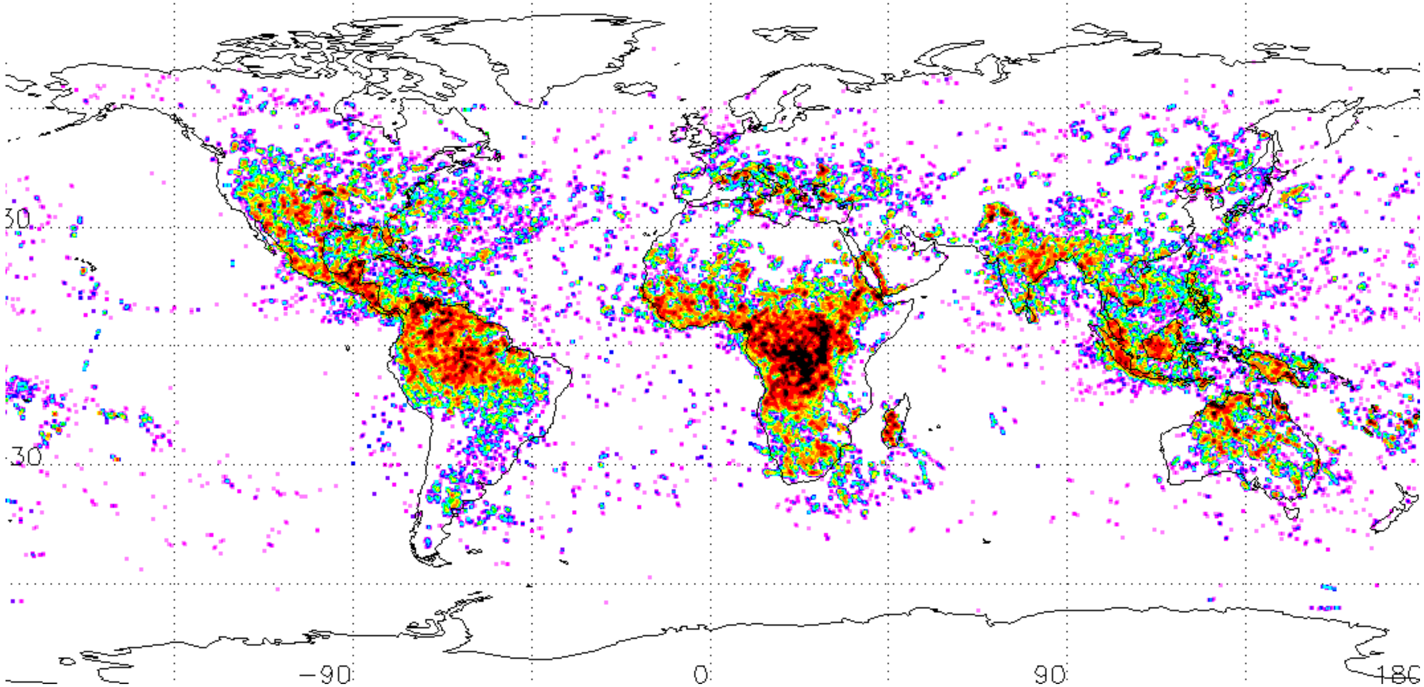
Ministerul Mediului

METEO ROMANIA
NATIONAL METEOROLOGICAL ADMINISTRATION

EUMETSAT NWC SAF
SUPPORT TO NOWCASTING AND VERY SHORT RANGE FORECASTING



MTG LI NWC SAF Products

Andrei Diamandi (diamandi@meteoromania.ro)
NWC SAF Team

NWC SAF Workshop
Madrid, March 2020

MTG Lightning Imager

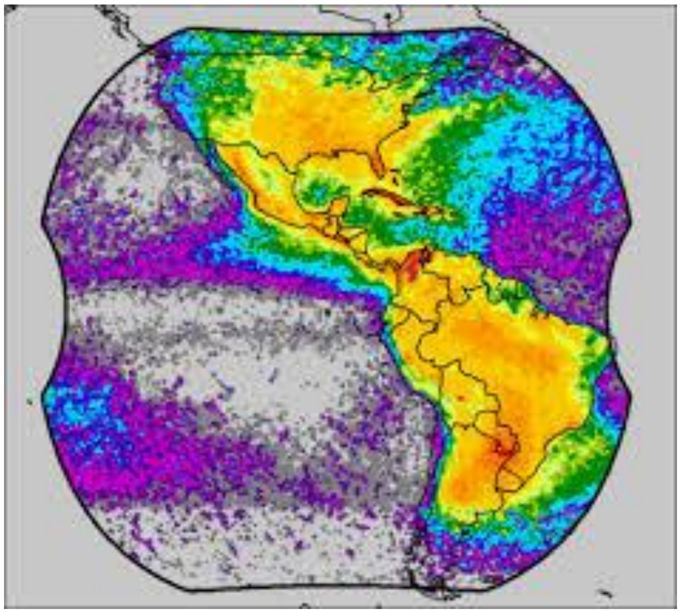
The MTG LI Instrument (courtesy of the LEONARDO Company)

MTG & GLM

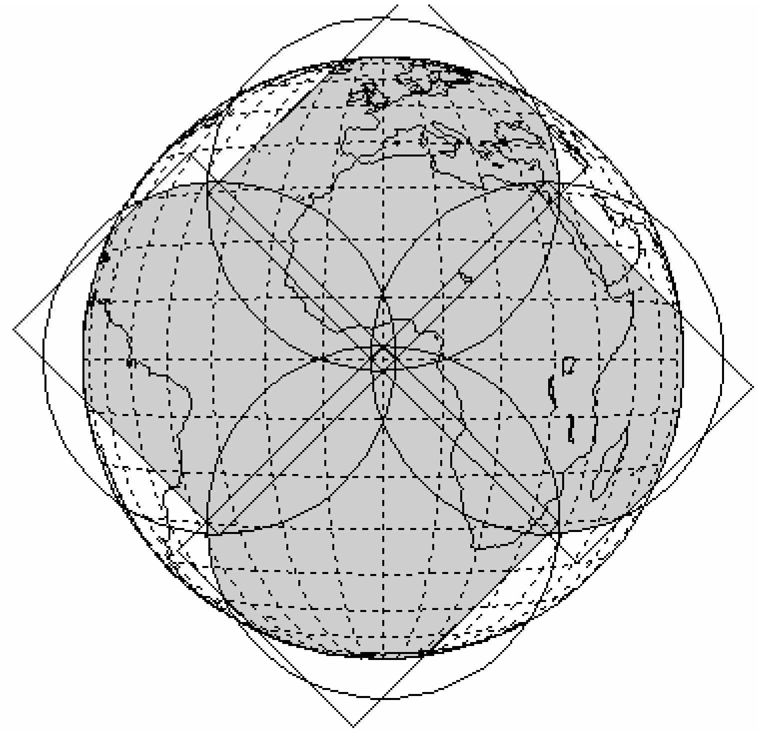
Instrument	MTG	GLM
Spectral	777.6 nm	777.4 nm (same as FY4A)
Spectral band pass filter	1.2-2 nm	1 nm
Spatial resolution	4.5 x 4.5 km	8 km nadir/14 km fov edge
Temporal	1 ms integration time	2 ms integration time
Sensor	4 CMOS 1170 x 1000	CCD 1372 x 1300 pixels
Data rate	< 30 Mbits/s	7.7 Mbits/s
Product latency(1)	30 s	20 s
Coverage	up to 86 deg N	up to 52 deg N

(1) Timeliness follows the MTG definition, as specified in the MTG Conventions and Terms document (EUM/MTG/DEF/08/0034). In essence, it states that timeliness is the time difference between the foreseen end of acquisition of the last contributing data by EUMETSAT and the end of reception of the corresponding data (processed) by the users.

MTG LI & GLM FOV's



GLM (image courtesy of NASA)



MTG LI (image courtesy of EUMETSAT)

Why Lightning from Space? (1)

- The main benefits of the MTG LI mission can be described as (from EUM/MTG/DOC/11/0155 v4, 24 March 2014 - ***ATBD for L2 processing of the MTG Lightning Imager data***) :
  - The MTG LI measurements of total lightning (IC+CG) are complementing the global/regional measurements of CG lightning as provided by ground based systems and will improve the quality of information which is essential for air traffic routing and safety.
  - Error characterized (i.e. after validation) IC+CG information can be assimilated to improve very short range forecasts of severe convective events or used to verify/validate other satellite data based NWC algorithms to forecast time and location of initiation of lightning in a new storm cell.
  - Information on lightning can also serve as proxy for adiabatic and latent heating to be assimilated in global/mesoscale NWP models.
  - The information on IC+CG will allow to assess the impact of climate change on thunderstorm activity by monitoring and long-term analysing lightning characteristics. In cooperation with the two NOAA GLMs on GOES-R and GOES-S a major part of the globe is covered by a long term committed GEO lightning (IC+GC) observing system.
  - Providing IC+CG information on a global scale will be a prerequisite for studying and monitoring the physical and chemical processes in the atmosphere regarding NOx, which is playing a key role in the ozone conversion process and acid rain generation.

Why Lightning from Space? (2)

- Use of total lightning information as a convective/stratiform separator for rain classification and rain retrieval.
- In high latitude boreal forests lightning is a major cause of forest fires. LI data can be used to issue warnings of high risk areas in affected regions.
- Lightning help diagnose the intensification of tropical cyclones over oceansobservations can be used to.
- Lightning observations can be used to **identify active convection for over-ocean air traffic**.
- Providing a linkage to TRMM LIS science and climatological datasets for the tropics that have been developed since 1998. LIS climatology is based on very long term observations due to the short viewtime available from the instrument. Verifying and developing the climatologies obtained with LIS/OTD from GEO observations will be an important task in the future.
- Some ground based system operating in the LF/VLF and VHF regions are more suitable for monitoring utilities, airports and such, which require very high location accuracy down to hundreds of meters. However, observations from space offer a complementary data source by identifying, tracking and extrapolating electrically active areas with a uniform observation quality.

Benefits of the MTG LI for Weather Forecasting

<u>How Lightning from space can improve weather forecasting?</u>

- Trends in total lightning that will be available with LI can provide critical information to forecasters, allowing them to focus on developing severe storms much earlier than they can currently, and before these storms produce damaging winds, rainfall/floods, hail. Such storms often exhibit a significant increase in total lightning activity, particularly in-cloud lightning, often many minutes before radar detects.
- The LI mission will be able to detect, monitor, track and extrapolate, in time, the development of active convective areas and storm life cycles — critical for nowcasting.

<u>What is the potential for severe weather?</u>

Used in combination with radar, data from the MTG Imager instrument (FCI), and surface observations, LI data has the potential to increase lead time for severe thunderstorm warnings.

<u>Extreme weather and severe storms under a changing climate.</u>

Instrument data can also be used to produce a long-term database to track changes in lightning activity. This is important due to lightning's role in maintaining the electrical balance between Earth and its atmosphere.

Lightning characteristics

- A lightning flash last typically 1-1.5 seconds and consist of 1..N lightning strokes (optical pulses)
- A lightning stroke, as observed from space through the clouds after multiple scattering, has a temporal duration of typically 0.6 ms.

Detection of Lightning Strokes

Lightning is not directly observed/measured as such by the MTG LI instrument but instead *it is reconstructed during Level-2 processing* (**Lightning Cluster Filter Algorithm**) out of the lightning strokes/lightning optical pulses measured by the instrument detectors as groups of Detected Transients (DTs) triggering events at the detector pixel level.

Detected Transients (DTs), Groups and Flashes

Lightning Flash = (time) sequence of various lightning optical pulses, each two spaced by no more than e.g. 300 ms, occuring at approximately the same location (e.g. within 50 km).

Physical phenomenon	Measured by instrument	Data level
-	DT (detector pixel)	L0/L1b
Lightning stroke/Lightning optical pulse	Group (of detector pixels)	L2
Lightning flash	-	L2

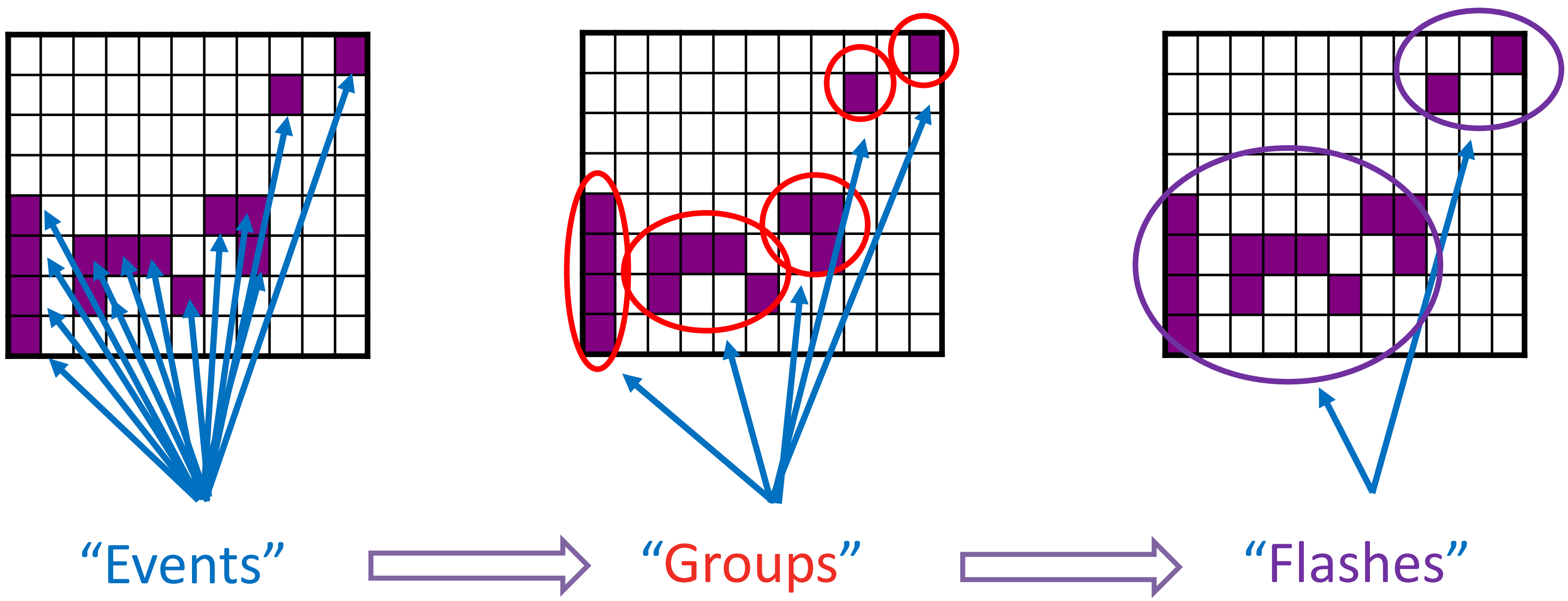
Product terminology same as for LIS/GLM

- ***Events:*** what the instrument measures, a triggered pixel in the detector grid
- ***Groups:*** collection of neighbouring triggered events in the same integration period (1 ms), representing a lightning stroke in nature
- ***Flashes:*** a collection of groups in temporal and spatial vicinity (XX km, YY milliseconds), representing a “geophysical” flash.

Groups and Flashes

Example/Conceptual representation of a L2 processing sequence:

LI grid of 4.5 km at SSP LI grid of 4.5 km at SSP LI grid of 4.5 km at SSP



SSP = Sub-Satellite Point

MTG LI – Processing Levels

- **Level 0**
  - Raw events (real + false) +
  - Raw background radiance images
- **Level 1**

  The L1b data set consists of three data products:
  - L1b Lightning data product: all triggered events with a flag to distinguish between false/true events. In addition, also other quality control flags are to be included (e.g. reason for filtering, reliability of a true event...).
  - Background radiance product (including geolocation for all ground pixels). This is based on triggering all detector elements in a given time interval.
  - Calibration data product.
- **Level 2 (baseline + accumulated products)**

The baseline L2 lightning data product consists of a full "flash tree", with the related groups and events related to a given flash

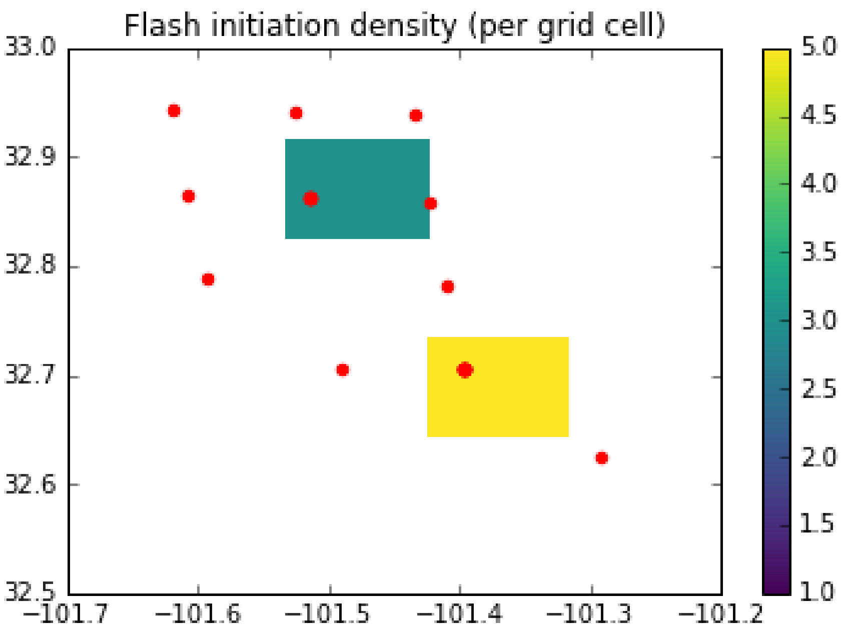
  - As a distinction to L1b, <u>only true events are included in the L2 "flash tree"</u>, since the false events are not linked to any flash.
  - Group location is computed based on radiance weighted centroids of events.
  - Flash location is computed based on radiance weighted centroids of groups.

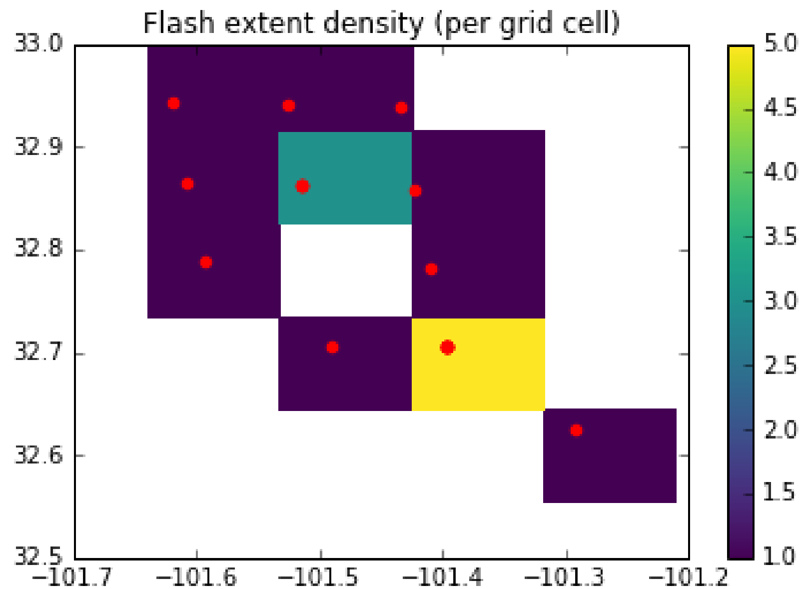
The accumulated products are obtained collecting samples from a 30 second buffer.

  - Presented in the same 2-km grid as the imager IR channel data for easier combining with imager information
  - <u>Events define the extent in the products</u>, Flashes define the values in the products

Point Data vs Grid Data

If we ignore the spatial extent of each flash and use only the flash center locations (individual points), imagery becomes very sparse (left). Flash extent density (right) captures much more information, such as the width of the storm.





Flash center locations (point data) – left, vs gridded products (from Eric Brunning, Development and status of GLM gridded (accumulated) products, LI MAG Meeting, 26-27 November 2018, Darmstadt)

MTG LI Level 2 Products (1)

Product	Description	Dissemination to users
	Baseline Products	
Events	Lightning events (only true lightning events)	Yes(1)
Groups	Intermediate product to reach L2 Flashes	Yes
Flashes	Final lighting data product of the baseline L2 processor	Yes
	Accumulated Products	
Accumulated flashes	Accumulated flashes (normalized by grid affected by each flash) in a 30 sec temporal scale and a 2 km grid.	Yes, together with the L2 Flash product
Accumulated flash index (accumulated flash area)	Accumulated flashes (not normalized) in a 30 sec temporal scale and a 2 km grid	Yes, together with the L2 Flash product
Accumulated flash radiance	Accumulated flashes radiance in a 30 sec temporal scale and a 2 km grid.	Yes, together with the L2 Flash product

(1) Not a real-time product, it will be available as an archive product

MTG LI Level 2 Products (2)

- L2 accumulated products are not “density” products as such since a division with pixel area (in km^2) is not done in the computation - left to the user. The accumulated flash product contains cumulative flash counts.
- Varying pixel size along the LI FOV means storms of similar “strength” would appear different in density plots depending on the LI pixel size (if not normalized in some way), therefore full disk products challenging. Zonal density products easier.
- In order to use the full amount of information available from the L2 Lightning data product, <u>the extent of the accumulated products will be defined by events</u>, but units and values are defined by the flashes.
- Density products shown in the fixed MTG-FCI (*) imager grid (same grid as for the FCI IR channels in the 2 km FDHSI resolution)

MTG LI Baseline, Accumulated and NWC SAF Products (1)

Nr	MTG LI Product	Description	Variables=>Units	Level	Input	Similar/Equivalent GLM Product	Description	Units	Grid
EUMETSAT Initial Products (baseline) – Produced by EUMETSAT. Timeliness: 30 seconds									
1	Filtered Lightning Events (LI-2-LEF)	L2 Filtered lightning event. Contains only lightning events that have been filtered and clustered into Flash products.	mJ/(m2*sr)	2	L1b events	Event Energy	Event radiant energy	J	LI Grid
2	Lightning Groups (LI-2-LGR)	L2 Lightning groups. Contains all the lightning group clusters as identified by the level 2 processing.	radiance=>mJ/(m2*sr, number of events=>1	2	L2 events	Group Energy	Group radiant energy	J	None
3	Lightning Flashes (LI-2-LFL)	Contains all the lightning flashes as identified by the level 2 processing together with the auxiliary data associated with the processing configuration and the quality assessment of the dataset.	radiance=>mJ/(m2*sr, footprint=>number of LI grid pixels, duration=>milliseconds	2	L2 groups	Flash Energy	Flash radiant energy	J	None
EUMETSAT Accumulated Products – Produced by EUMETSAT. Timeliness: 30 seconds									
4	Accumulated Flashes (LI-2-AF)	Number of contributing unique flashes to each pixel (grid cell), in a 30 sec temporal scale and a 2 km grid, normalized by the number of events in each contributing flash. Sum of LI accumulated flash over some region is equal to the total number of flashes, which is a useful property.	flashes/30 seconds	2	L2 flashes, L2 events	N/A			FCI IR
5	Accumulated Flash Index, (LI-2-AFA)	Number of contributing unique flashes to each pixel (grid cell), in a 30 sec temporal scale and a 2 km grid. The grid box value increases by 1 for each flash having an event inside the grid box. It is a flash rate product.	flashes/30 seconds (counts)	2	L2 flashes, L2 events	Flash Extent Density (count)	# of flashes that occur within a grid cell over a given period of time	flashes/minute Best portrays, in a single product, the quantity/extent of flashes/events	FCI IR
6	Accumulated Flash Radiance (LI-2-AFR)	Area averaged flash radiance accumulation, i.e. accumulated flashes radiance in a 30 sec temporal scale and a 2 km grid. Grid box values are counted by dividing the radiances affecting that grid box by the number of grid boxes subject to each flash. It allows the user to integrate over a sub-area of the full FOV to get the cumulative flash count for that sub--area.	μJ/m2/μm/30sec	2	L2 flashes, L2 events	Total Optical Energy (TOE)	Is the sum of all optical energy that the GLM observes within each grid cell during a specified time period	fJ (fJ = 10^{-15} J)	FCI IR

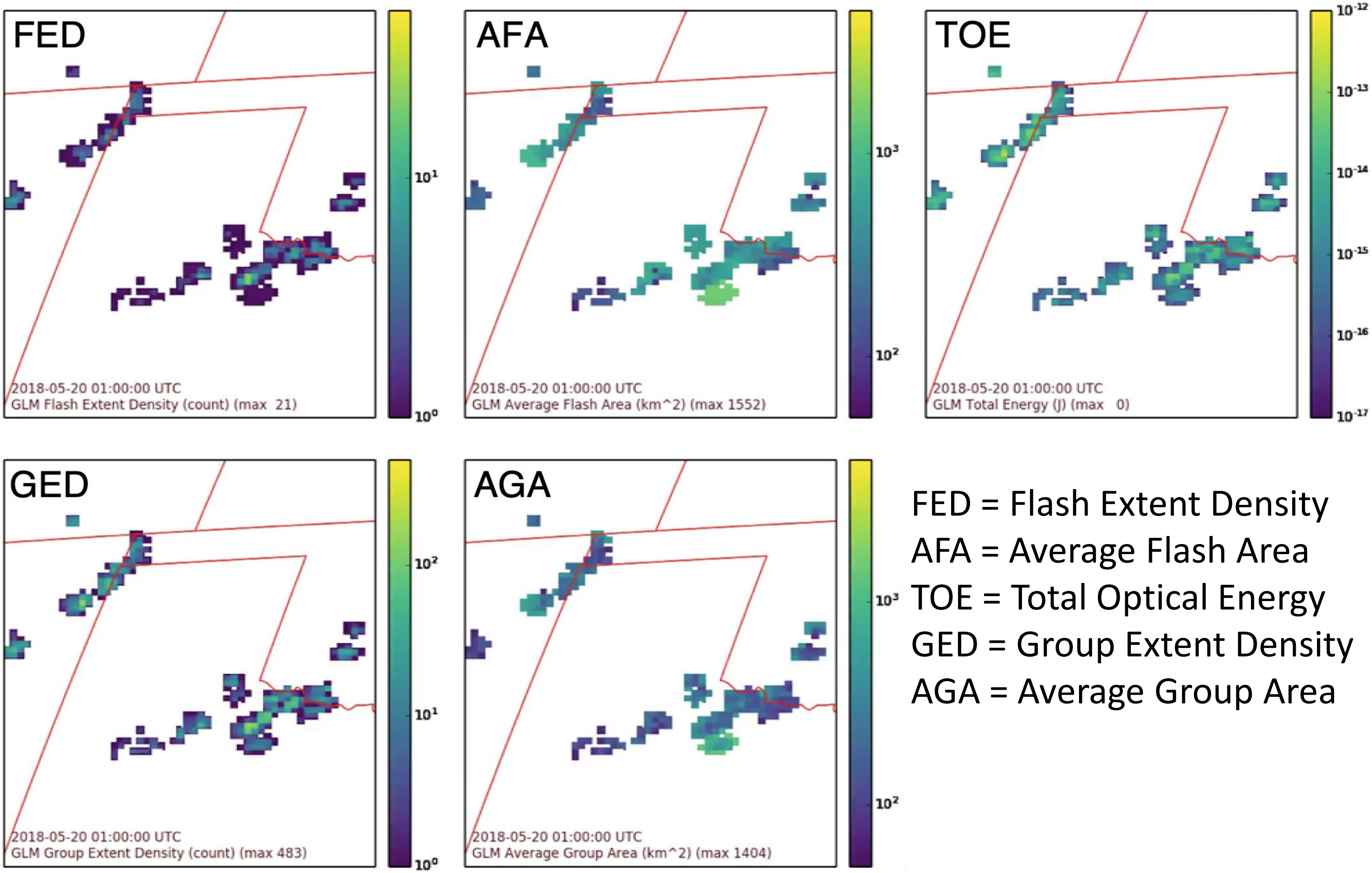
MTG LI Baseline, Accumulated and NWC SAF Products (2)

Potential MTG LI NWC SAF Products (EUMETSAT NWC SAF) – Produced by NWC SAF GEO software									
L2 Parallax Corrected Products									
7	Paralax Corrected Accumulated Flashes (LI-3-AF-PC)	Accumulated Flashes (LI-2-AF) corrected for parallax error	flashes/ 30 sec	3	LI-2-AF, delta-ϕ/delta-λ FCI table	N/A			FCI IR
8	Paralax Corrected Accumulated Flash Index (LI-3-AFA-PC)	Accumulated Flash Index (LI-2-AFA*) corrected for parallax error	flashes/ 30 sec	3	LI-2-AFA, delta-ϕ/delta-λ FCI table	N/A			FCI IR
9	Paralax Corrected Accumulated Flash Radiance (LI-3-AFR-PC)	Accumulated Flash Radiance (LI-2-AFR) corrected for parallax error	mJ/(m2*sr)	3	LI-2-AFR, delta-ϕ/delta-λ FCI table	N/A			FCI IR
Stacked Products									
10	Stacked Accumulated Flashes (LI-3-SAF)	The original EUMETSAT L2 accumulated product stacked into a longer, user selected period, as a multiple integer (N) of the 30 seconds buffer, updated every M minutes	flashes/N*30 seconds	3	LI-2-AF/LI-2-AF-PC	N/A			FCI IR
11	Stacked Accumulated Flash Index (LI-3-SAFA)	The original EUMETSAT L2 accumulated product stacked into a longer, user selected period, as a multiple integer (N) of the 30 seconds buffer, updated every M minutes	flashes/N*30 seconds	3	LI-2-AFA/ LI-2-AFA-PC	N/A			FCI IR
12	Stacked Accumulated Flash Radiance (LI-3-SAFR)	The original EUMETSAT L2 accumulated product stacked into a longer, user selected period, as a multiple integer (N) of the 30 seconds buffer, updated every M minutes	mJ/(m2*sr)	3	LI-2=AFR/ LI-2-AFR-PC	N/A			FCI IR

MTG LI Baseline, Accumulated and NWC SAF Products (3)

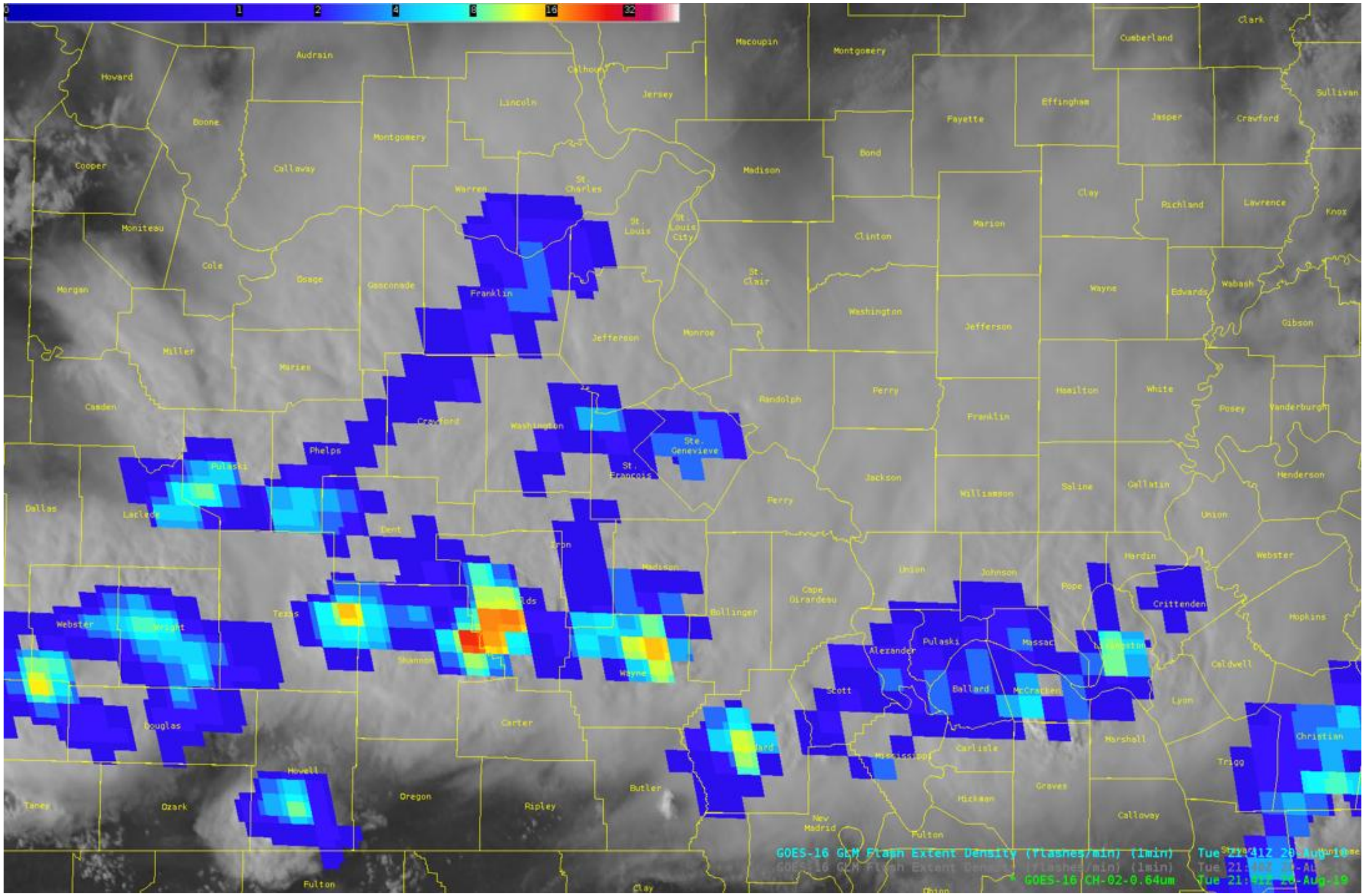
GLM-like Products (descriptions taken from GLM Gridded Product Description Scott Rudlosky (NESDIS/STAR) and Eric Bruning (Texas Tech University), Released on 25 March 2018)									
13	Average Flash Area (LI-3-AFA)	Average area of all MTG LI flashes spatially coincident with each 2×2 km FCI grid cell during a specified time period. The average flash area product calculates the average area of all flashes that passed through a grid cell. It is the sum of the areas of all flashes that passed through a grid cell divided by the flash extent density. <u>It is relative to each grid cell.</u>	km^2/flash	3	LI-3-FA	Average Flash Area (AFA)	The average area of all GLM flashes spatially coincident with each 2×2 km grid cell during a specified time period	km^2/flash	FCI IR
14	Average Group Area (LI-3-AGA)	Average area of all MTG LI groups spatially coincident with each 2×2 km FCI grid cell during a specified time period.	km^2/group	3	LI-3-GA	Average Group Area (AGA)	The average area of all GLM groups spatially coincident with each 2×2 km grid cell during a specified time period	km^2/group	FCI IR
Flash Rate Products									
15	Flash Rate Tendency (LI-3-FRT)	Variation of the cumulative flash count for a user selected subarea of the full FOV during 2 consecutive 30 seconds accumulations.	<1>	3	LI-2-AF	N/A			FCI IR
Kinematic Products									
16	Flash Tracking	Flash path	-	3	LI-2-AF	N/A			FCI IR
Other Products (TBD)									
17	Flash Climatology	Annual mean flash rate, mean diurnal cycle of flash rate with 24 hour resolution, mean annual cycle of flash rate with daily, monthly, or seasonal resolution, time series of flash rate over N year record etc.	flashes/min	3	LI-2-AF	N/A			FCI IR
18	CG/CC Discriminator	Dicriminates between CG and CC lightning	CC flashes, GC flashes	4	LI-2-AFA	N/A			FCI IR

GLM Gridded Products



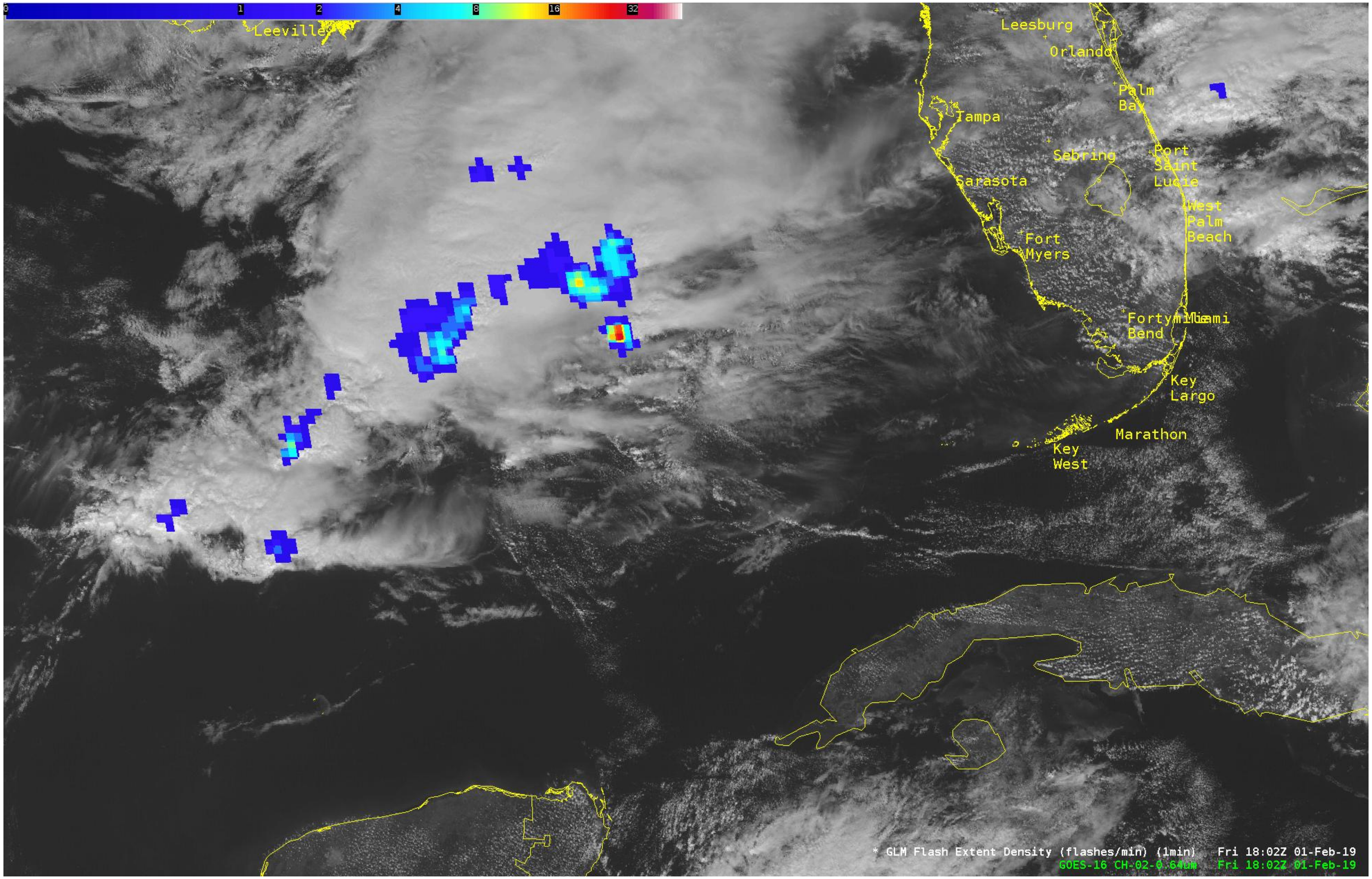
FED = Flash Extent Density
AFA = Average Flash Area
TOE = Total Optical Energy
GED = Group Extent Density
AGA = Average Group Area

Flash Extent Density (FED)



GOES GLM Flash Extent Density overlaid on 0.64 μm ABI data at 2141 UTC (441 pm CDT)
(Courtesy of NASA SpoRT - Short-term Prediction Research and Transition Center)

Flash Extent Density (FED)



GLM (Flash Extent Density) and GOES-16 visible imagery (0.64 µm) loop from 1802-1830 UTC, 01 Feb 2019. Active deep convection and lightning over the Gulf of Mexico (Courtesy of NASA SpoRT - Short-term Prediction Research and Transition Center)

Lightning Flash Rate & Flash Rate Tendency (1)

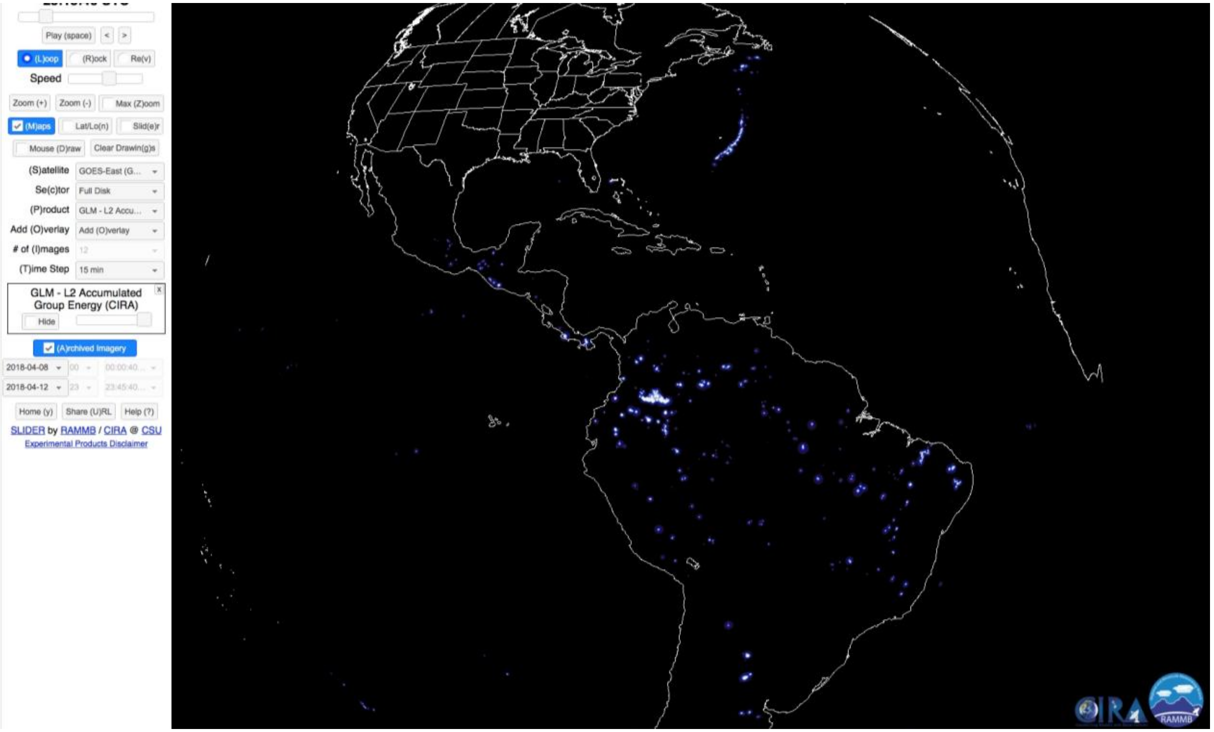
- Flash Rate = # of flashes per unit time (usually fl/min).
- Flash Rate Tendency = Flash Rate variation in time (fl/min^2)
- Trends in total lightning that will be available with LI can provide critical information to forecasters, allowing them to focus on developing severe storms much earlier than they can currently. Such storms often exhibit a significant increase in total lightning activity, particularly in-cloud lightning, often many minutes before radar detects.
- Williams (1999), Schultz et al. (2009), and Gatlin and Goodman (2010), Schultz et al. 2011) :
  - demonstrate the correlation between rapid increases in total flash rate (i.e., "lightning jumps") and severe weather occurrence.
  - have quantified the lightning jump based on statistical measures.
- Schultz et al. (2009, 2011) presented strong results for the use of total lightning from lightning mapping arrays (LMAs) to aid in the prediction of severe and hazardous weather using an objective lightning jump algorithm (LJA)
- MTG LI will see flashes differently than LMA, yielding different flash counts and locations.
- Automation of the Lightning Jump Algorithm for operational use – what do we need?
  - Flash rate
  - Thunderstorm tracking
  - LJA algorithm

- Storm cell tracking needed in order to compute flash rate history / tendency – a good starting point could be the NWCSAF RDT product

Flash energy (1)

- **Incident Energy = Very Small Fraction of Flash Energy**
- Flash energy ~ GJ is dissipated by acoustical waves, radiation, thermal conduction, & convection (mixing)
  - radiation: radio, microwave, IR, visible, UV, X-Ray, gamma
- Incident flash optical energy on the sensor is very small - hundred(s) of µJ (sensor dependent)
- An even smaller portion gets converted to digital counts (losses from reflections, lens absorption, CCD quantum efficiency)
- <u>Reconstructing the Flash energy from what the optical sensor measure is not realistic.</u>

Flash ~~energy~~ radiance (2)



Example of GLM Accumulated Group Counts from RAMMB (Regional and Mesoscale Meteorological Branch, NOAA/NESDIS)

Thank You!