

NWCSAF MTG LI Prototype Products

Andrei Diamandi (diamandi@meteoromania.ro)

NWC SAF Team

Convection Working Group 2018

Ljubljana, April 2018

MTG Lightning Imager



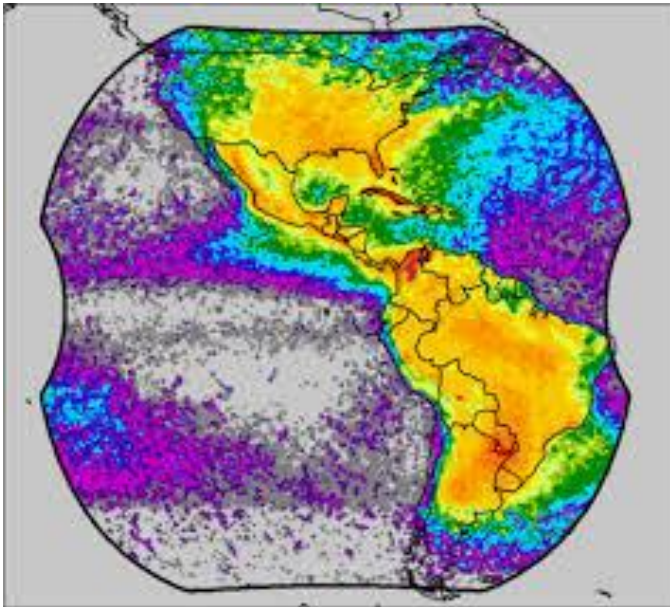
The MTG LI Instrument (courtesy of the LEONARDO Company)

MTG & GLM

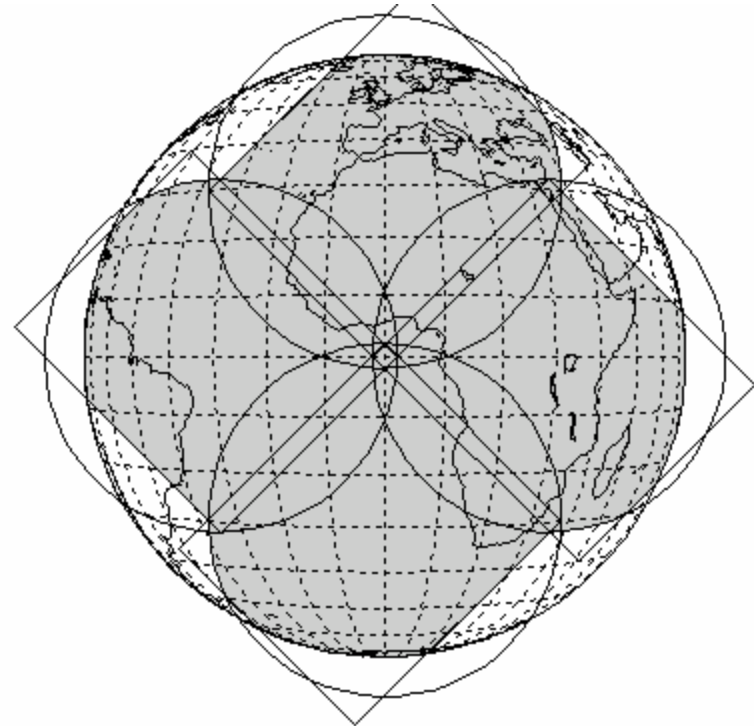
Instrument	MTG	GLM
Spectral	777.6 nm	777.4 nm (same as FY4A)
Spectral band pass filter	1.2-2 nm	1 nm
Spatial resolution	4.5 x 4.5 km	8 km nadir/14 km fov edge
Temporal	1 ms integration time	2 ms integration time
Sensor	4 CMOS 1170 x 1000	CCD 1372 x 1300 pixels
Data rate	< 30 Mbits/s	7.7 Mbits/s
Product 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 NO_x, 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 oceans observations 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

How Lightning from space can improve weather forecasting?

- 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.

What is the potential for severe weather?

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.

Extreme weather and severe storms under a changing climate.

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.

CDOP-3 NWCSAF MTG-LI Prototype Products (WP2290)

START/END: Q2 2018 / Q1 2022

Objective:

Development of MTG-LI based prototype products. Proposed products are (but not limited to): Flash tracking, Flash rate tendency, Flash area and Flash energy. The selected products will be further developed in CDOP-4.

WP2290 MTG-LI Prototype Products

Algorithm development:

- Products requirements
- Start from L1/L2 MTG-LI data
- L2 products for LI consist of
 - Initial processing data (groups and flashes)
 - Accumulated product data
- Use simulated MTG-LI data
- Use GOES-R GLM L2 data for prototyping/testing
- ATBD's

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

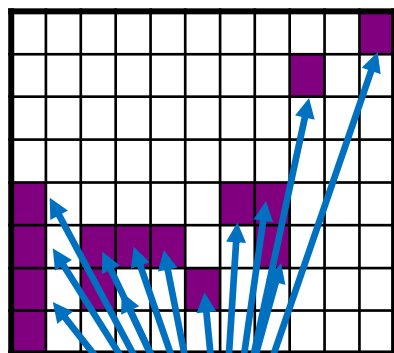
Product terminology same as for LIS/GLM

- **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

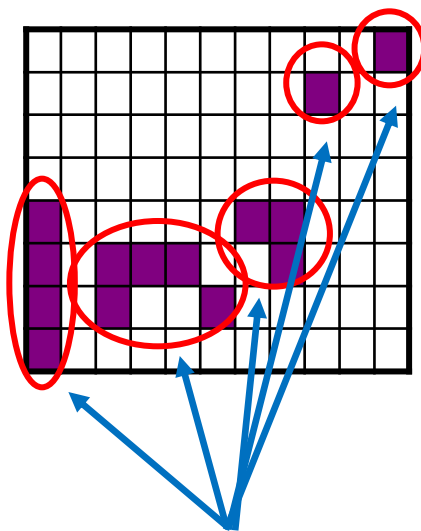
Example/Conceptual representation of a L2 processing sequence:

LI grid of 4.5 km at SSP



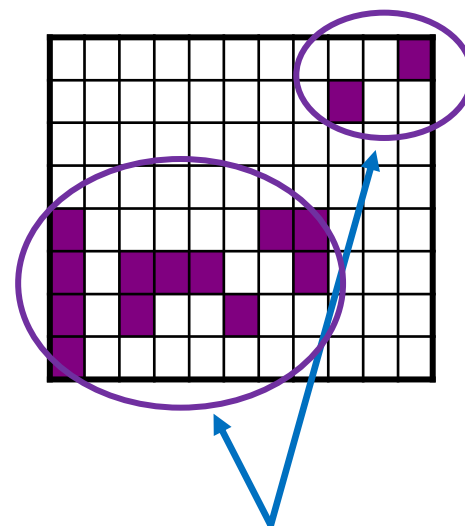
“Events”

LI grid of 4.5 km at SSP



“Groups”

LI grid of 4.5 km at SSP



“Flashes”

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, only true events are included in the L2 “flash tree”, 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
- Events define the extent in the products, Flashes define the values in the products

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 lightning 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 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)

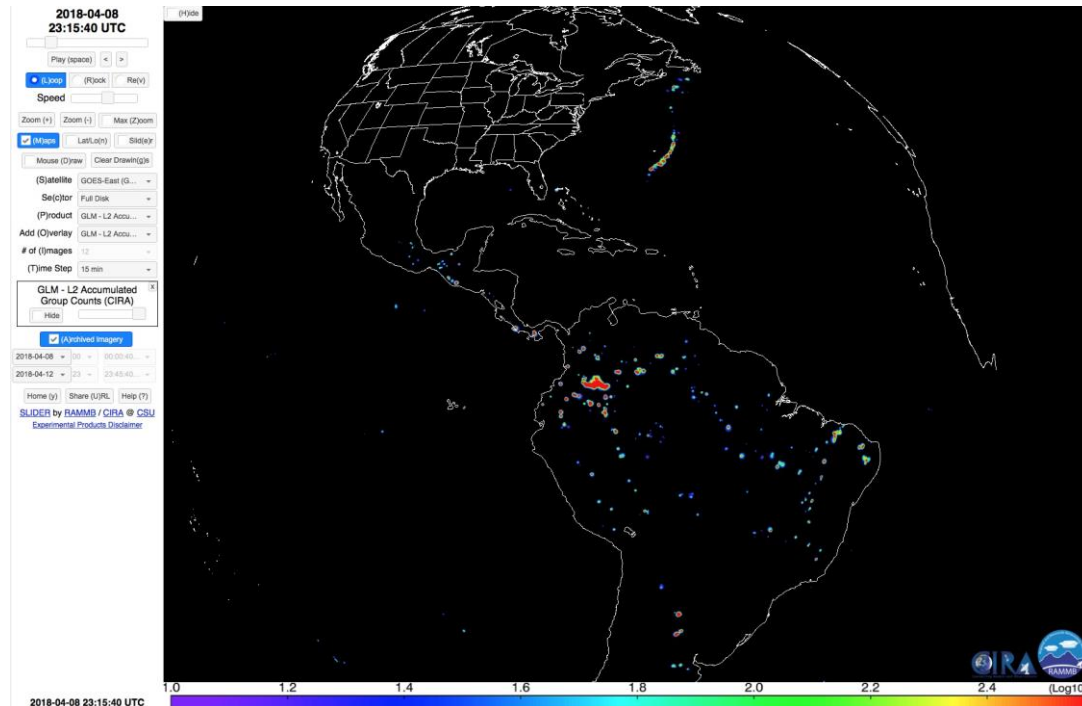
- L2 accumulated products are not “density” products as such since a division with pixel area (in km²) is not done in the computation - left to the user. The accumulated flash product contains cumulative flash counts.
- Varying pixel size along the LI FOV means storms of similar “strength” would appear 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, the extent of the accumulated products will be defined by events, 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)

Potential MTG LI SAFNWC Products (Level 3)

Product	Description	Input
Flash Area/Extent	L2 accumulated flash area integrated over N minutes and updated every 30 sec	L2 accumulated flashes
Flash Rate	Number of flashes per unit time (usually fl/min)	L2 accumulated flashes
Flash Rate Tendency	Flash Rate variation (fl/min ²)	L3 flash rate
Zonal Products		
Flash Density ⁽²⁾	Number of flashes/pixel area (in km ²)	L2 flashes
Accumulated Flash Density ⁽²⁾	Number of accumulated flashes/pixel area (in km ²)	L2 accumulated flashes
Accumulated Flash Density Index ⁽²⁾	Accumulated flash density index/pixel area (in km ²)	L2 accumulated flash index
Accumulated Flash Radiance Density ⁽²⁾	Accumulated radiance density/pixel area (in km ²)	L2 accumulated flash radiance

Flash Area/Flash Extent Density

- L2 Accumulated flash area stacked: L2 30 sec accumulated flash area
- Possible flash area density product: accumulated flash area integrated over N minutes and updated every 30 sec



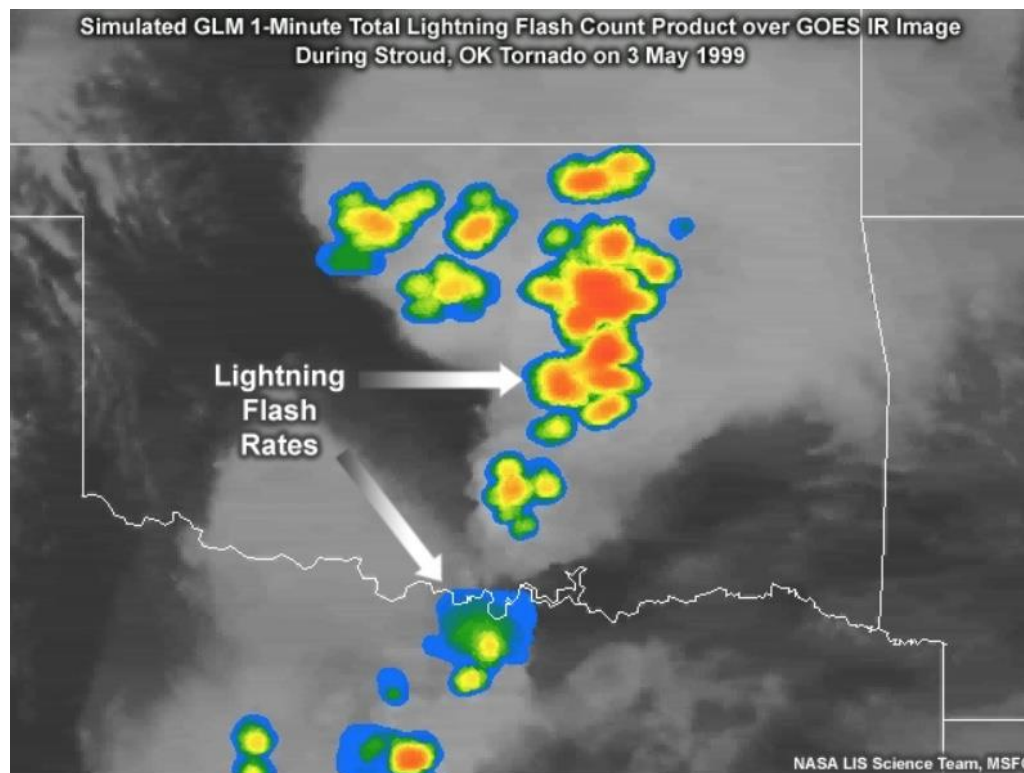
Example of GLM Accumulated Group Counts from RAMMB (Regional and Mesoscale Meteorological Branch, NOAA/NESDIS)

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/min²)
- 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

Lightning Flash Rate & Flash Rate Tendency (2)

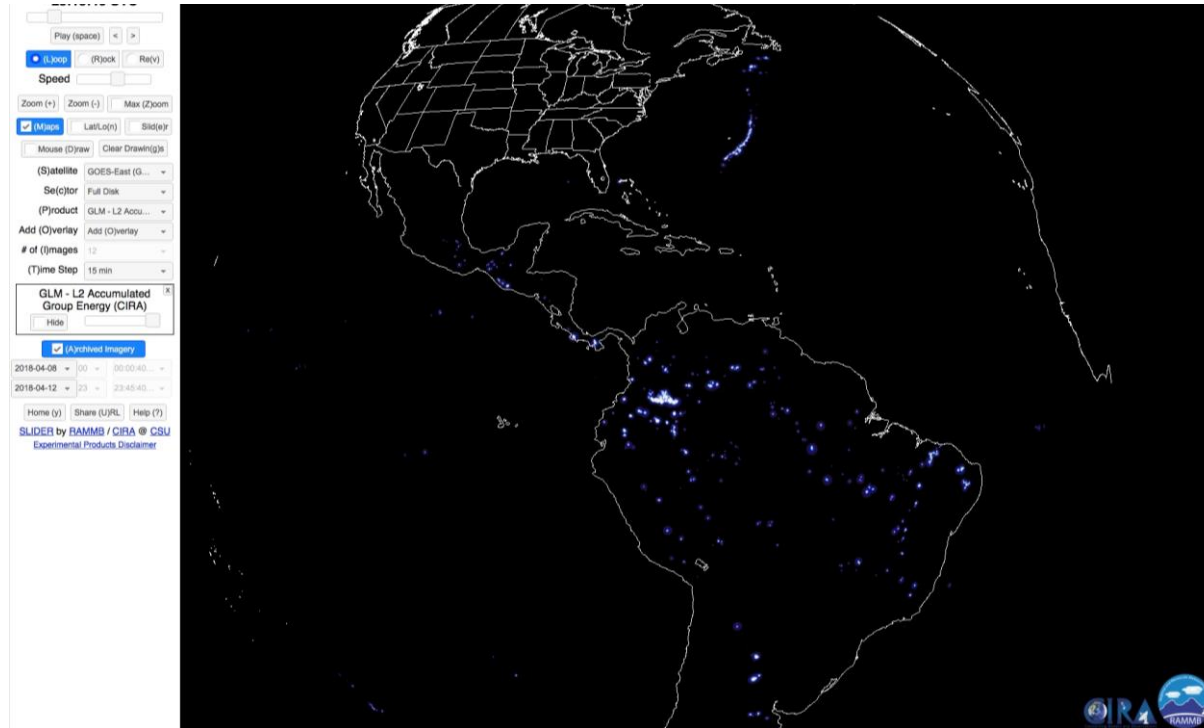
Example of Lightning Flash Rate: simulated GLM 1-Minute total lightning flash count product over GOES IR image (from COMET – GOES-R GLM: Introduction to Geostationary Lightning Mapper)



Flash energy (1)

- **Incident Energy = Very Small Fraction of Flash Energy**
- Flash energy \sim 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 μ J (sensor dependent)
- An even smaller portion gets converted to digital counts (losses from reflections, lens absorption, CCD quantum efficiency)
- Reconstructing the Flash energy from what the optical sensor measure is not realistic.

Flash ~~energy~~ radiance (2)



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

Flash zonal products

➤ Flash zonal products:

- flash density
 - accumulated flash density
 - accumulated flash density index
 - accumulated flash radiance density
-
- The flash zonal products are “true” density products, since a division with pixel area (in km²) is done in the computation. 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 “true” density products challenging.

NEXT

- Closely follow MTG LI evolution toward completion
- Closely follow GOES-R GLM, FY4A
- Learn from already developed products

Thank You!