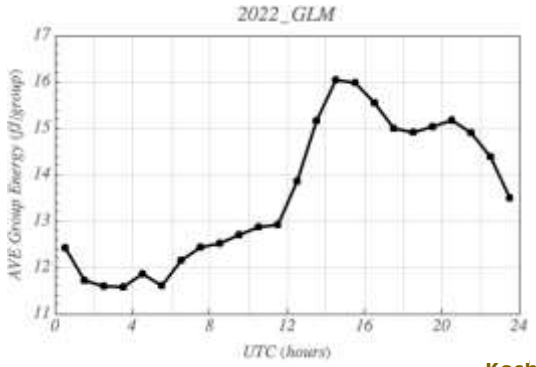

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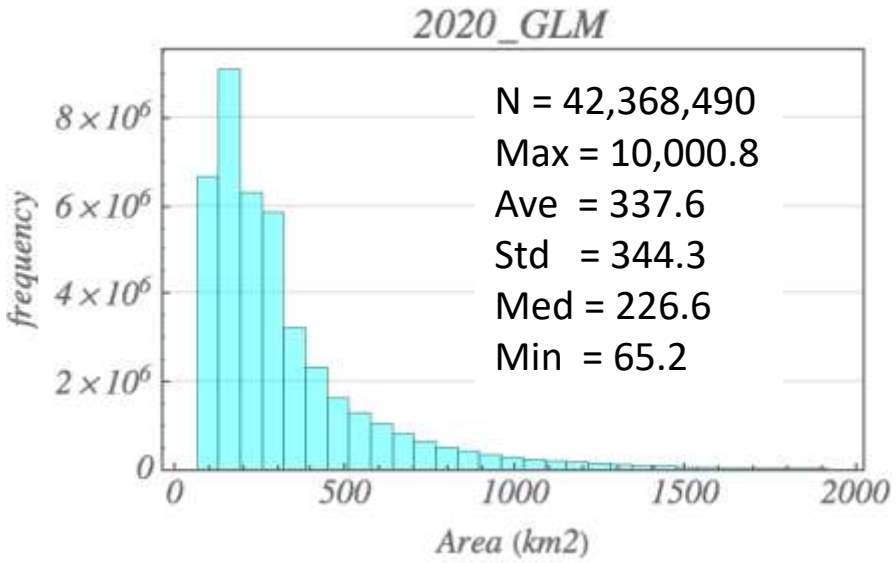
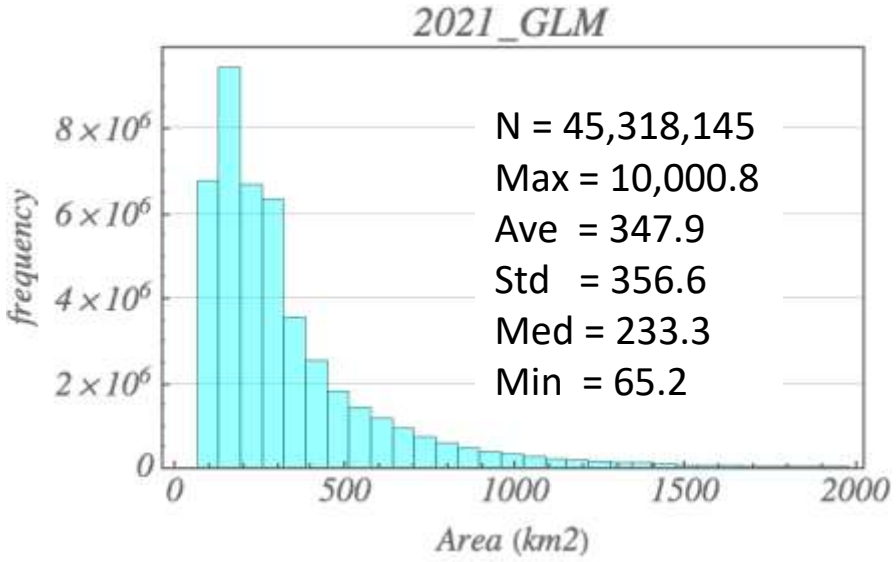
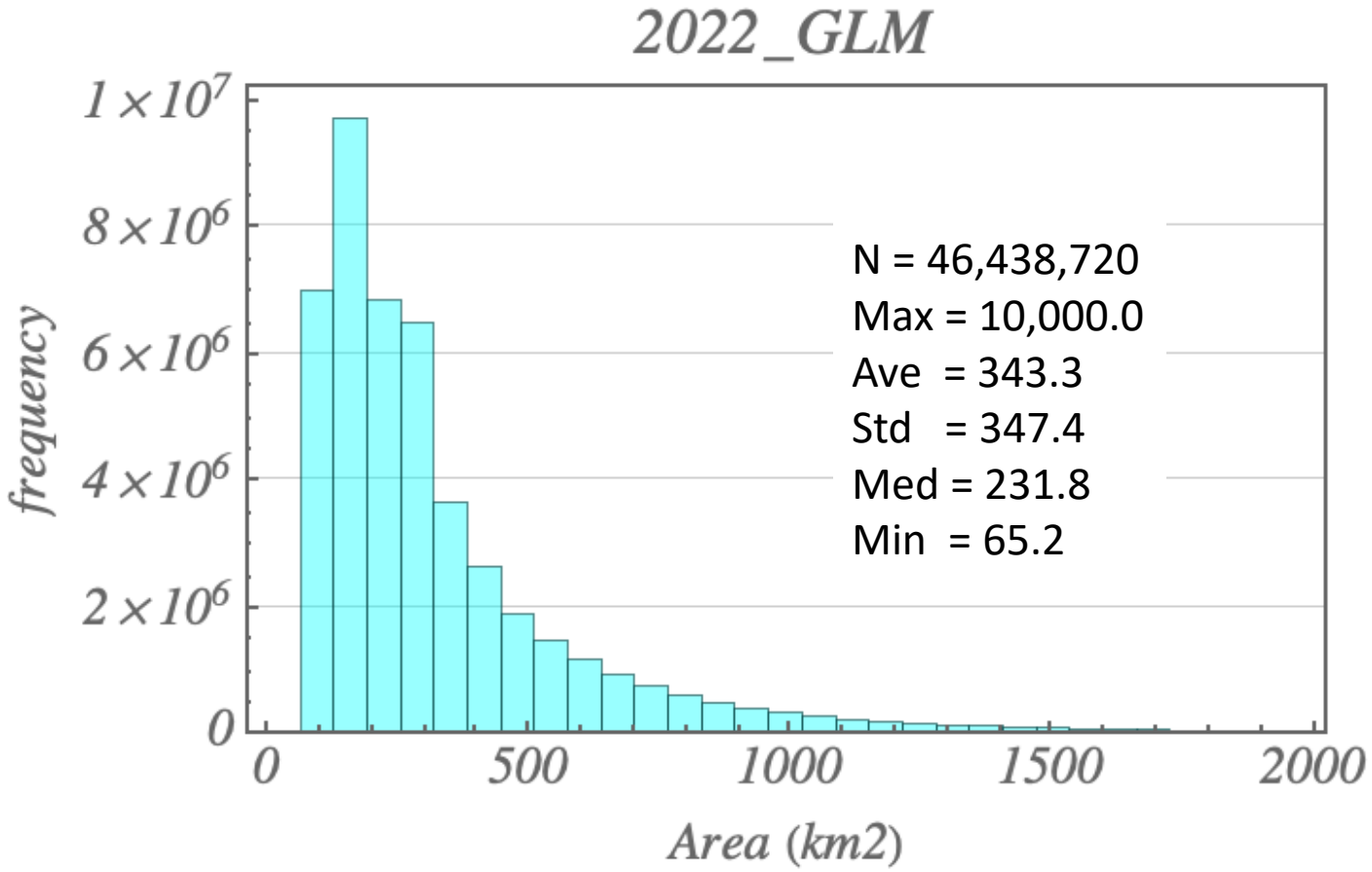
GLM-16 Flash Area (2020 – 2022)







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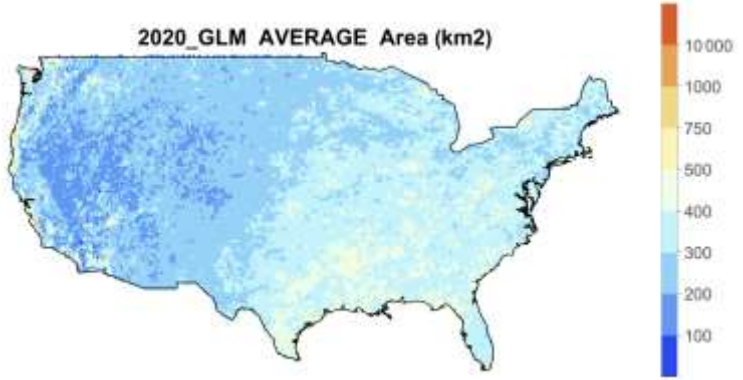

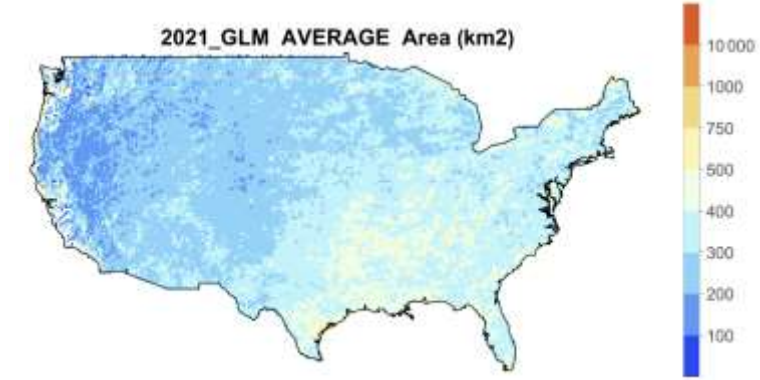

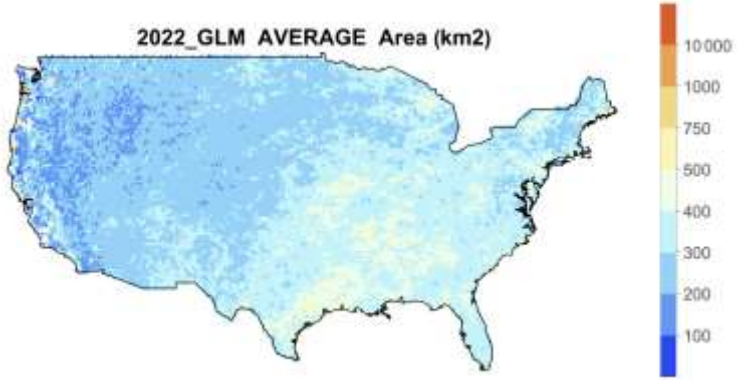

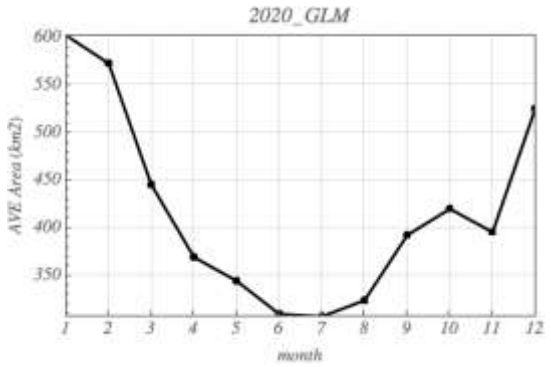

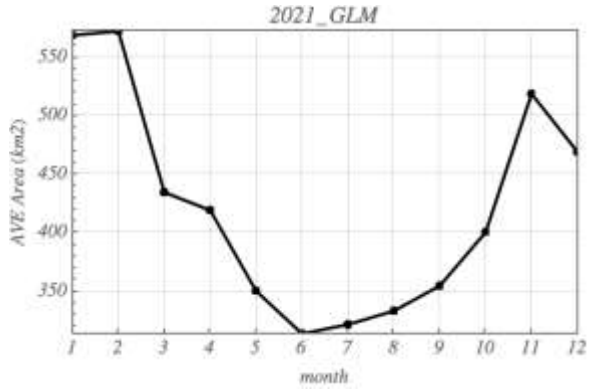

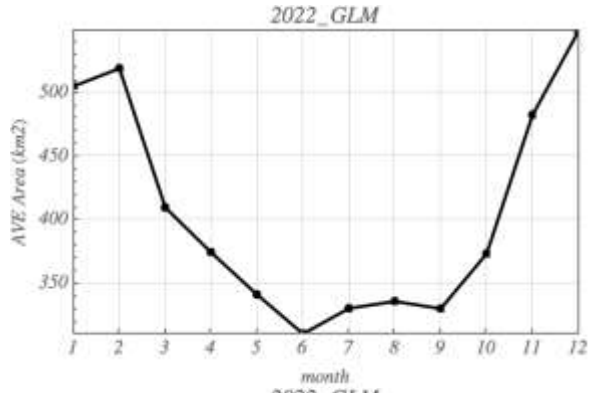

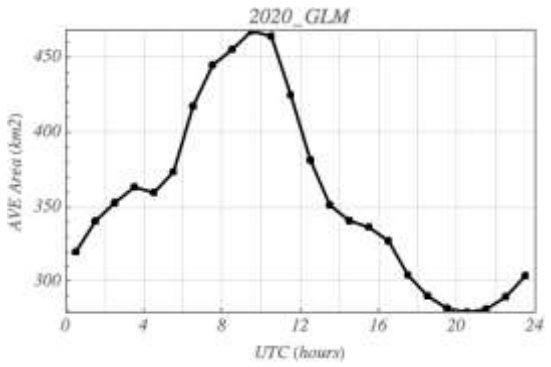

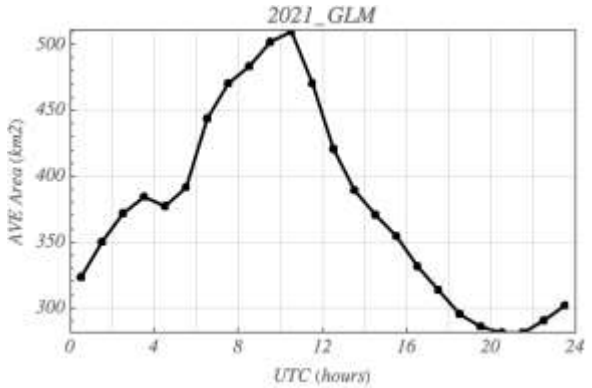

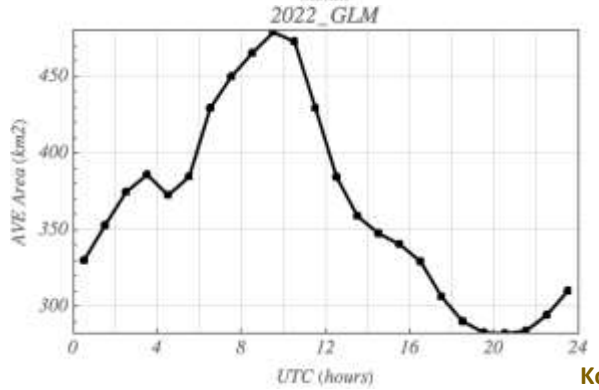

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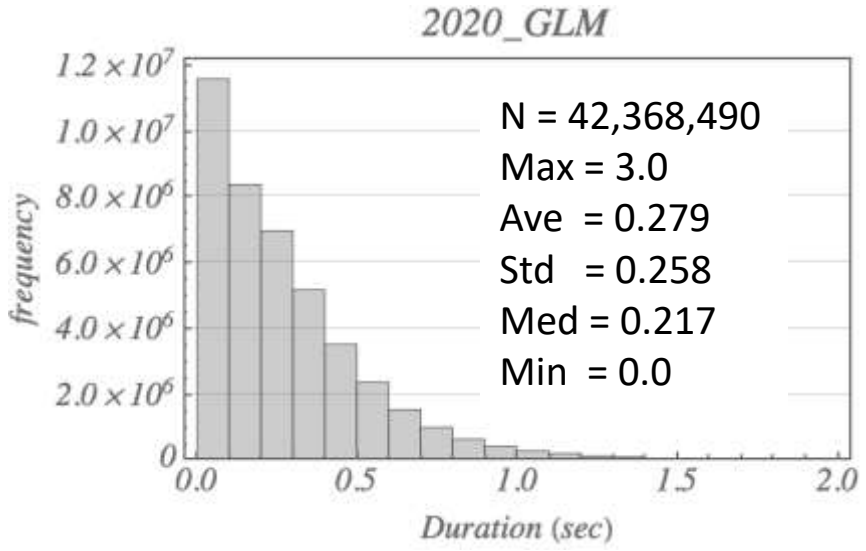
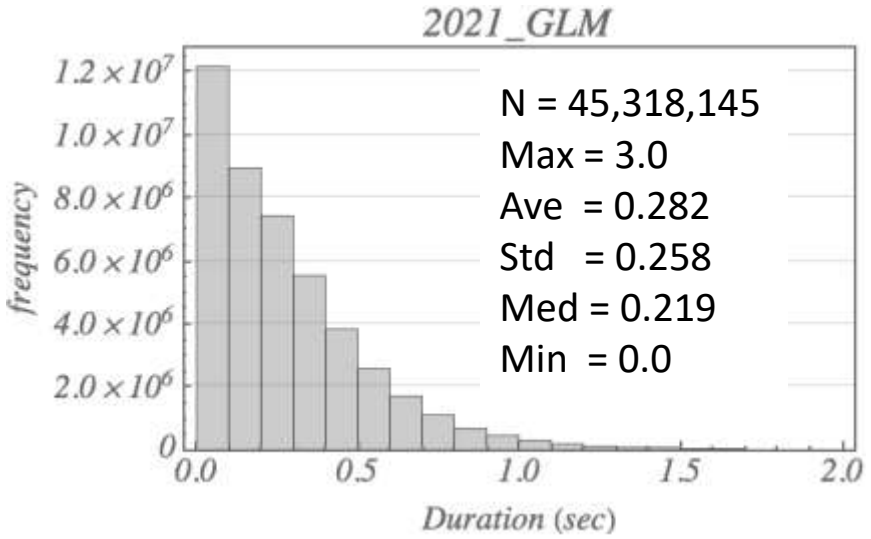
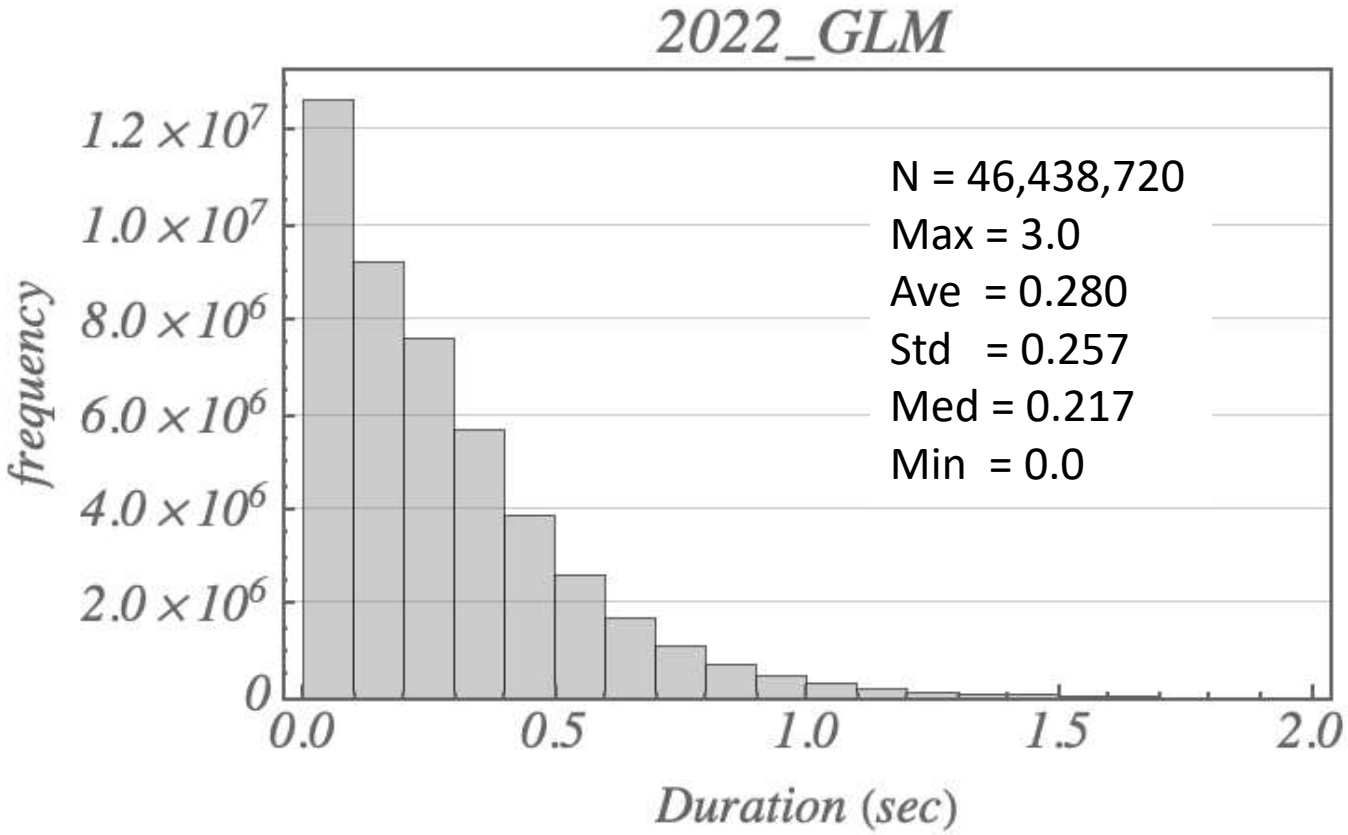
GLM-16 Flash Duration (2020 – 2022)







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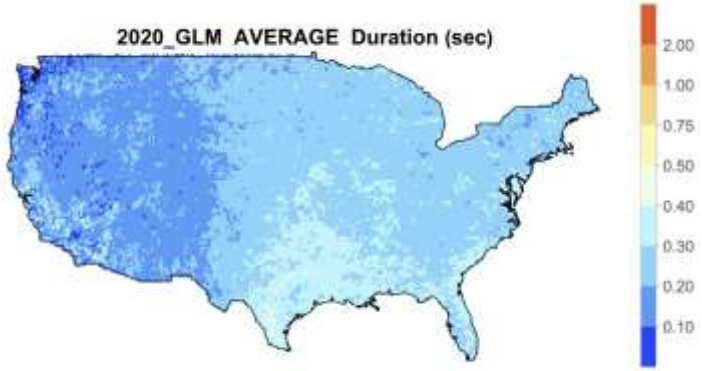
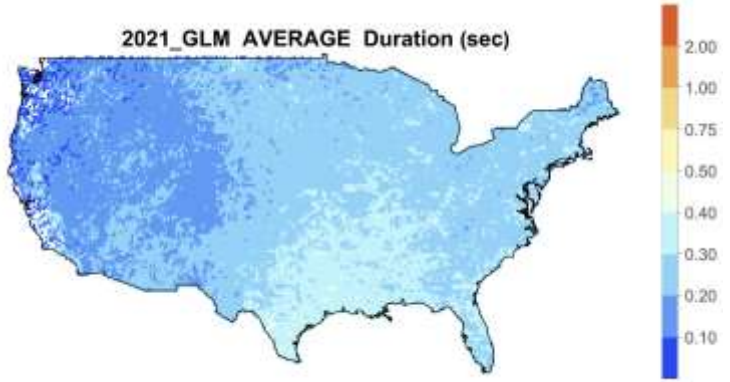
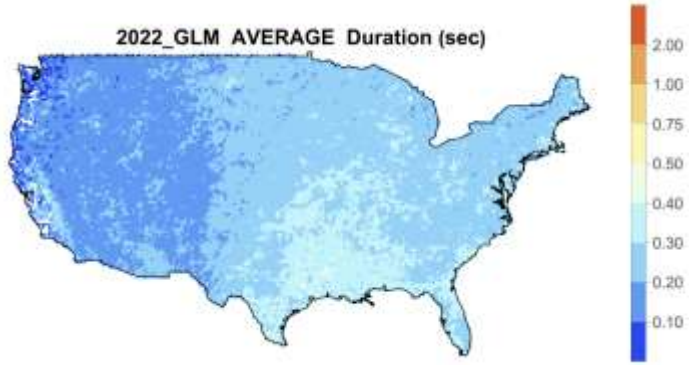
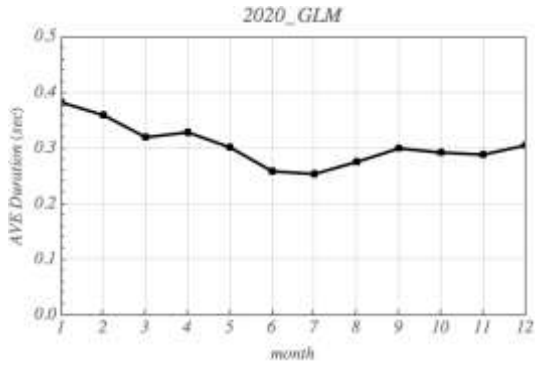
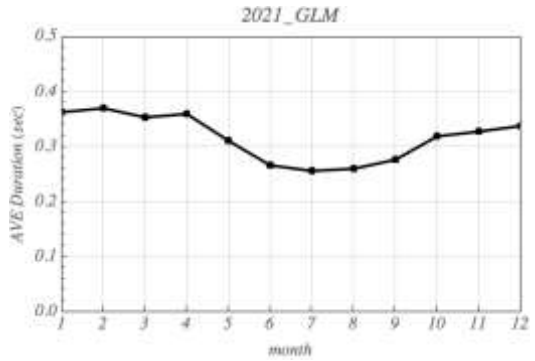
GLM-16 Flash Duration (2020 – 2022)

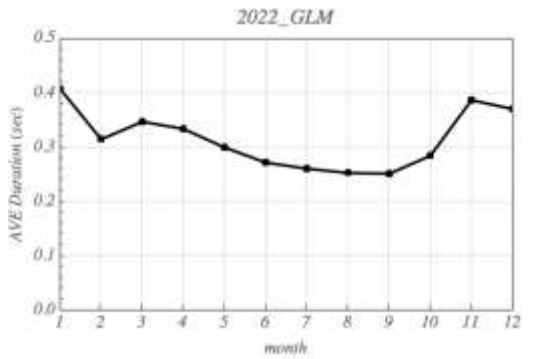


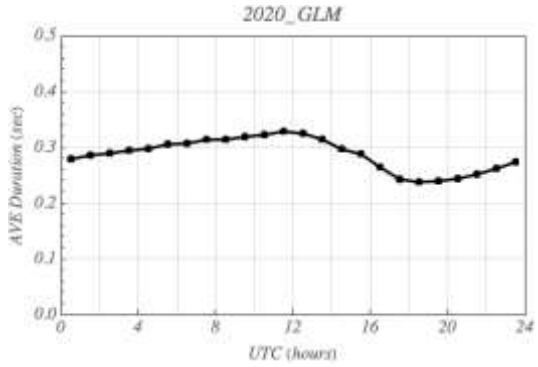


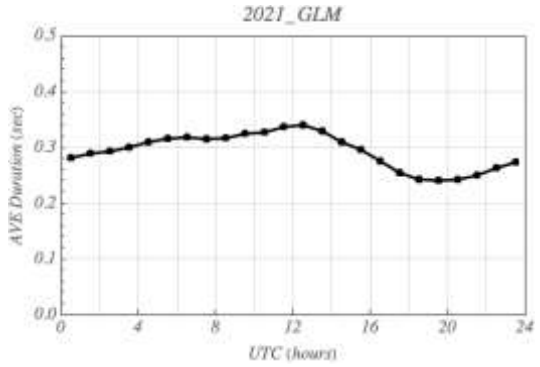


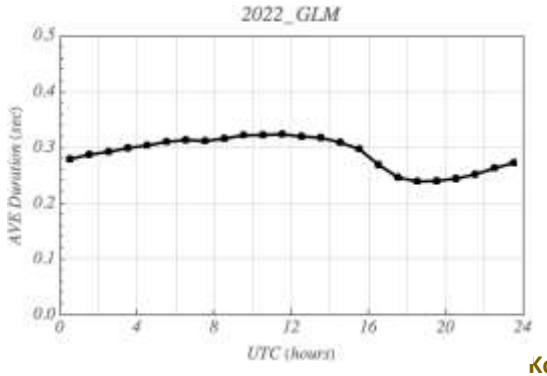












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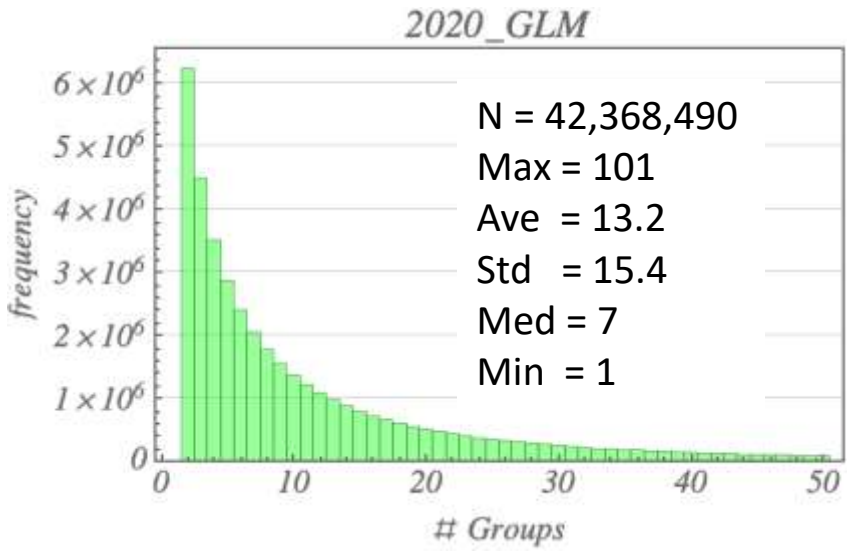
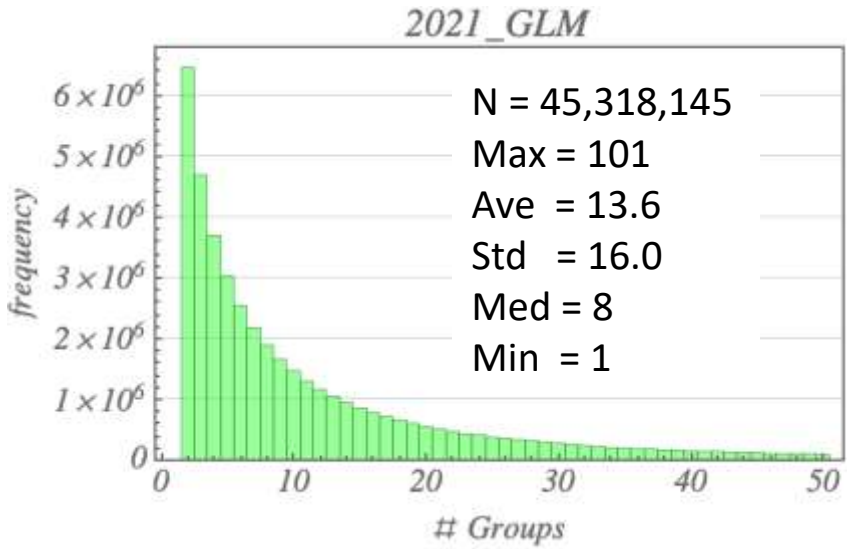
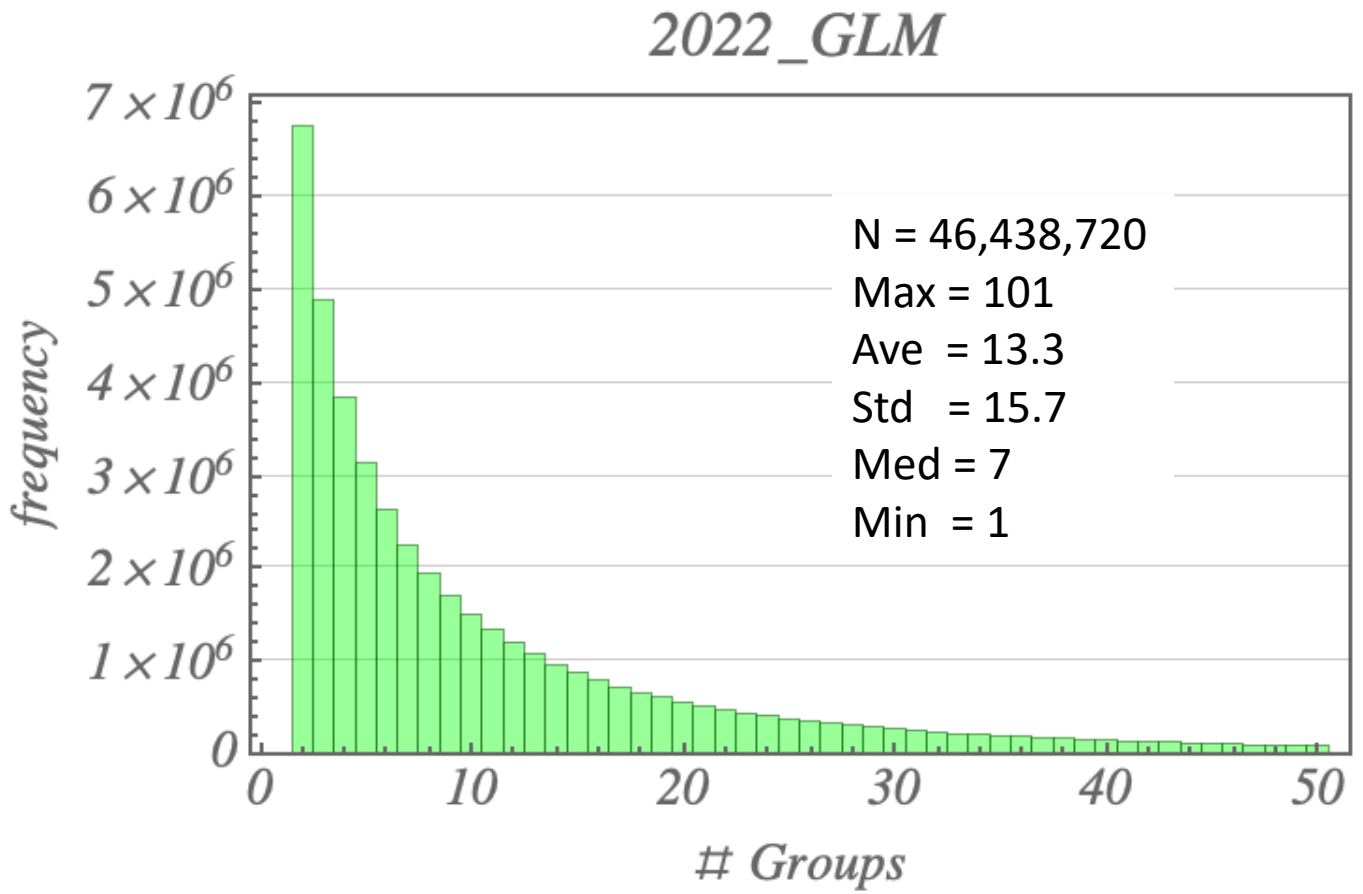
GLM-16 # Groups in Flash (2020 – 2022)







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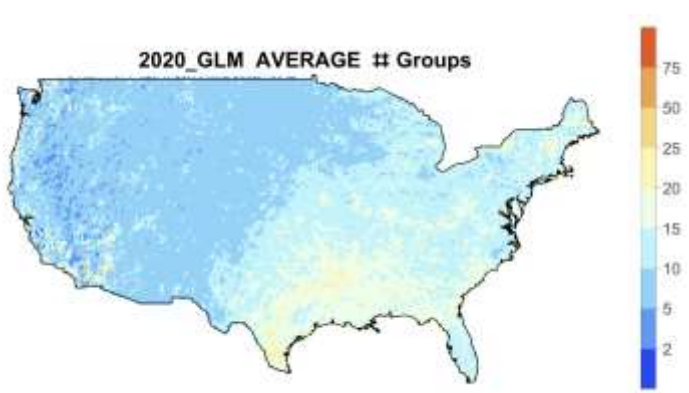
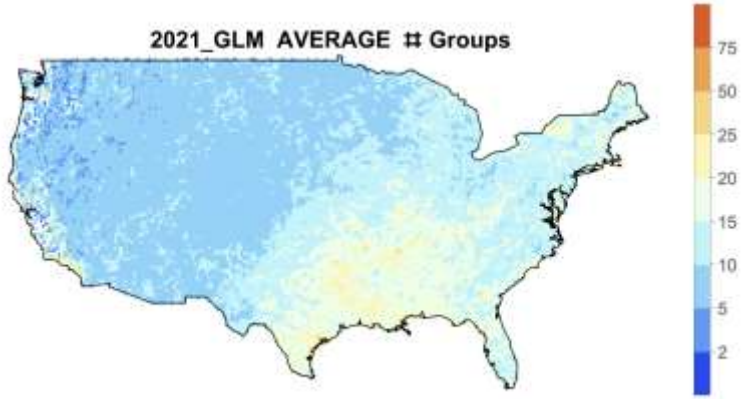
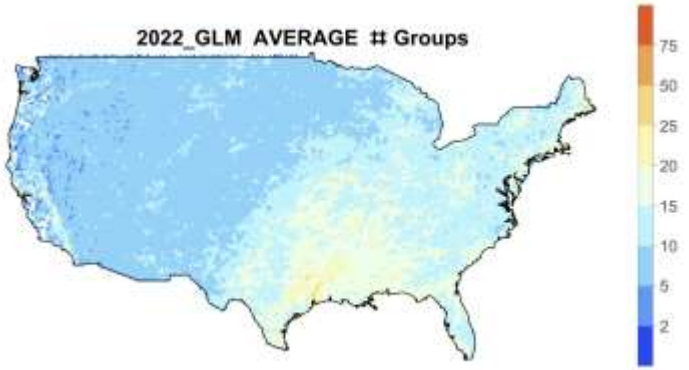
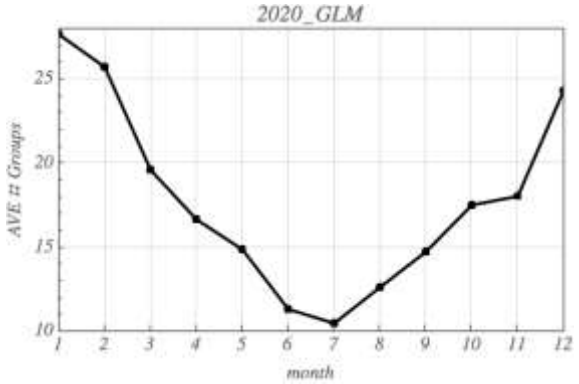
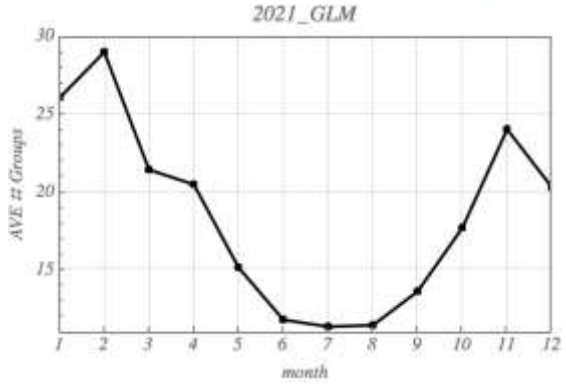
GLM-16 # Groups in Flash (2020 – 2022)

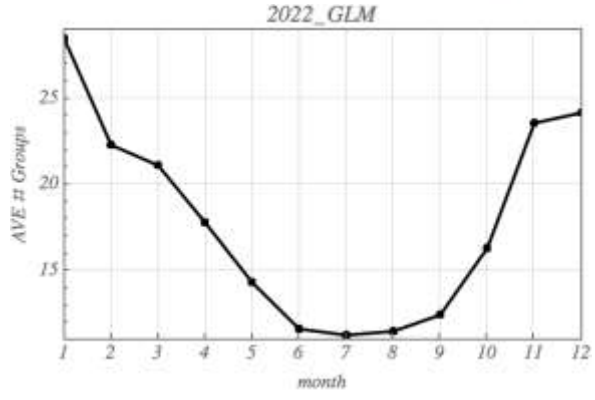


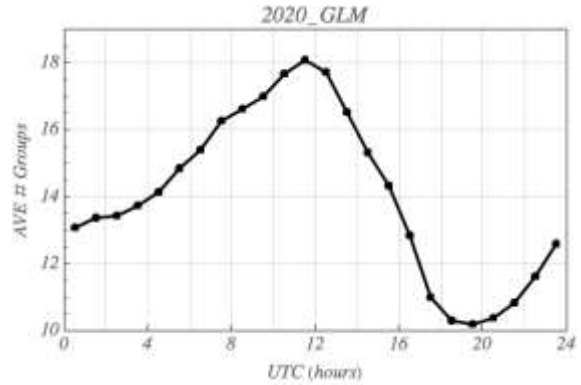


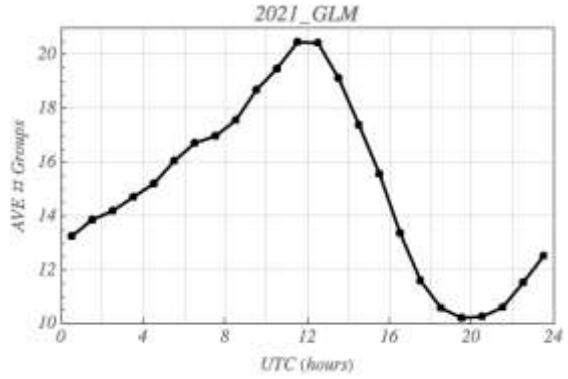


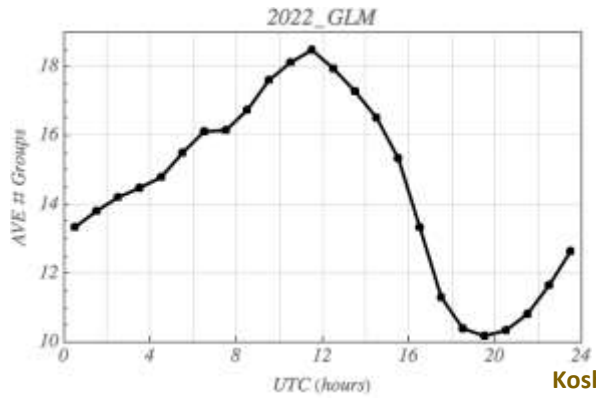












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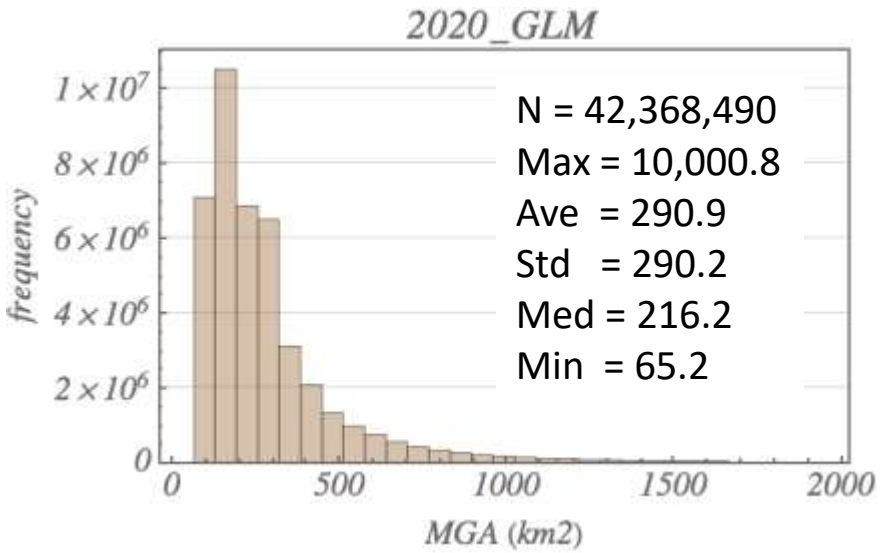
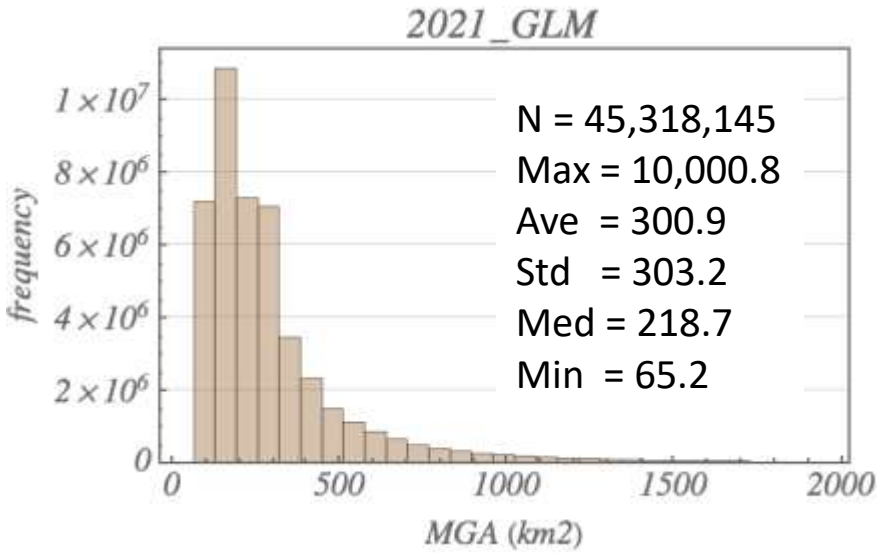
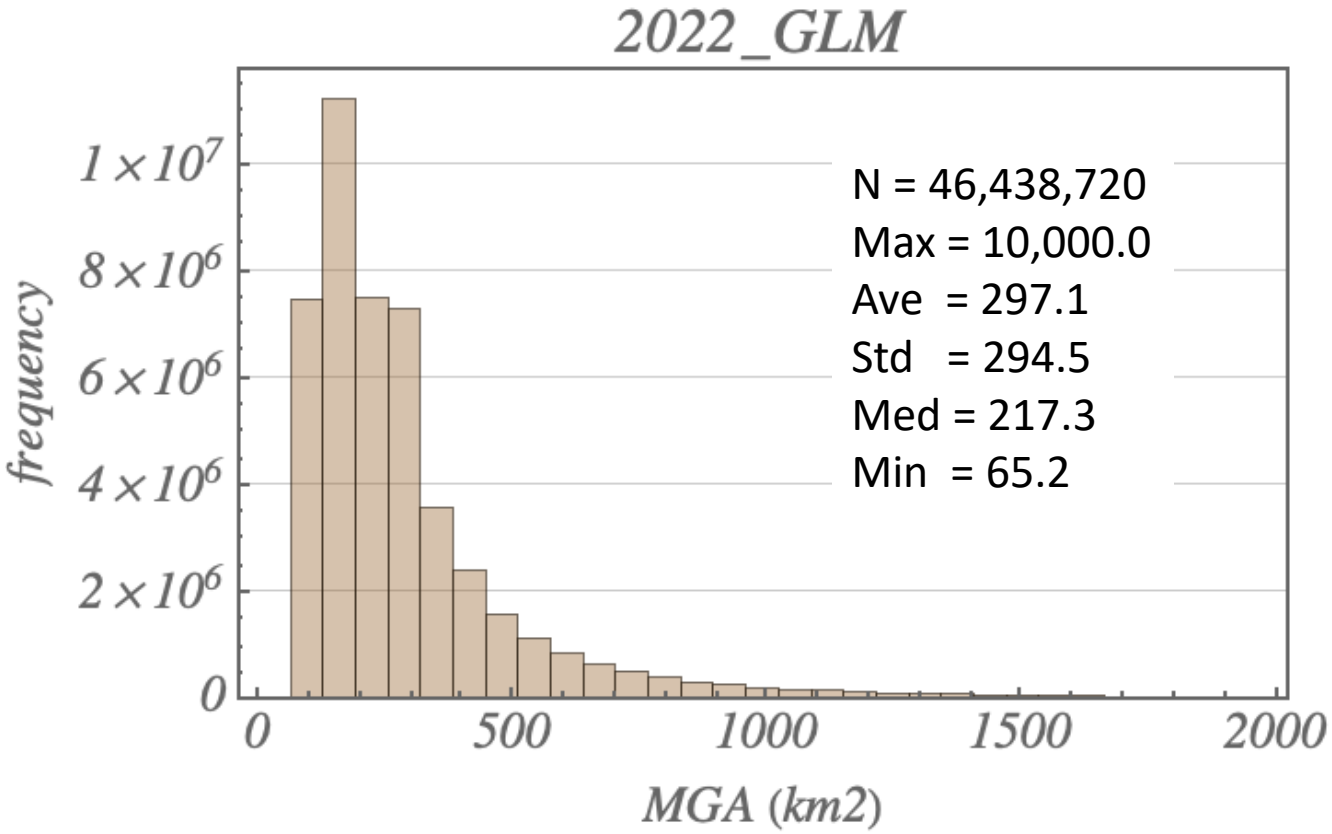
GLM-16 Max Group Area (2020 – 2022)







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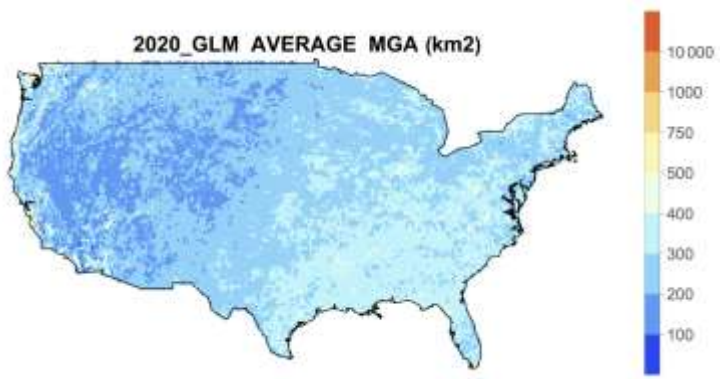
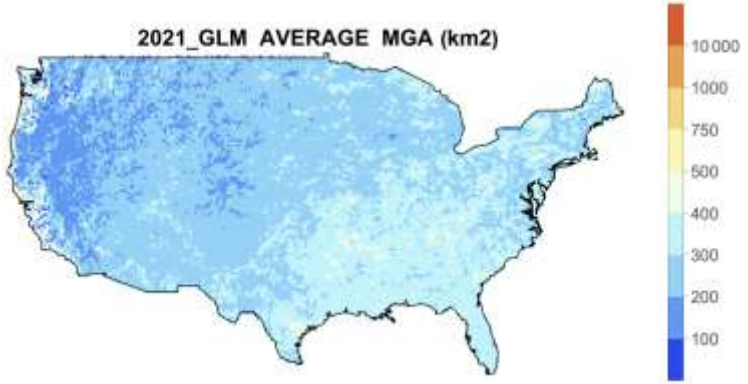
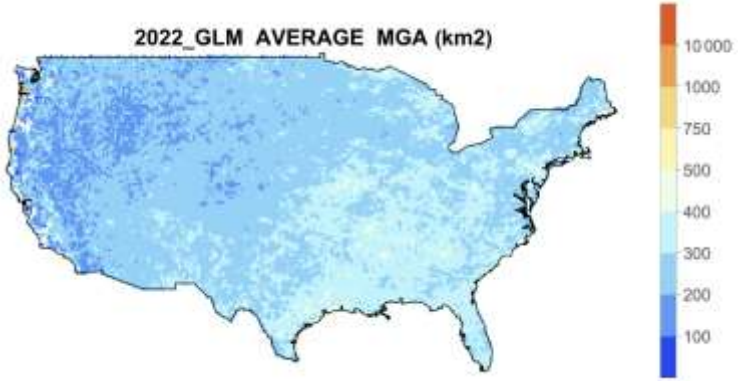
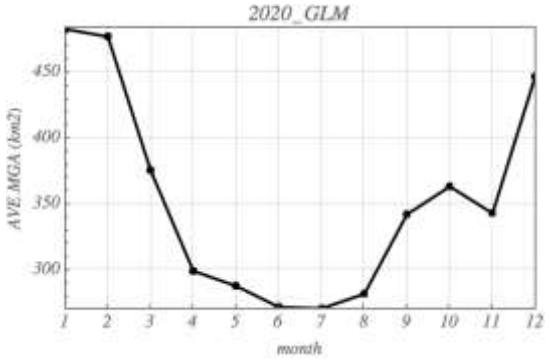
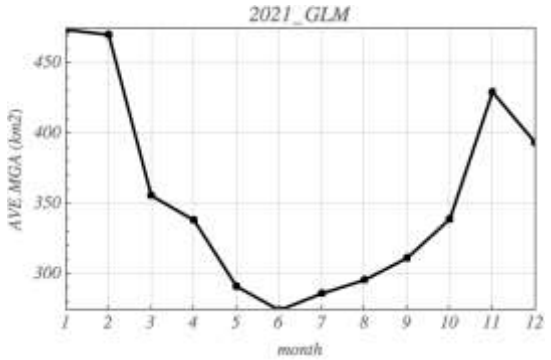
GLM-16 Max Group Area (2020 – 2022)

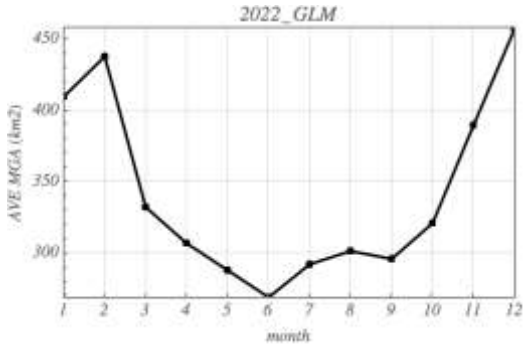


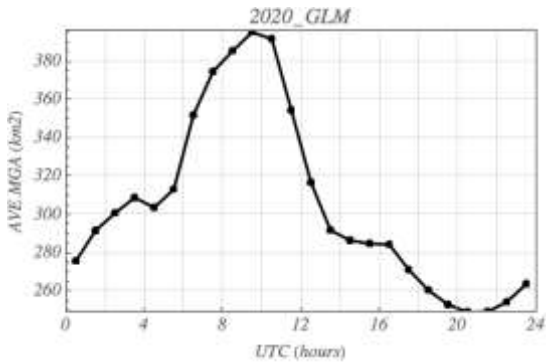


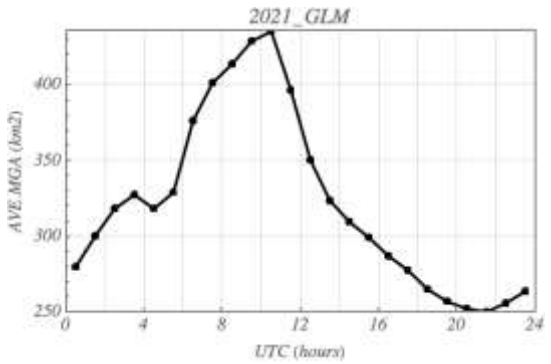


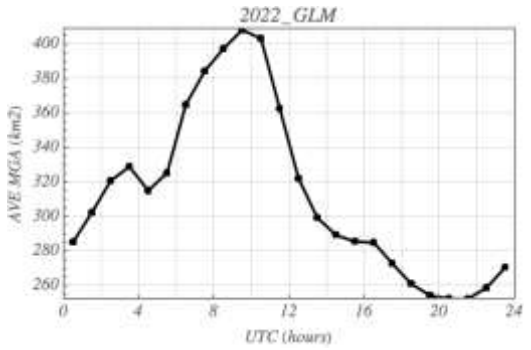












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Summary

- **The 20 yr NLDN CG Count has trended downward**
  - Data from 2015-2022 was reclassified to normalize the 20yr record (removed even a steeper downward trend)
  - Downward trend of about 31% over the 20 yr period.

- **Best (2020-2022) GLM-16 total flash count showed mild upward trend coming out of COVID, as did NLDN CG flash count**

- **A solid benchmark of basic GLM-16 measurements (**flash count, flash energy, group energy, flash area, flash duration, # groups per flash, maximum group area**) were provided to help detect/assess possible future changes in instrument performance & natural lightning variability over CONUS pertinent to NCA analyses**

- **Future Improvements**
  - Future reprocessing of GLM-16 data will back-fill results (TBDmonth/2016 – July/2019)
  - GLM-16 counts to be boosted by dividing by GLM-16 DE results
  - GLM-17/18 data to be used to examine/patch GLM-16 low DE in NW CONUS