Geostationary Lightning Observations in Support of NWC and Severe Weather Monitoring

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Topics of Presentation

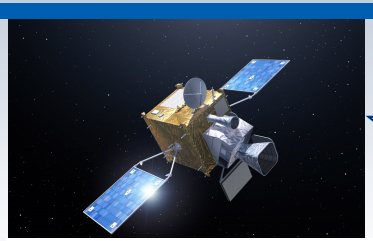
- Quick introduction to Meteosat Third Generation (MTG)
- Geostationary lightning imaging
  - Why we do it...?
- MTG LI instrument
  - Main characteristics and status update
- Lightning Imager Products for direct dissemination
  - Flashes
  - Accumulated products (for density plots)
- User readiness
  - Access to proxy data
- Summary

MTG to Secure Continuity and Evolution of EUMETSAT Services

1977 — 2002 — 2018 and 2020

MOP/MTP **MOP/MTP**

MSG **MSG**



MTG-I and MTG-S

Observation mission:
- MVIRI: 3 channels

Spinning satellite
Class 800 kg

Observation missions:
- SEVIRI: 12 channels
- GERB

Spinning satellite
Class 2-ton

Observation missions:
- Flex.Comb. Imager: 16 channels
- Infra-Red Sounder
- Lightning Imager
- UVN

3-axis stabilised satellites
Twin Sat configuration
Class 3.6-ton

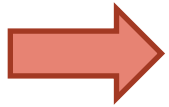
Implementation of the EUMETSAT Mandate for the Geostationary Programme

Atmospheric Chemistry Mission (UVN-S4): via GMES Sentinel 4
(Ultraviolet Visible Near-infrared spectrometer)

Geostationary lightning imaging – objectives and benefits

The LI on MTG measures Total Lightning:
Cloud-to-Cloud Lightning (IC) and Cloud-to-Ground Lightning (CG)

Main benefit from GEO observations:
homogeneous and continuous observations delivering information on location and strength of lightning flashes to the users with a timeliness of 30 seconds



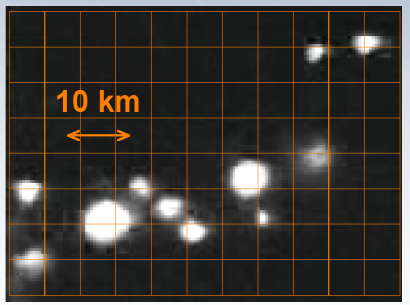
Main objectives are to detect, monitor, track and extrapolate in time:

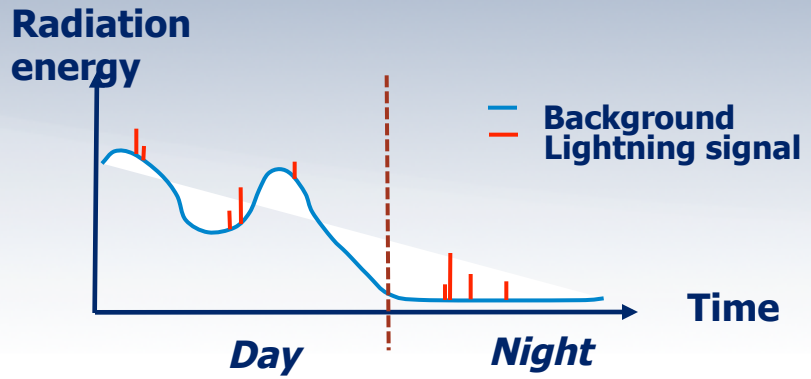
- **Development of active convective areas and storm lifecycle**
- **Lightning climatology**
- **Chemistry (NOx production)**

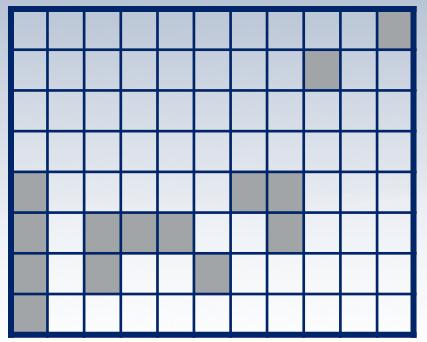
Complementary to existing and future ground-based systems (LLS):

- **Clearly some applications are locally better served by ground-based systems, if available.**
- **On the other hand, some applications are better served by a uniform and constant observation from space, and if no good-quality ground based data is available**

From a Lightning Optical Signal to MTG LI Events







Background scene tracking and removal → **Thresholding** → **Event detection**

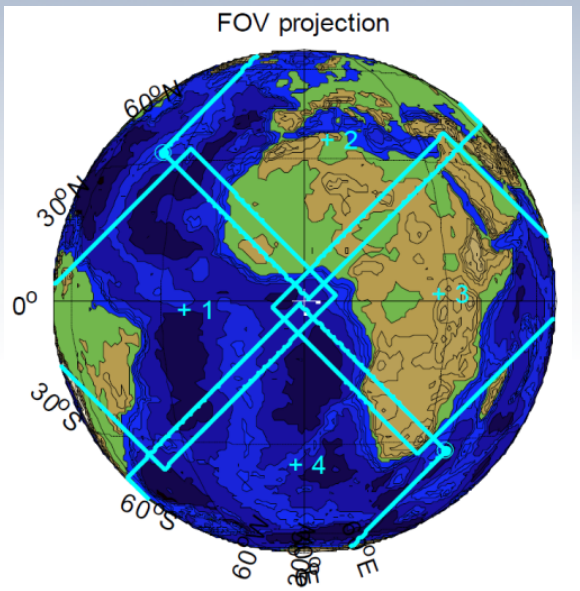
- **True lightning events** (triggered by a lightning)
- **False events** (not related to lightning)

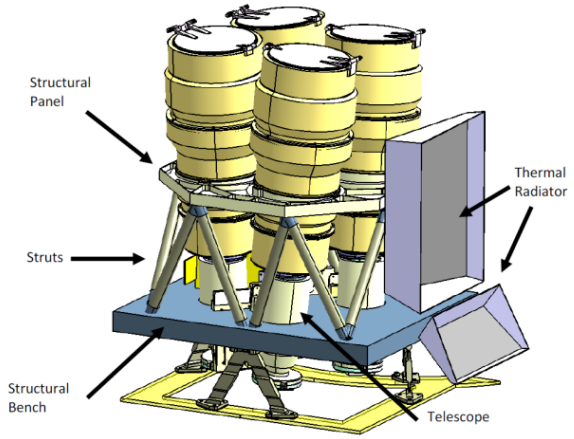
→ **False event filtering needed in L0-L1 processing**

Lightning Imager (LI) main characteristics

LI main characteristics:

- Measurements at 777.4 nm
- The instrument works in a staring mode, detecting lightning events within its FOV of its 4 cameras
- Coverage close to visible disc (instantaneous view)
- Integration time 1 ms, based on lightning optical pulse characteristics
- Ground sample distance at SSP 4.5 x 4.5 km => 4.7 million pixels
- Background subtraction and event detection done on-board (real time processing at 1 kHz)





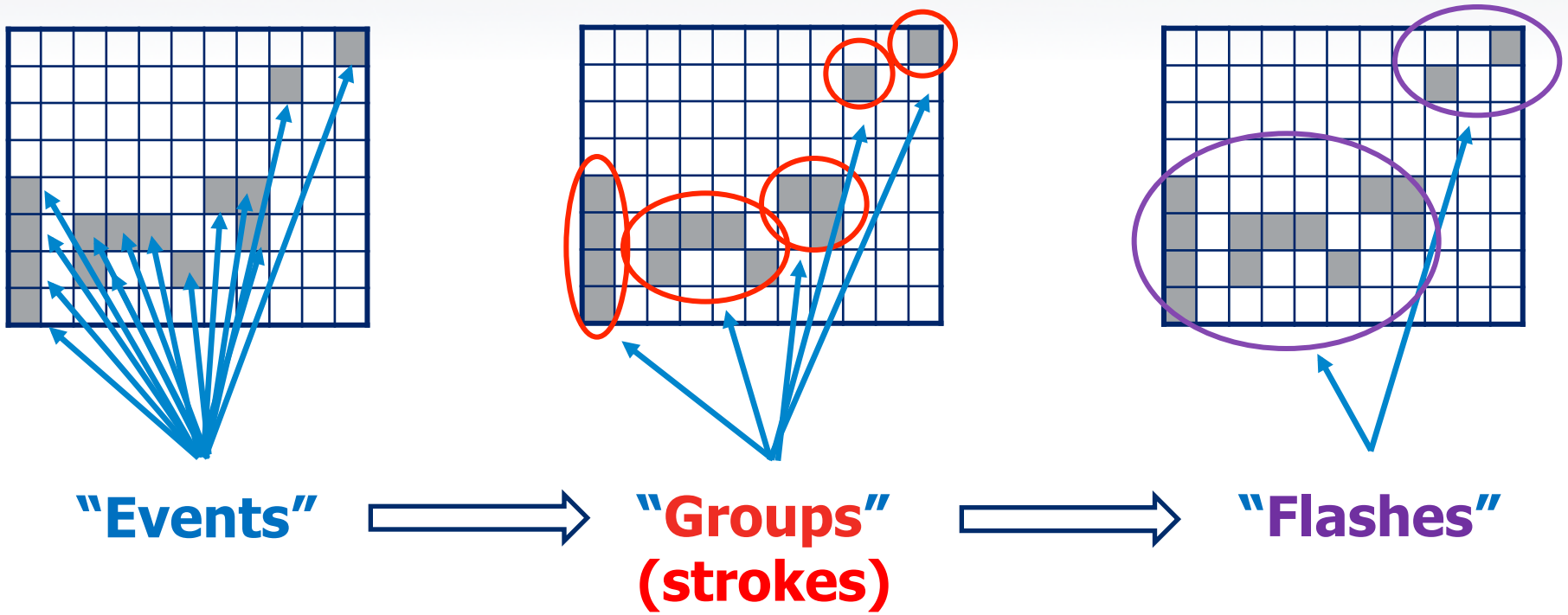
MTG LI baseline products disseminated to users

- **Groups/Lightning Strokes**
  - **Spatially neighbouring events in the same or neighbouring 1 ms integration frame**
- **Flashes**
  - **Spatially/temporally clustered groups/strokes (up to 330 ms and/or 16.5 km)**
- **Accumulated products**
  - **Accumulated flashes & radiance**
  - **Can be employed to obtain a density product**
  - **Integration period: 30 seconds, can be stacked for longer times**

Illustration on flash clustering on the next slide!

Lightning Imager Groups (strokes) and Flashes

Example/Conceptual representation of a Flash processing sequence:



User readiness - Background

- **Since MTG Lightning Imager is a new instrument, user readiness is a one of the key issues requiring attention**
  - Need to **inform** potential future data users
  - Need to **prepare** these users to what is available
  - Need to **train** these users in using the products
- **How to achieve this…?**
  - **By providing potential users LI "proxy data" well in advance of operations**
  - **Aiming at a realistic LI experience, without the real spacebased osbervation available**

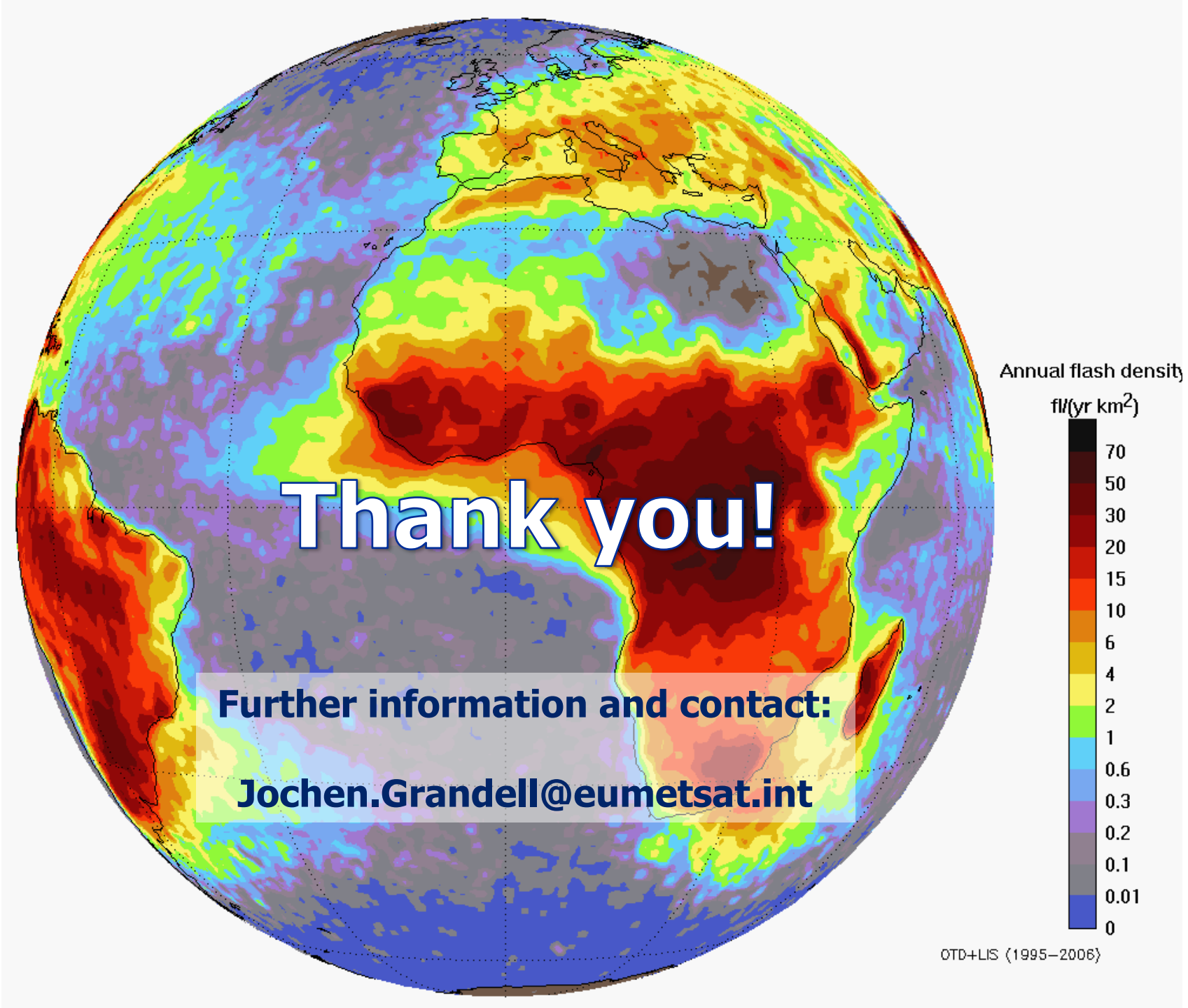
LI proxy data

- **Proxy data in development, to allow real-time application for forecasters**
- **Based on data comparisons between ground-based LINET and Lightning Imaging Sensor(*) observations**
  - **Modeling of MTG LI optical signals by transformation of LINET RF stroke data into optical groups – requires the creation of additional groups based on LIS/LINET statistics**
  - **Adjustment of the proxy data generation to the varying LINET baselines in Europe**
  - **To be available both as an "archive product", as well eventually as a Near Real Time proxy data product**
  - **European wide LINET coverage as a baseline**

(*) LIS – a spaceborne lightning instrument on LEO orbit

Summary

- **Meteosat Third Generation (MTG) will secure continuity and evolution of EUMETSAT geostationary services from 2018 onwards**
    - **One of the new instruments on MTG is the Lightning Imager (LI) providing continuous lightning observation (CG+CC) over almost the full disk (at 0 deg).**
- **Instrument prime selected (Selex Galileo), KO in July 2012**
- **Products disseminated to users:**
    - **Flashes (with groups/strokes)**
    - **Accumulated products (flashes & radiance)**
- **User readiness activities to be more in the focus in the years to come**
- **Proxy data in development, with potential for NRT applications**



Thank you!

Further information and contact:

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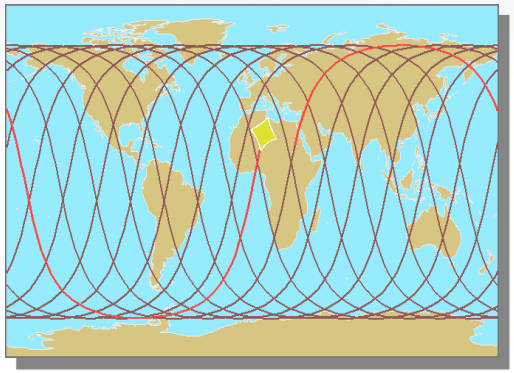
MTG Space Segment Configuration

- Twin Satellite Concept, based on 3-axis platforms
  - 4 Imaging Satellites (MTG-I) (20 years of operational services)
  - 2 Sounding Satellites (MTG-S) (15.5 years of operational services)
- Payload complement of the MTG-I satellites
  - The Flexible Combined Imager (FCI)
  - The Lightning Imager (LI)
  - The Data Collection System (DCS) and Search and Rescue (GEOSAR)
- Payload complement of the MTG-S satellites
  - The Infrared Sounder (IRS)
  - The Ultra-violet, Visible and Near-infrared Sounder (UVN)

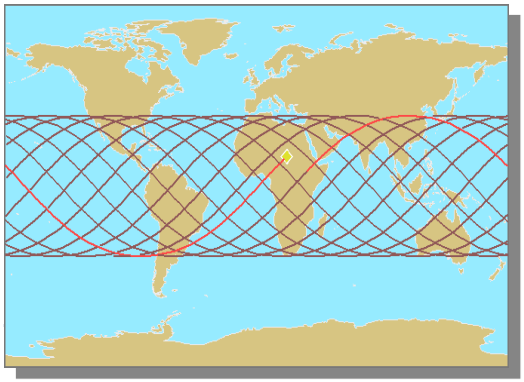
Lightning Detection from Space – from LEO to GEO

Feasibility of lightning detection from space by optical sensors has been proven by NASA instruments since 1995 on low earth orbits (LEO)

OTD (1995-2000)

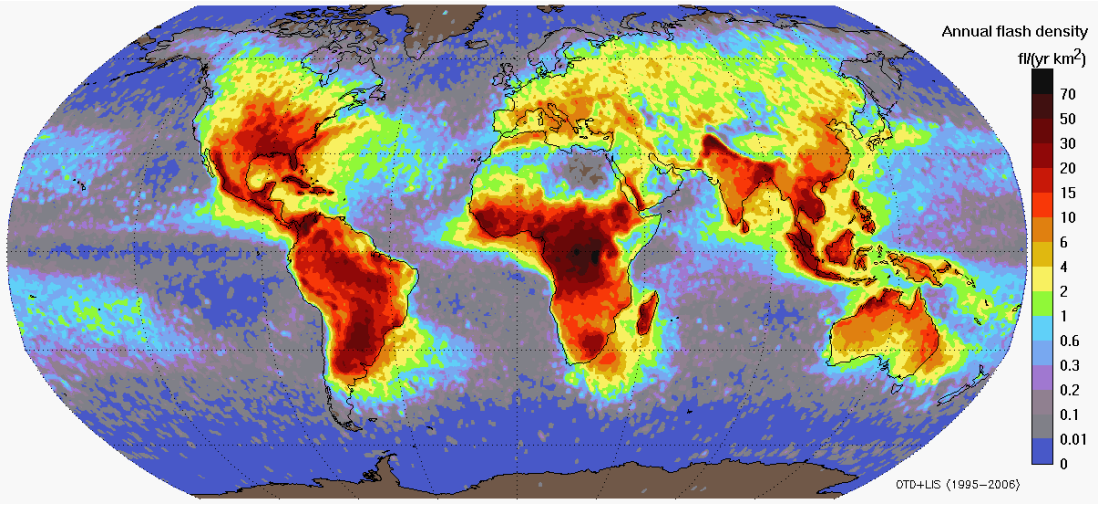


LIS (1997-present)



Results from LIS/OTD: Global lightning distribution

Annual flash density



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...Air Traffic is one area of application, and not just around major airports...

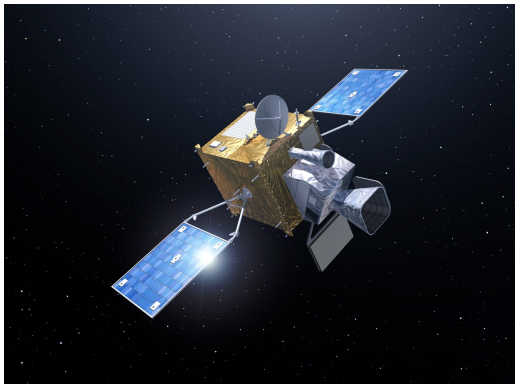
Lightning Detection from Space – from LEO to GEO

GEO lightning missions in preparation by several agencies (in USA, Europe, China) for this decade...
...all of these are building on LIS/OTD heritage

Geostationary Lightning Mapper (GLM) on GOES-R (USA)

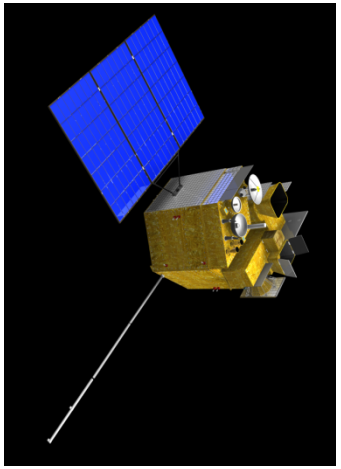
2015 ⇒

Lightning Imager (LI) on MTG (Europe)



2018 ⇒

Geostationary Lightning Imager (GLI) on FY-4 (China)



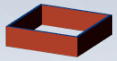
2014 ?

MTG-LI User Products – Disseminated (2)

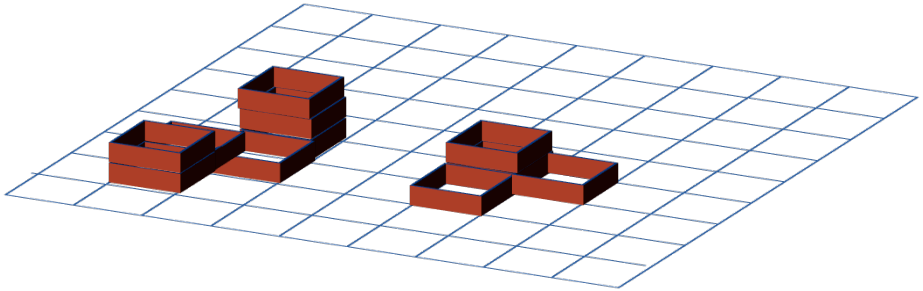
- **Accumulated products from a 30 second buffer and resampled to the 2-km FCI-IR grid**
- **Accumulated flashes**
  - **Events define the extent in the product**
  - **Flashes define the values in the product**
  - **Flash counts in the IR grid divided by the number of LI grid elements involved in each flash (= allows integration over the full or sub-grid to get the correct total flash counts)**
- **Accumulated flash index**
  - **Same as above but without division with involved LI grid elements (= answers the question, "how many flashes affect this pixel")**
- **Accumulated flash radiance**

Illustration on next slide(s)!

Accumulated flashes, status at *t* = 10s



= Events in Flash #1



Event count in the 30 sec buffer (still in LI grid)

		3			2	1		
	1	1			1			
	2							

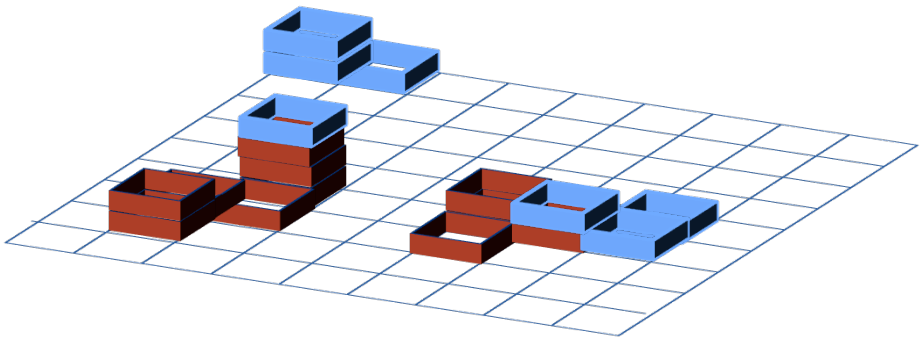
Flash count in the 30 sec buffer (still in LI grid)

		1			1	1		
	1	1			1			
	1							

Accumulated flashes, status at *t* = 20s

= Events in Flash #1

= Events in Flash #2



Event count in the 30 sec buffer (still in LI grid)

2	1							
							1	
		4			2	2	1	
	1	1			1			
	2							

Flash count in the 30 sec buffer (still in LI grid)

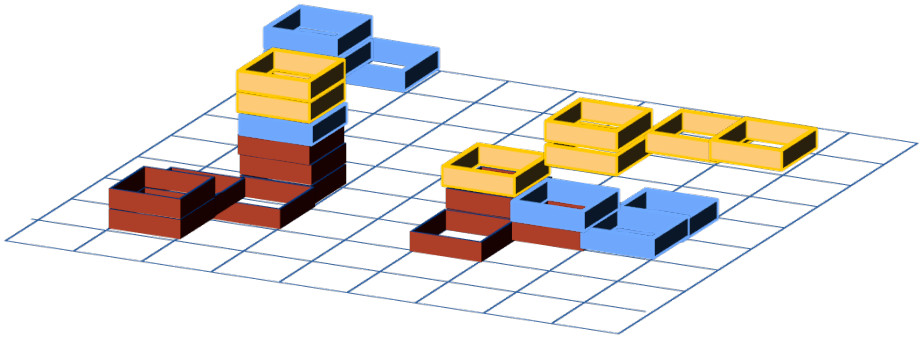
1	1							
							1	
		2			1	2	1	
	1	1			1			
	1							

Accumulated flashes, status at *t* = 29s

= Events in Flash #1

= Events in Flash #2

= Events in Flash #3



Event count in the 30 sec buffer (still in LI grid)

2	1							
						1	1	
					2			
							1	
		6			3	2	1	
	1	1			1			
	2							

Flash count in the 30 sec buffer (still in LI grid)

1	1							
						1	1	
					1			
							1	
		3			2	2	1	
	1	1			1			
	1							

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MTG-LI User Products – Disseminated (3)

Timeliness (goal) is 30 seconds for the L2 products to be disseminated !!

Shared application areas of GLM / MTG LI (1)

- **Clearly some applications listed below are locally better served by ground-based systems, if available.**

- **On the other hand, some applications are better served by a uniform and constant observation from space, or if no good-quality ground based data is available**

Application areas as follows:

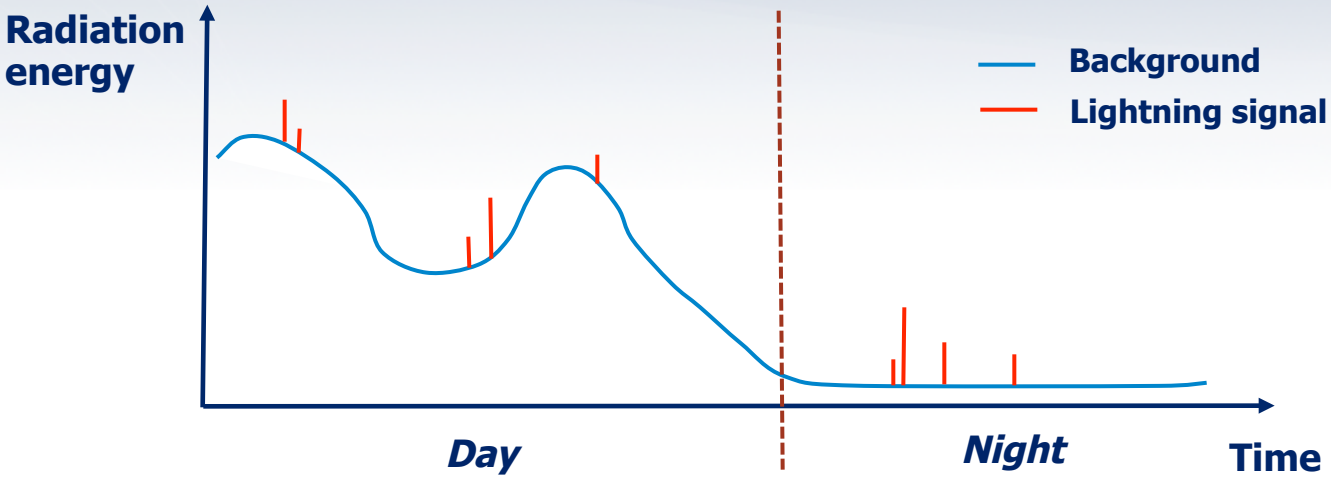
- Predict onset of tornadoes [**GLM specific**], hail, flash floods
  - **Current tornado lead time -13 min national average [in the US]**
- Improve airline/airport safety
  - **routing around thunderstorms, saving fuel, reducing delays**
  - **In-cloud lightning lead time of impending ground strikes, often 10 min or more**

Shared application areas of GLM / MTG LI (2)

- Track thunderstorms, warn of approaching lightning threats
  - **USA: Average fatalities are ~51, Lightning strikes responsible for >500 injuries per year (second leading source after flooding)**
  - **Global: An estimated 24,000 people are killed by lightning strikes around the world each year and about 240,000 are injured**
  - **90% of victims suffer permanent disabilities, long term health problems, chiefly neurological**
- Provide real-time hazard information, improving efficiency of emergency management
  - **Large venue public safety, hazardous material safety, & outdoor/marine warnings, forest fire warnings**
- NWP/Data Assimilation
- Multi-sensor precipitation algorithms
- Climate applications: role of thunderstorms and deep convection in global climate
- Seasonal to interannual (e.g. ENSO) variability of lightning and extreme weather
- Provide new data source to improve air quality / chemistry forecasts (NOx)

Detection of a Lightning Optical Signal

- Lightning with a background signal changing with time:



- Lightning on top of a bright background is not recognised by its bright radiance, but by its transient short pulse character
- For detection of lightning, a variable adapting threshold has to be used for each pixel which takes into account the change in the background radiance
- (in LIS: background calculated as a moving average)

Challenge for processing: “False Events” (noise)

- Noise can be (instrument) internal or external depending on the mechanism

- **“Internal” noise:**
  - Electronic noise
  - Thermo-mechanical noise
  - Stray light noise
  - Ghost noise?

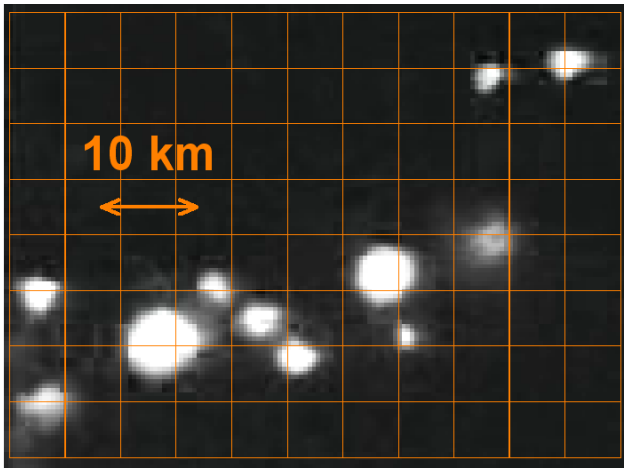
- **“External” noise:**
  - Jitter (spacecraft motion)
  - Cloud radiation (background in general)
  - Sun glint
  - Particles flux

Rough order of severity (based on GLM analysis):

Spacecraft motion, Photon/electronics noise, Sun glint, Radiation

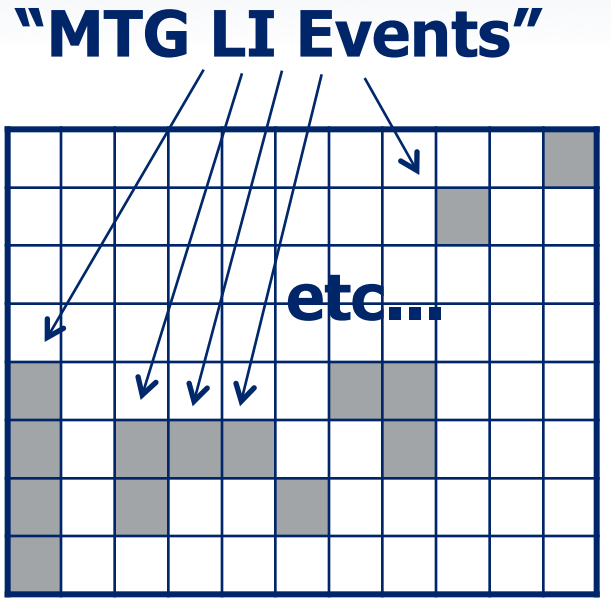
Spatial Pattern of Lightning from Space

- **Characteristics:**
  - Size scales with cloud thickness above source
  - Mean area of lightning pulses corresponds well to a 10 km x 10 km footprint



Optical pattern of lightning on cloud surface (observed from space shuttle)

1. Background scene tracking and removal
2. Thresholding
3. Event detection



Possible schema of detected lightning pulses

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Lightning Imager (LI) Status Update (2)

- MTG LI Phase B2 has been kicked off:
  - beginning of July 2012
- Selex Galileo are preparing for SRR (System Requirements Review):
  - 1st part end of October 2012, 2nd part during spring 2013
- LI instrument PDR (Preliminary Design Review)
  - not before October 2013.

MTG-LI User Products – NOT Disseminated

- There are products resulting from the L1b processing, which are:
  - not disseminated to users
  - ...but are archived

- L1b Events
  - with geolocation, UTC time stamp and calibrated radiance, with a flag indicating false events
- L2 Events
  - As L1b Events, but without false events
- Background images
  - Every 60 seconds all detector elements triggered
  - Mainly used for image navigation
  - Other uses currently TBC

MTG Lightning Imager Science Team (LIST)

- In order to support activities for establishing a scientific baseline for the operational Lightning Imager (LI) L2 processor, a MTG LI Science Team was set up in 2009.
- The main objectives of this (external) team is to:
  - **Support EUMETSAT in the implementation of the MTG LI L2 processor.**
  - **Prepare and update the *Algorithm Theoretical Basis Document* (ATBD).**
  - **Also guidance in issues related to L1b are to be expected (especially regarding false event filtering)**
- ATBD:
  - **V1** was reviewed at the Preliminary Design Review (PDR) concluding the MTG system Phase B activities in May-June 2011
  - **V2** to be released in early 2013

MTG Lightning Imager Science Team (LIST)

- **The MTG LI Science Team, led by EUMETSAT, currently consists of the following members:**
  - **Graeme Anderson (MetOffice – United Kingdom)**
  - **Daniele Biron (USAM – Italy)**
  - **Eric Defer (LERMA – France)**
  - **Ullrich Finke (U. Hannover – Germany)**
  - **Hartmut Höller (DLR – Germany)**
  - **Philippe Lopez (ECMWF)**
  - **Douglas Mach (NASA – USA)**
  - **Antti Mäkelä (FMI – Finland)**
  - **Dieter Poelman (RMI – Belgium)**
  - **Serge Soula (Laboratoire d'Aerologie – France)**
- **In addition, invited experts are contributing to individual meetings.**

Pseudo-GLM as a GOES-R initiative for user readiness (1)

- NOAA has a wider "GOES-R Proving Ground" framework of activities, covering all GOES-R missions
- Within this framework, a straightforward approach of creating "pseudo-GLM" data based on averaging and resampling LMA lightning density data has been developed:

http://weather.msfc.nasa.gov/sport/goesrpg/pglm.html

http://www.goes-r.gov/downloads/2012-GLM/day2/SPC-pg.pdf

- This **pseudo-GLM (PGLM)** data is provided to forecasters (every 2 min with a 3-4 min latency) to support their daily work.
- The data has been demonstrated to users in various occasions, such as the "Hazardous Weather Testbed"

Pseudo-GLM as a GOES-R initiative for user readiness (2)

- The idea has been to make the forecaster end-user aware of and used to the kind of product that would be available from the GLM.
- The pseudo-GLM data is not "proxy" in a sense that it could imitate the optical signal of lightning very closely
- Good training material (webinar) available online:

http://weather.msfc.nasa.gov/sport/training/

- A similar activity but using the existing proxy data methodology with the ground-based LINET data in Europe is planned
  - **A near-real time application of the proxy data will be needed**
  - **With real proxy data, we could aim closer to realistic LI observation characteristics**

Lightning Imager (LI) Status Update (1)

- The MTG satellite PDR (Preliminary Design Review) was held in May 2012.
    - The LI instrument was not part of this review, only MTG-LI interface requirement documents were reviewed.

- LI industrial consortium consolidated via ITT, concluded by April 2012.
- LI instrument prime contractor is Selex Galileo in Italy.
- LI mission prime activities are still to be allocated.
    - This includes the 0-1b data processing software.
    - These activities will most likely be allocated to either Thales (MTG prime contractor) or to Selex Galileo (TBC).

Next steps

- Define in more detail the requirements for the NRT-LI proxy data
  - **Coverage, periodicity, timeliness, grid…**
- Establish contacts to **operational forecasters** within/through:
  - **National Met Services**
  - **Other forums (ESSL Testbed, ATM, …)**
- Define concrete steps for establishing a trial based on NRT-LI proxy data