Meteosat Third Generation (MTG) with focus on the Lightning Imager (MTG-LI) Status and Activities

Jochen Grandell, Marcel Dobber, Rolf Stuhlmann

GLM Science Team
19-20 September 2011
Huntsville, Alabama

Short Introduction to the MTG Programme

MTG-I; 4 satellites

MTG-S; 2 satellites

Courtesy of ThalesAlenia Space
A Thales / Finmeccanica Company

EUM/MTG/VWG/11/0515
September 2011
GLM Science Team, Huntsville

EUMETSAT

MTG to Secure Continuity and Evolution of EUMETSAT Services

1977 — 2002 — 2017 and 2019

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-ton

Atmospheric Chemistry Mission (UVN-S4): via GMES Sentinel 4

Implementation of the EUMETSAT Mandate for the Geostationary Programme

MTG - Five Missions to Satisfy User Needs

- Full Disk High Spectral resolution Imagery (FDHSI), global scales (Full Disk) over a BRC = 10 min, with 16 channels at spatial resolution of 1 km (8 solar channels) and 2 km (8 thermal channels)

- High spatial Resolution Fast Imagery (HRFI), local scales (1/4th of Full Disk) over a BRC = 2.5 min with 4 channels at high spatial resolution 0.5 km (2 solar channels), and 1.0 km (2 thermal channels)

- InfraRed Sounding (IRS), global scales (Full Disk) over a BRC = 60 min at spatial resolution of 4 km, providing hyperspectral soundings at 0.625 cm^{-1} sampling in two bands: Long-Wave-IR (LWIR: 700 – 1210 cm^{-1} ~ 820 spectral samples)
  Mid-Wave-IR (MWIR: 1600 – 2175 cm^{-1} ~ 920 spectral sample)

- Lightning Imagery (LI), global scales (80% of Full Disk) detecting and mapping continuously the optical emission of cloud-to-cloud and cloud-ground discharges. Detection efficiency between DE=90% (night) and DE=40% (overhead sun)

- UVN Sounding, implemented as GMES Sentinel 4 Instruments provided by ESA

MTG Implementing Arrangements EUMETSAT - ESA Programmes

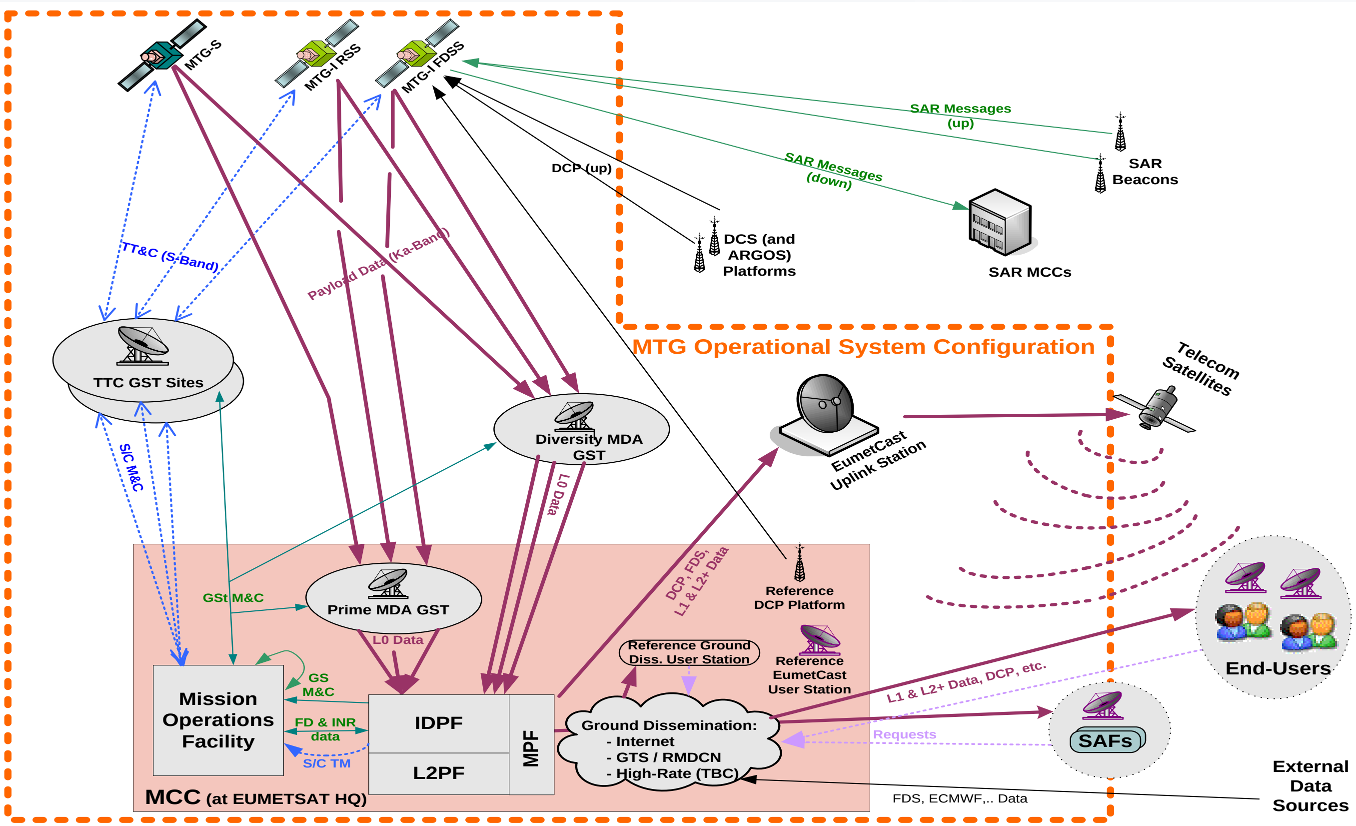
MTG implemented as result of EUMETSAT and ESA Programmes:

- ESA develops the MTG-I and MTG-S protoflight satellites as part of the ESA MTG Programme.
  - Space segment requirements established by ESA, in agreement with EUMETSAT. Fixed financial contribution by EUMETSAT to the ESA Programme.

- Scope of the EUMETSAT MTG Programme encompasses:
  - Overall system and interface to the Users
  - Procurement via ESA of the four recurrent satellites and fixed financial contribution to the ESA MTG Programme;
  - Launch and LEOP services for all six MTG satellites;
  - Establishment of the MTG Ground Segment to support the in orbit operations;
  - At least twenty years of routine operations of the imagery mission, and fifteen and half years of routine operations of the sounding mission;
  - SAFs: Ten years of continuous development and operations (CDOP).

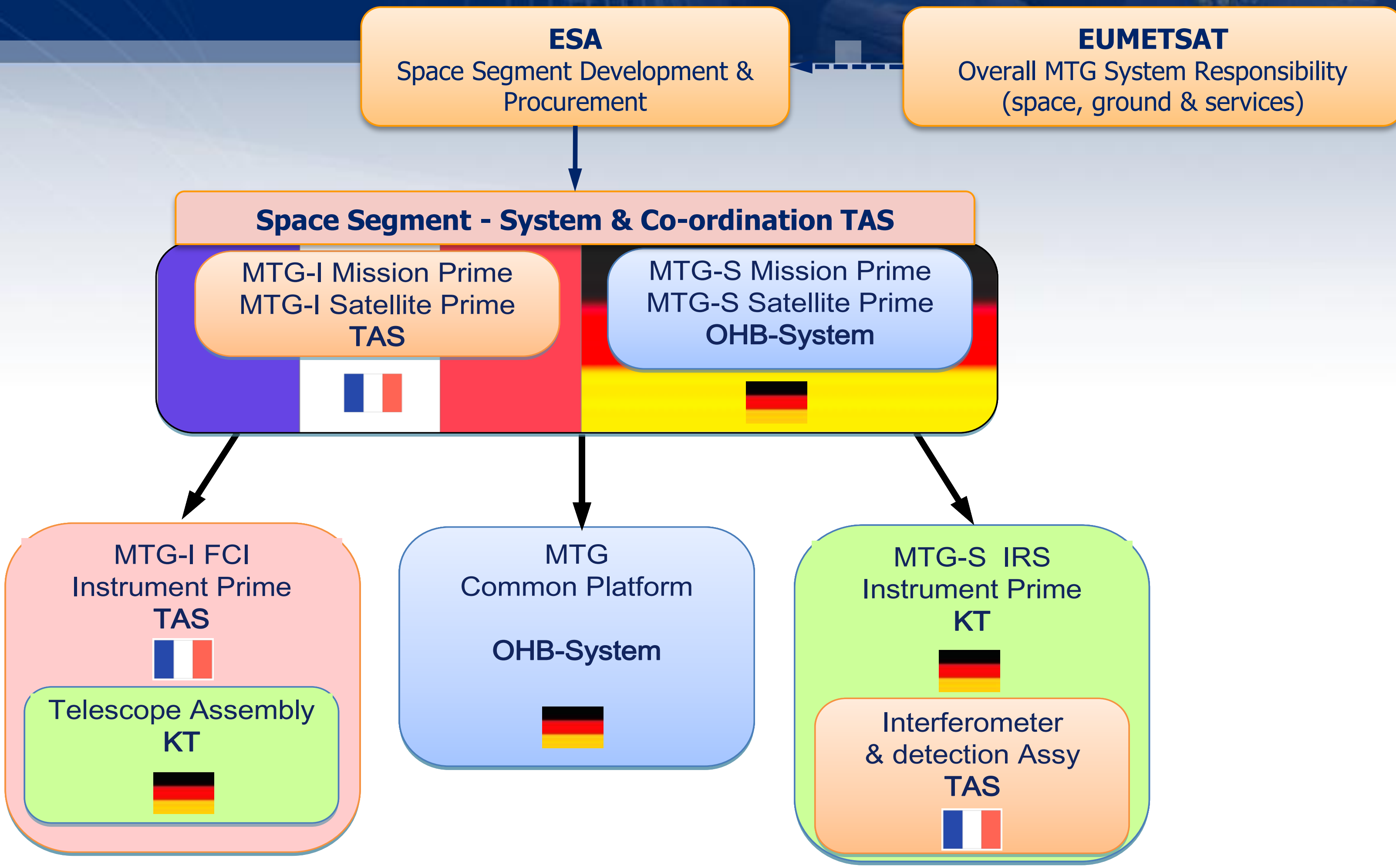
System Engineering Status - Phase C0

- The System Requirement Review Part 2 (SRR-2) took place end of 2010 baselining the MTG System Requirement Document.
- The MTG System Preliminary Design Review (PDR) took place from May (release of documents) to end of June 2011 (Collocation, Board and Steering Committee meetings) and included a System-, a Ground Segment- and a Science Panel.



EUMETSAT

Space Segment Status - Phase B2



+ other MTG-I Payloads:

- ***Lightning Imager (LI) Mission Role AST-F;***
- *Search & Rescue (GEOSAR)*
- *Data Collection Service (DCS)*

+ other MTG-S Payload:

- *Sentinel 4 (UVN) - CFI*

Space Segment Status - Phase B2

- Technical aspects for starting Space Segment Phase B2 activities including the development of the Flexible Combined Imager (FCI) and the InfraRed Sounder (IRS)* were negotiated in summer 2010.
- The related Space Segment activities of Phase B2 were kicked off with ThalesAlenia Space (TAS)* as overall prime on 18 November 2010
- The Space Segment System Requirement Review (SRR)* took place between February and April 2011. Majority of residual open items will be closed out by November 2011 with a Baseline Definition Review (BDR)*.
- The Space Segment Preliminary Design Review (PDR)* closing Phase B2 is scheduled for 2nd Quarter 2012, after the PDRs of Platform, FCI and IRS.

(* Lightning Imager (LI) is on separate schedules – for LI see next slide)

Status: Lightning Imager (LI) – Phase A

- Currently no consolidated LI instrument design, because the instrument is among the items still to be procured in competition; (40% of MTG development procured via Best Practice)

  (Astrium Toulouse (ASF) and TAS are performing phase-A trade-off studies)
- ITT released begin October 2011.
- Interested parties will get 8 weeks to respond to the ITT (proposals expected December 2011)
- Proposal evaluation by ESA/EUMETSAT until end December 2011.
- Consolidated LI industrial consortium by end of 2011 – LI PDR expected 2013.

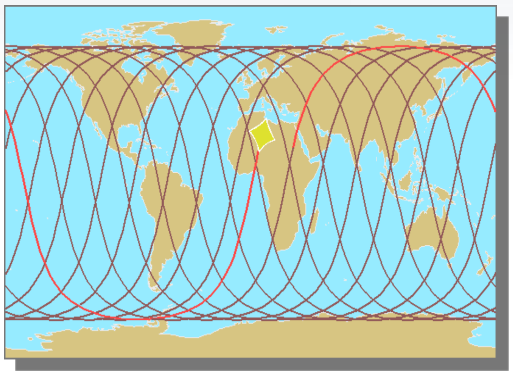
LI main characteristics:

- Coverage about equal to visible disc (instantaneous view).
- Continuous measurements of triggered events / lightning triggered events.
- Continuous measurements of background images, typically one every minute.
- Data rate <30 Mbps; Mass < 70Kg; Power < 320W.
- Ground pixel size required < 10 km at 45 degrees latitude
- Measurements at 777.4 nm with 1.0-1.5 nm spectral bandpass filter.

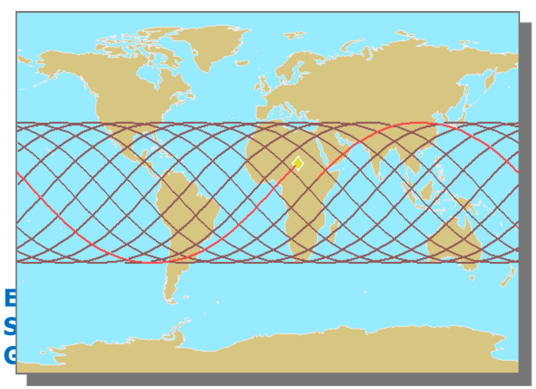
MTG-LI Capitalises on US Activities on Lightning Detection from Space

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)

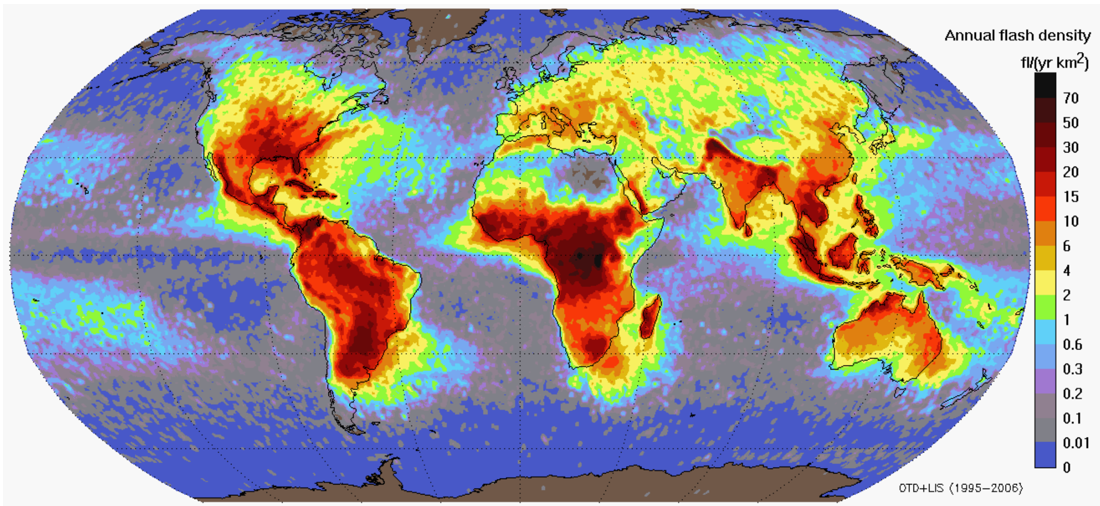


LIS (1997-present)



Results from LIS/OTD: Global lightning distribution

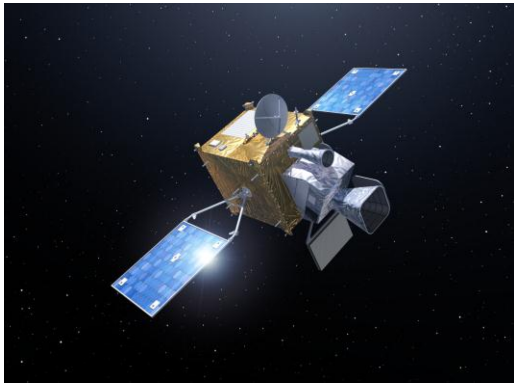
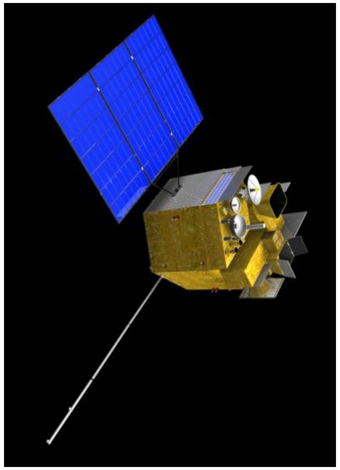
Annual flash density



EUMETSAT

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)	Lightning Imager (LI) on MTG (Europe)	Geostationary Lightning Imager (GLI) on FY-4 (China)
		
2015 ⇒	2018 ⇒	2014 ?

MTG-LI – Requirements and Objectives

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

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

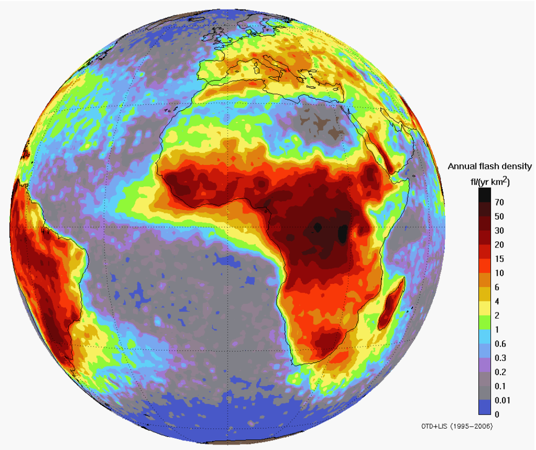
Main objectives are:

detect, monitor, track and extrapolate in time

- **Development (Intensity/Location) of active convective areas**
- **Monitoring of storm lifecycle**

As well as...

- **Lightning climatology**
- **Chemistry (NOx production)**



LIS/OTD flash density in the MTG LI field of view

EUMETSAT

MTG LI – Main Mission Requirements

- **Wavelength**
  - 777.4 nm
- **Sensitivity**
  - pulses as small as 100 km^2 with energies down to 4 $\mu J/(m^2 sr)$ should be detected
- **Spatial sampling**
  - Less or equal to 10 km at 45ºN for the sub-satellite longitude
- **Detection Efficiency**
  - 70% in average, 90% over central Europe, 40% as a minimum over EUMETSAT member states
- **False Alarm Rate**
  - 2.5 false flashes/s
- **Background images**
  - every 60 seconds

EUMETSAT

MTG LI Events: L0 -> L1b processing

- Detection of events in a nutshell:

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

- Output (=events) of the Lightning Imager at L0 is two-fold:

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

→ **False event filtering needed in L0 -> L1b processing**

Challenge for L1b processing: "False Events"

- False events are typically caused by:
  - High energy particle collisions
  - Noise (instrument, spacecraft etc)
  - Solar glint
  - Spacecraft motion ("jitter")

- Specific filters are required for each case:

→ Radiation filter

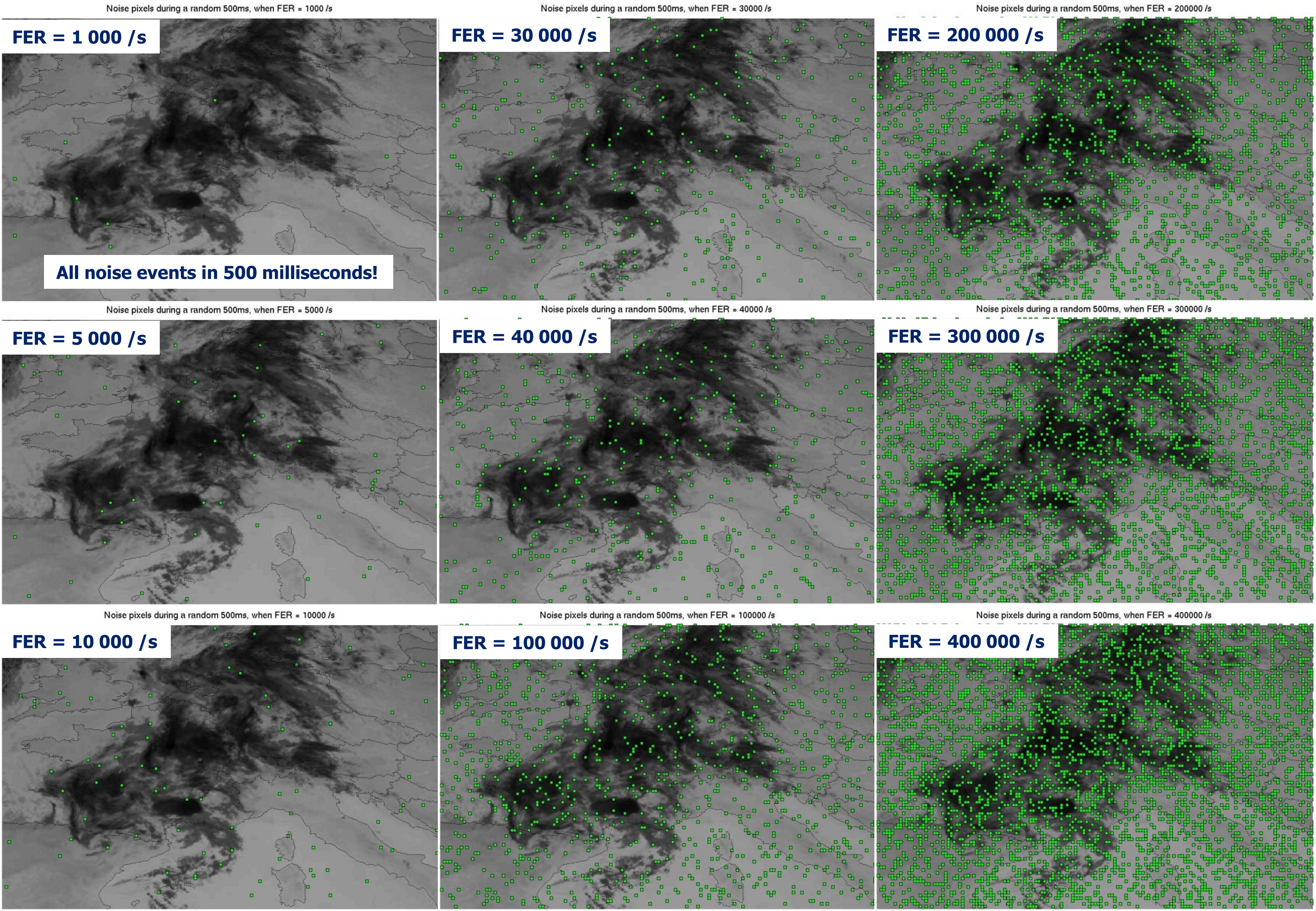
→ Shot noise/coherency filter

→ Solar glint filter

→ Contrast filter

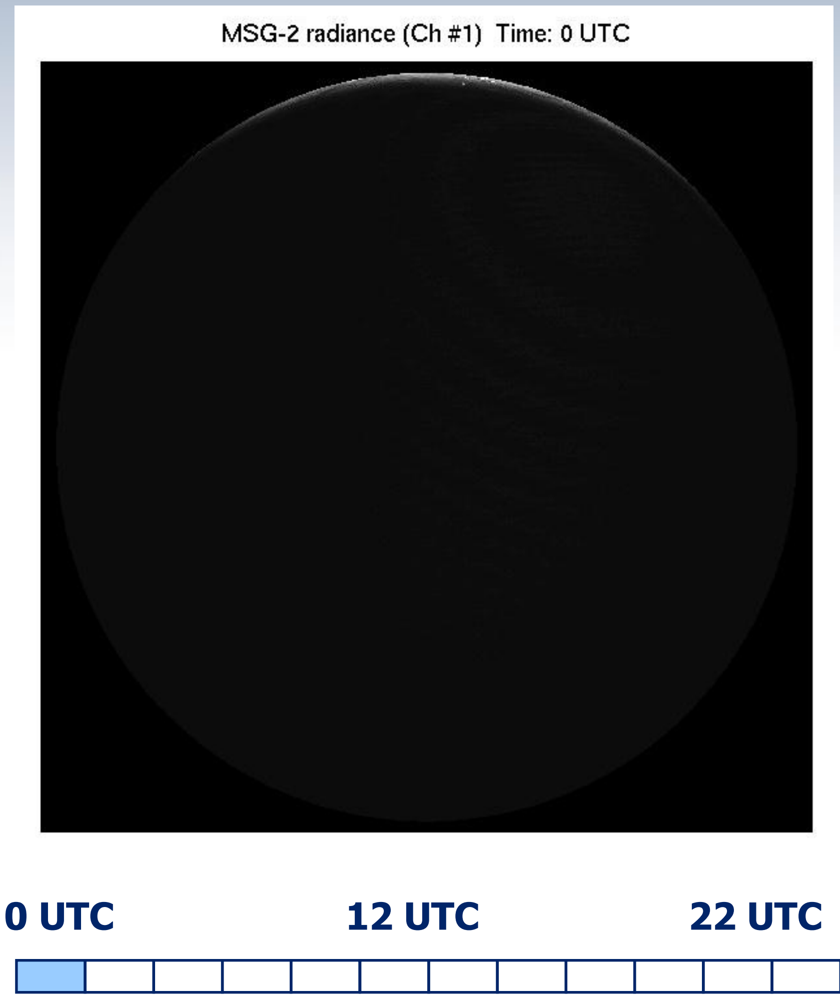
Rough order of severity (based on GLM analysis):

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


Noise pixels during a random 500ms, when FER = 1000 /s
FER = 1 000 /s
All noise events in 500 milliseconds!
Noise pixels during a random 500ms, when FER = 30000 /s
FER = 30 000 /s
Noise pixels during a random 500ms, when FER = 200000 /s
FER = 200 000 /s
Noise pixels during a random 500ms, when FER = 5000 /s
FER = 5 000 /s
Noise pixels during a random 500ms, when FER = 40000 /s
FER = 40 000 /s
Noise pixels during a random 500ms, when FER = 300000 /s
FER = 300 000 /s
Noise pixels during a random 500ms, when FER = 10000 /s
FER = 10 000 /s
Noise pixels during a random 500ms, when FER = 100000 /s
FER = 100 000 /s
Noise pixels during a random 500ms, when FER = 400000 /s
FER = 400 000 /s

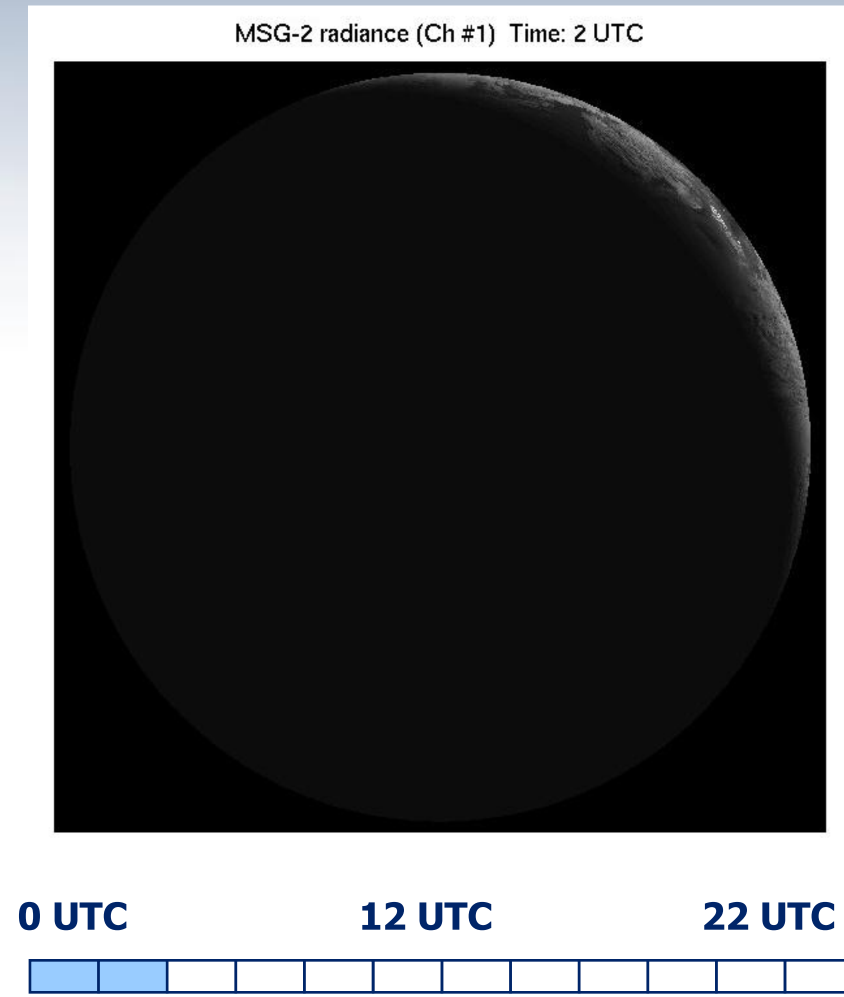
Background radiance: Solar reflection on clouds and ground surfaces

- Background radiation from clouds determines the signal to noise ratio for detection of transient lightning signals
- Challenges:
  - **Day-night contrast in FOV**
  - **Microvibrations (fast changing background)**
  - **Sun glint**



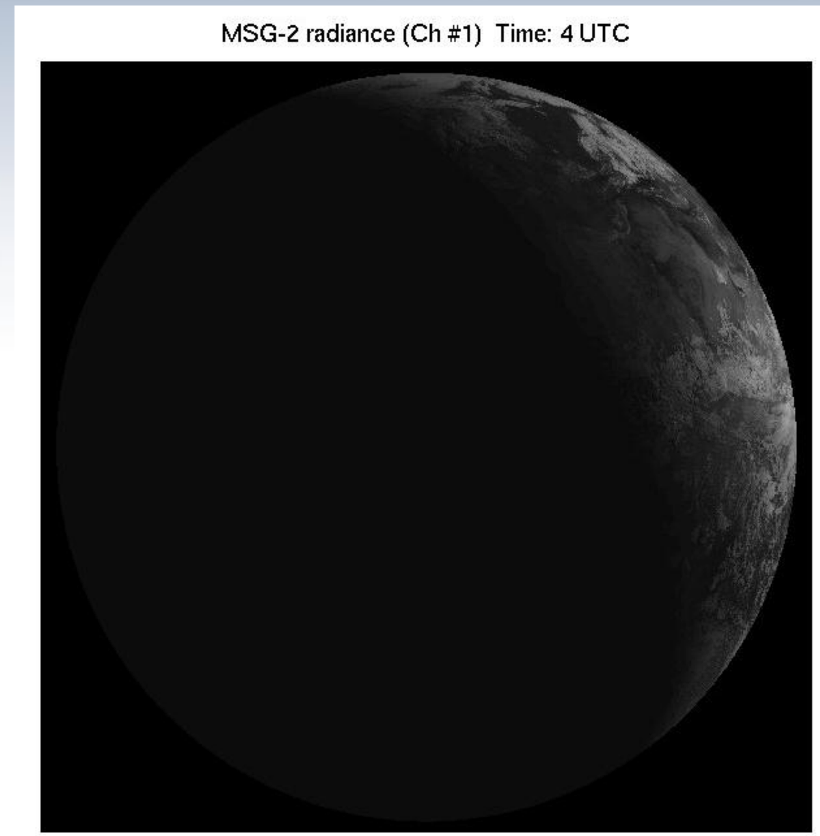
Background radiance: Solar reflection on clouds and ground surfaces

- Background radiation from clouds determines the signal to noise ratio for detection of transient lightning signals
- Challenges:
  - **Day-night contrast in FOV**
  - **Microvibrations (fast changing background)**
  - **Sun glint**



Background radiance: Solar reflection on clouds and ground surfaces

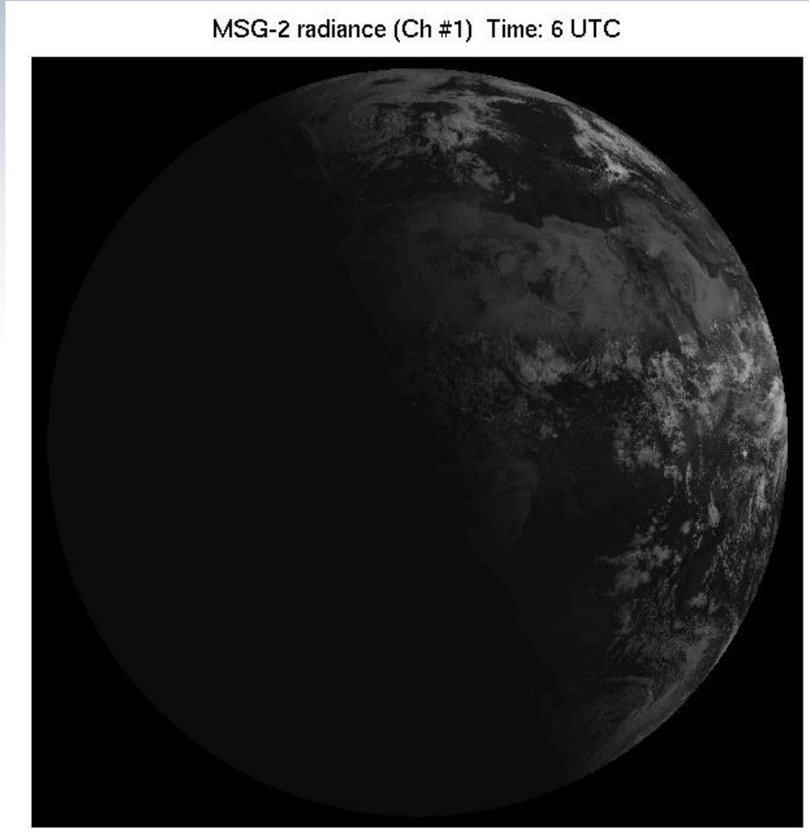
- Background radiation from clouds determines the signal to noise ratio for detection of transient lightning signals
- Challenges:
  - **Day-night contrast in FOV**
  - **Microvibrations (fast changing background)**
  - **Sun glint**



0 UTC **12 UTC** **22 UTC**

Background radiance: Solar reflection on clouds and ground surfaces

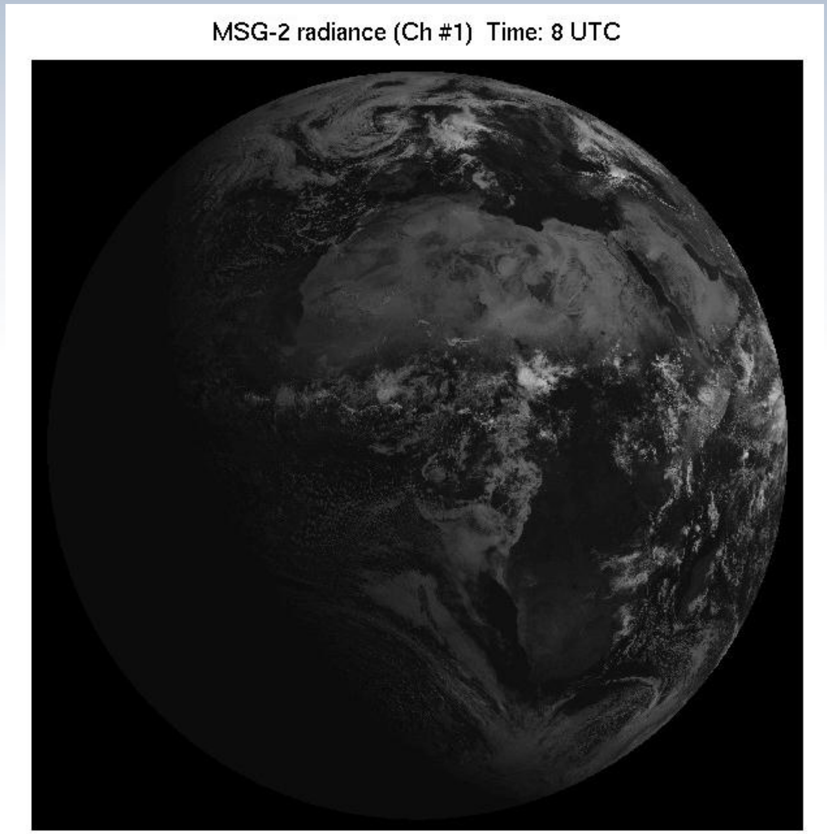
- Background radiation from clouds determines the signal to noise ratio for detection of transient lightning signals
- Challenges:
  - **Day-night contrast in FOV**
  - **Microvibrations (fast changing background)**
  - **Sun glint**



0 UTC **12 UTC** **22 UTC**

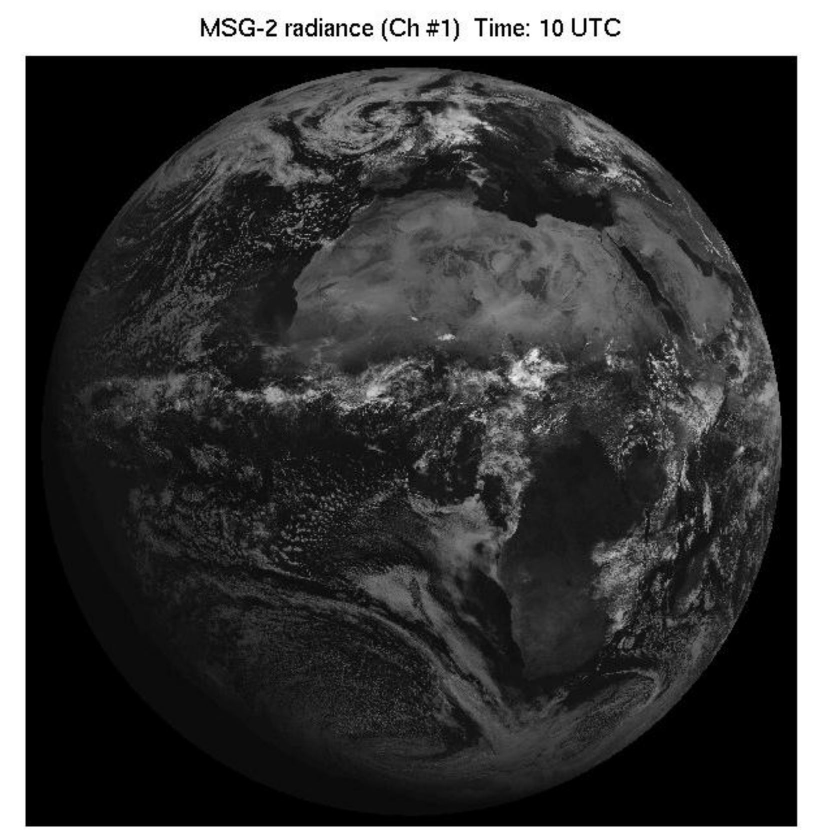
Background radiance: Solar reflection on clouds and ground surfaces

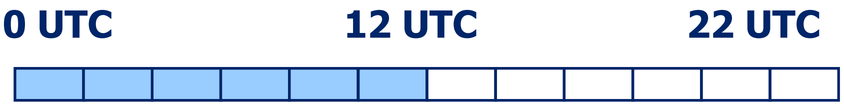
- Background radiation from clouds determines the signal to noise ratio for detection of transient lightning signals
- Challenges:
  - **Day-night contrast in FOV**
  - **Microvibrations (fast changing background)**
  - **Sun glint**



Background radiance: Solar reflection on clouds and ground surfaces

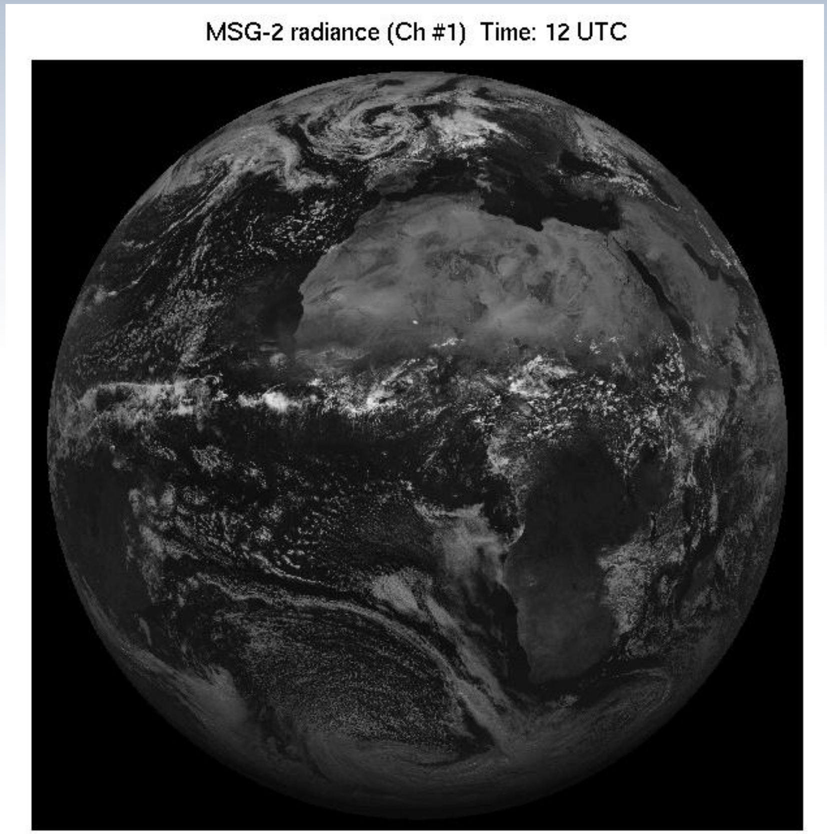
- Background radiation from clouds determines the signal to noise ratio for detection of transient lightning signals
- Challenges:
  - **Day-night contrast in FOV**
  - **Microvibrations (fast changing background)**
  - **Sun glint**





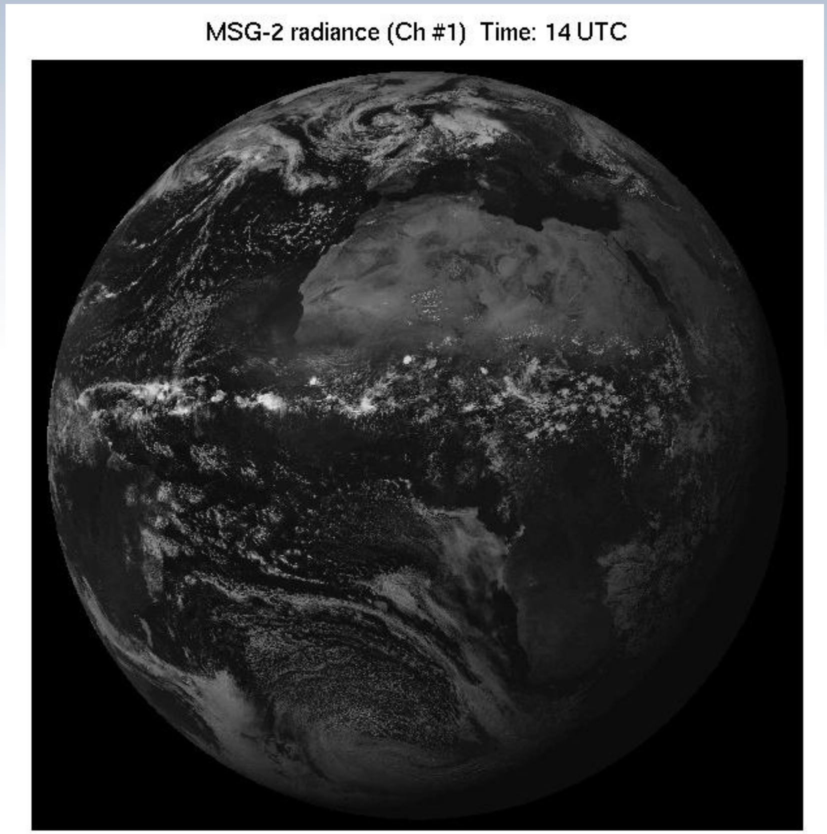
Background radiance: Solar reflection on clouds and ground surfaces

- Background radiation from clouds determines the signal to noise ratio for detection of transient lightning signals
- Challenges:
  - **Day-night contrast in FOV**
  - **Microvibrations (fast changing background)**
  - **Sun glint**



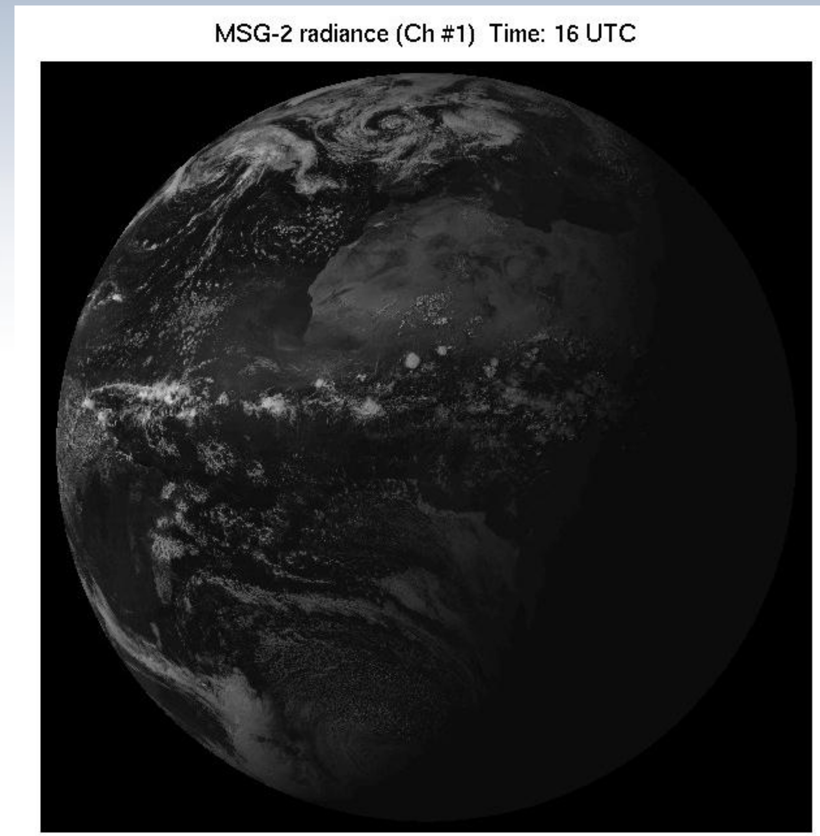
Background radiance: Solar reflection on clouds and ground surfaces

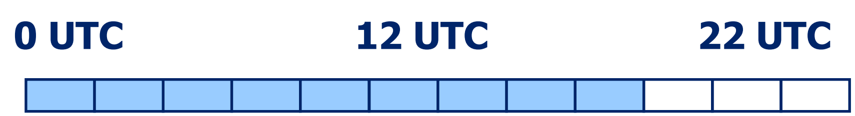
- Background radiation from clouds determines the signal to noise ratio for detection of transient lightning signals
- Challenges:
  - **Day-night contrast in FOV**
  - **Microvibrations (fast changing background)**
  - **Sun glint**



Background radiance: Solar reflection on clouds and ground surfaces

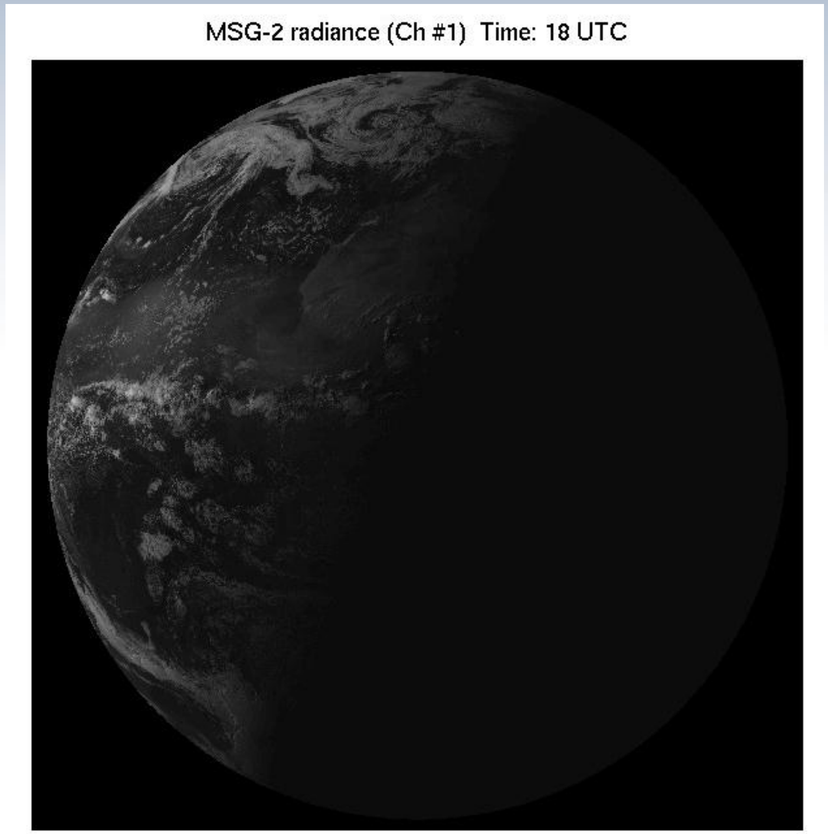
- Background radiation from clouds determines the signal to noise ratio for detection of transient lightning signals
- Challenges:
  - **Day-night contrast in FOV**
  - **Microvibrations (fast changing background)**
  - **Sun glint**





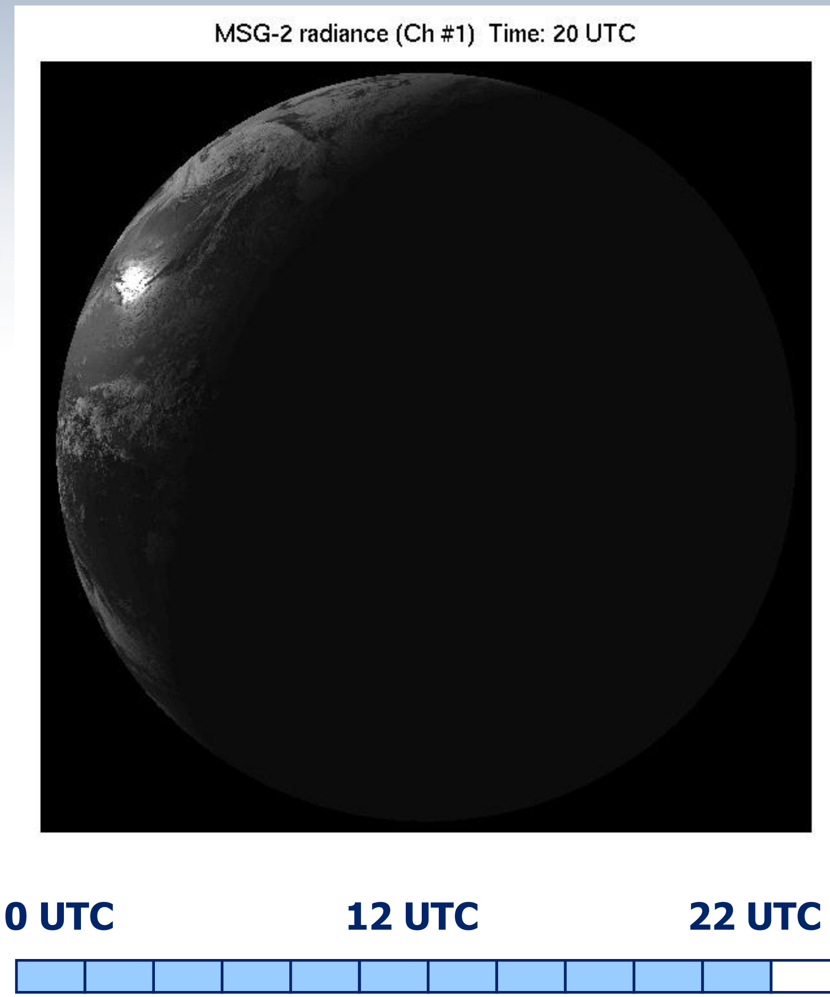
Background radiance: Solar reflection on clouds and ground surfaces

- Background radiation from clouds determines the signal to noise ratio for detection of transient lightning signals
- Challenges:
  - **Day-night contrast in FOV**
  - **Microvibrations (fast changing background)**
  - **Sun glint**



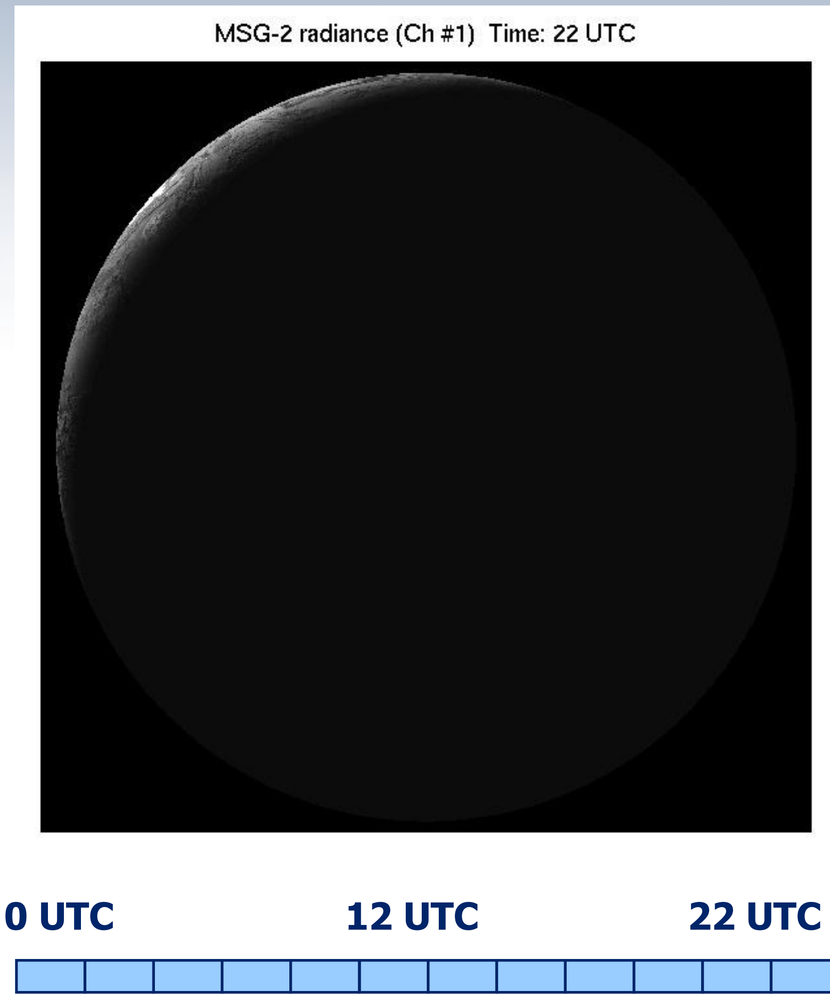
Background radiance: Solar reflection on clouds and ground surfaces

- Background radiation from clouds determines the signal to noise ratio for detection of transient lightning signals
- Challenges:
  - **Day-night contrast in FOV**
  - **Microvibrations (fast changing background)**
  - **Sun glint**



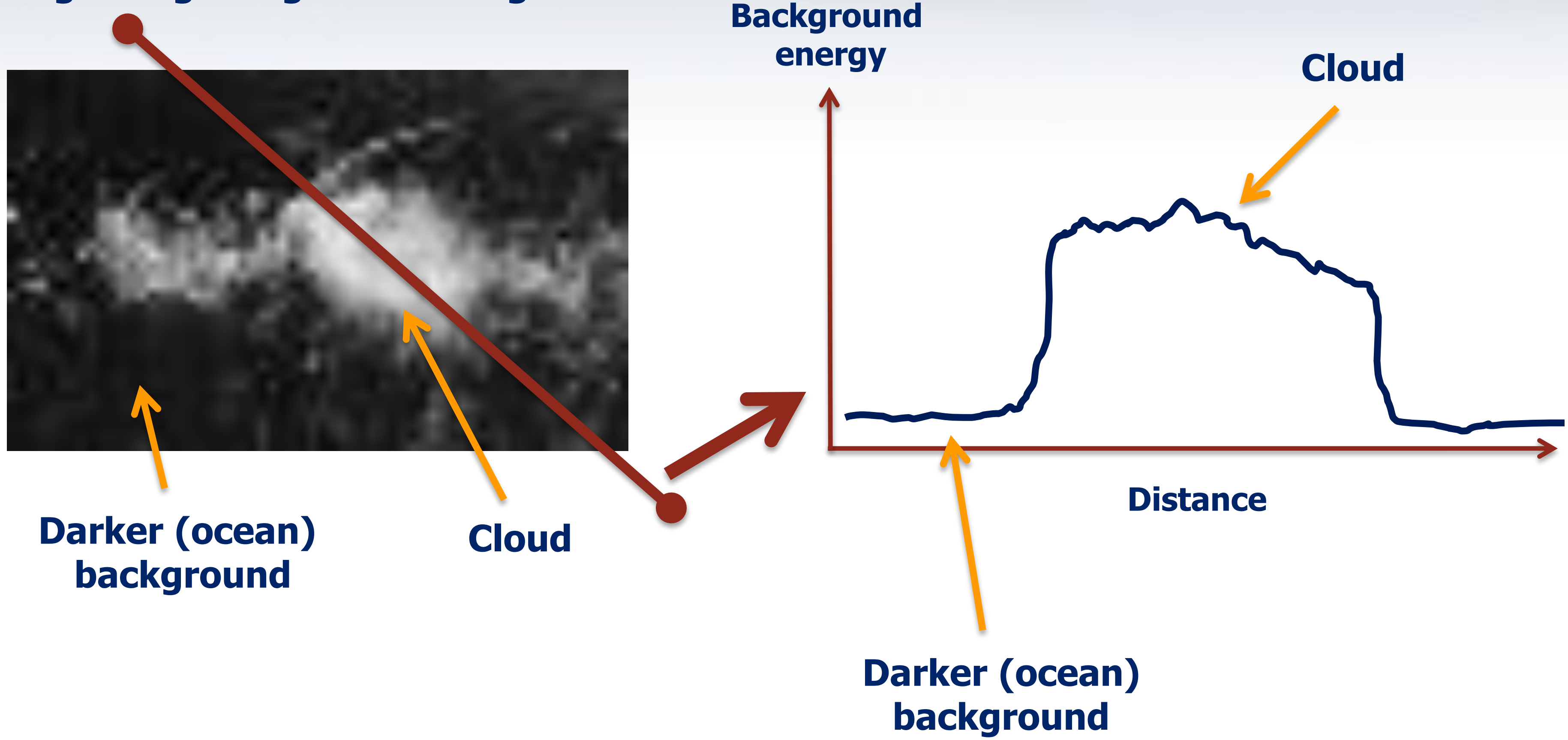
Background radiance: Solar reflection on clouds and ground surfaces

- Background radiation from clouds determines the signal to noise ratio for detection of transient lightning signals
- Challenges:
  - **Day-night contrast in FOV**
  - **Microvibrations (fast changing background)**
  - **Sun glint**



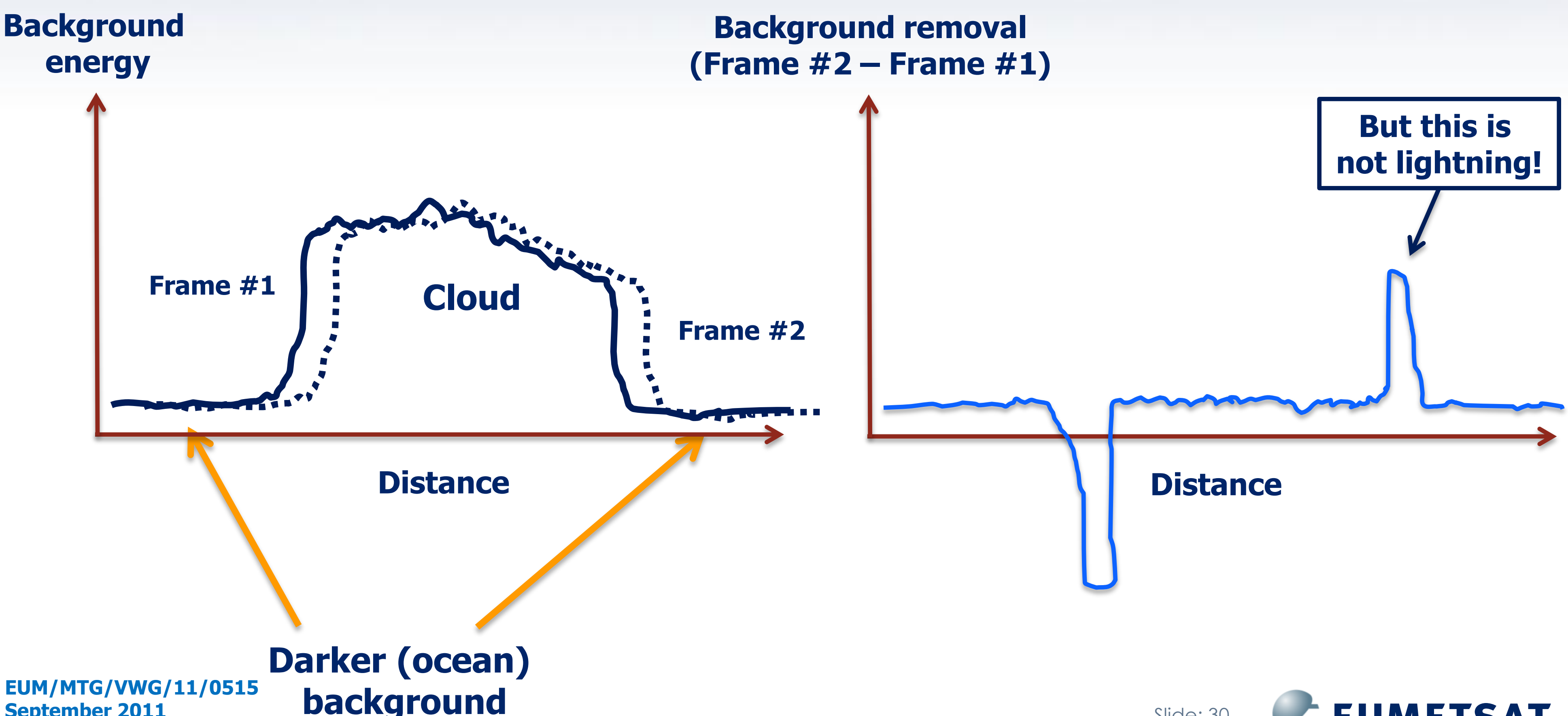
Effect of Microvibrations ("jitter") on Lightning Detection

Assuming that this is what the Lightning Imager is looking at…



Microvibrations ("jitter") – False Events

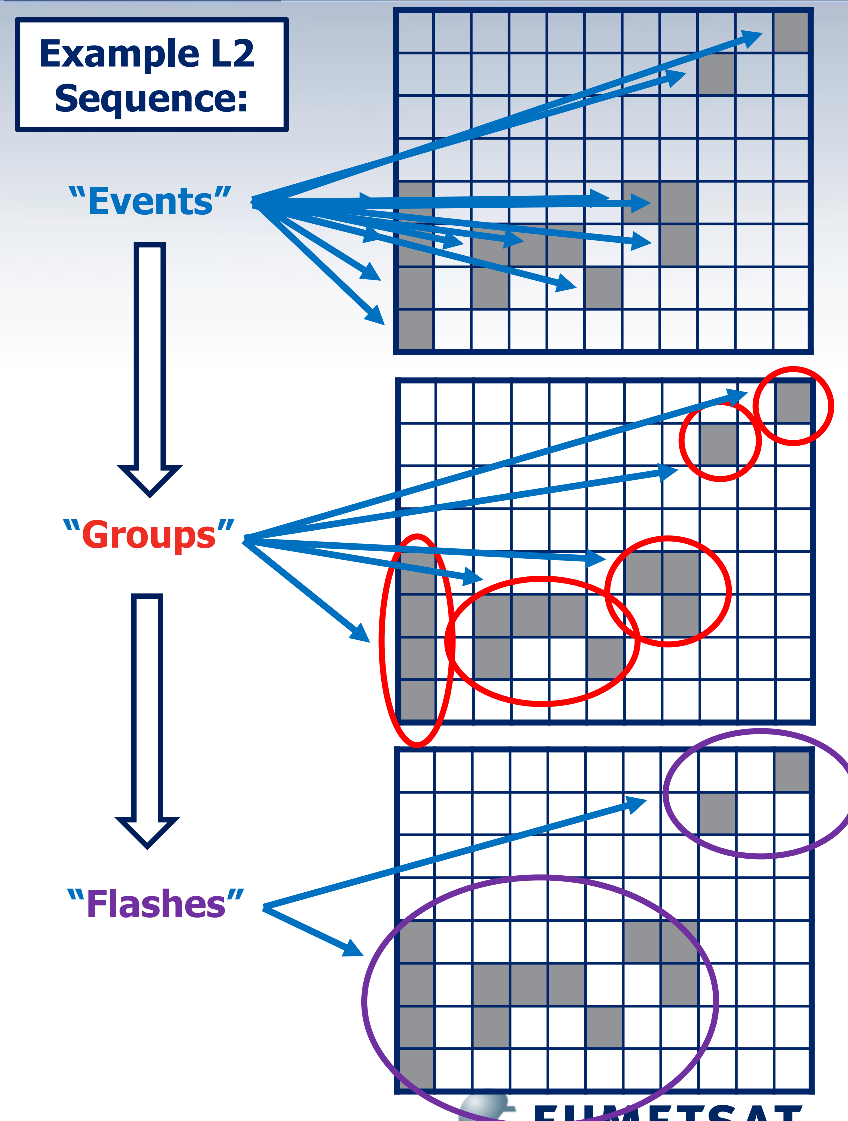
What if the instrument (satellite) moves slightly between integration frames...?



MTG-LI Products: L1b -> L2 processing

- The following products are resulting from the **L1b processing:**
  - Events with geolocation, UTC time stamp and calibrated radiance
  - background images, supporting navigation, quality asessment

- The **baseline L2 product**, as result of clustering of events in time and space:
  - Groups (representing lightning strokes)
  - Flashes (main product for most users)
  - Events quality indicator added

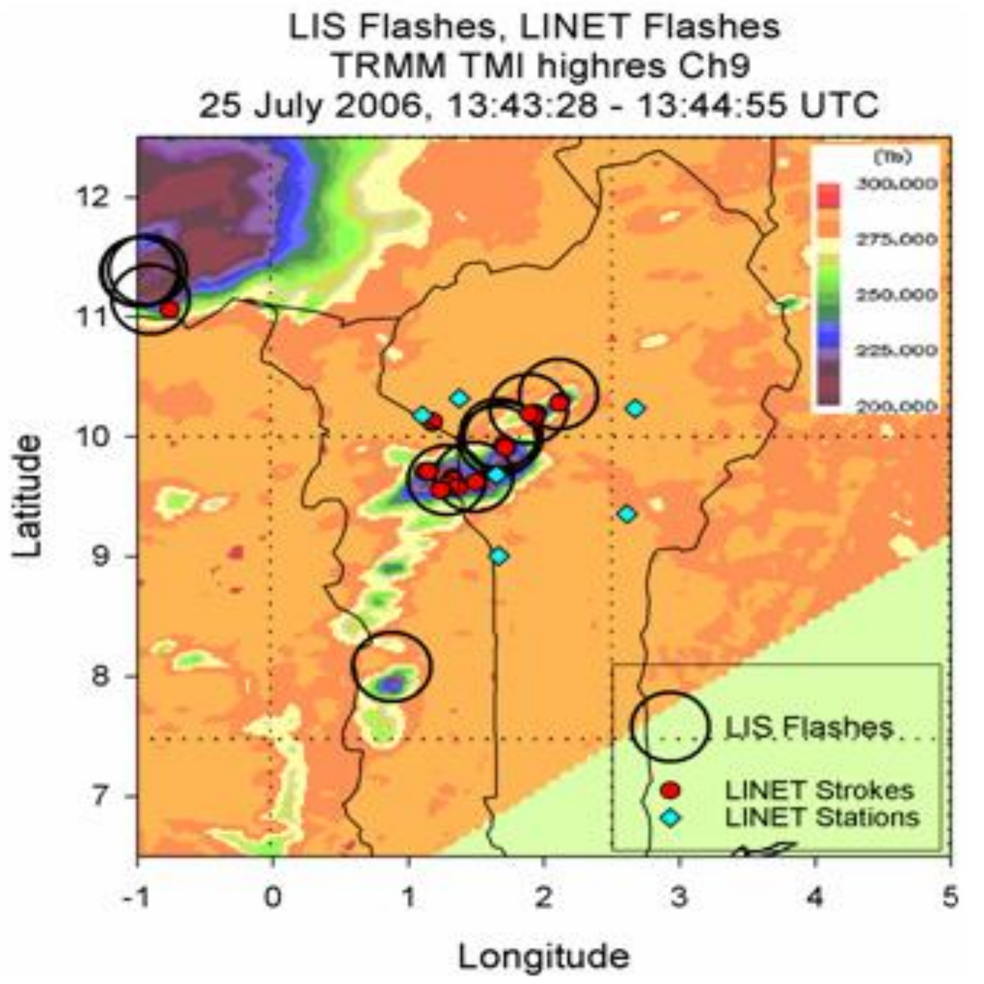


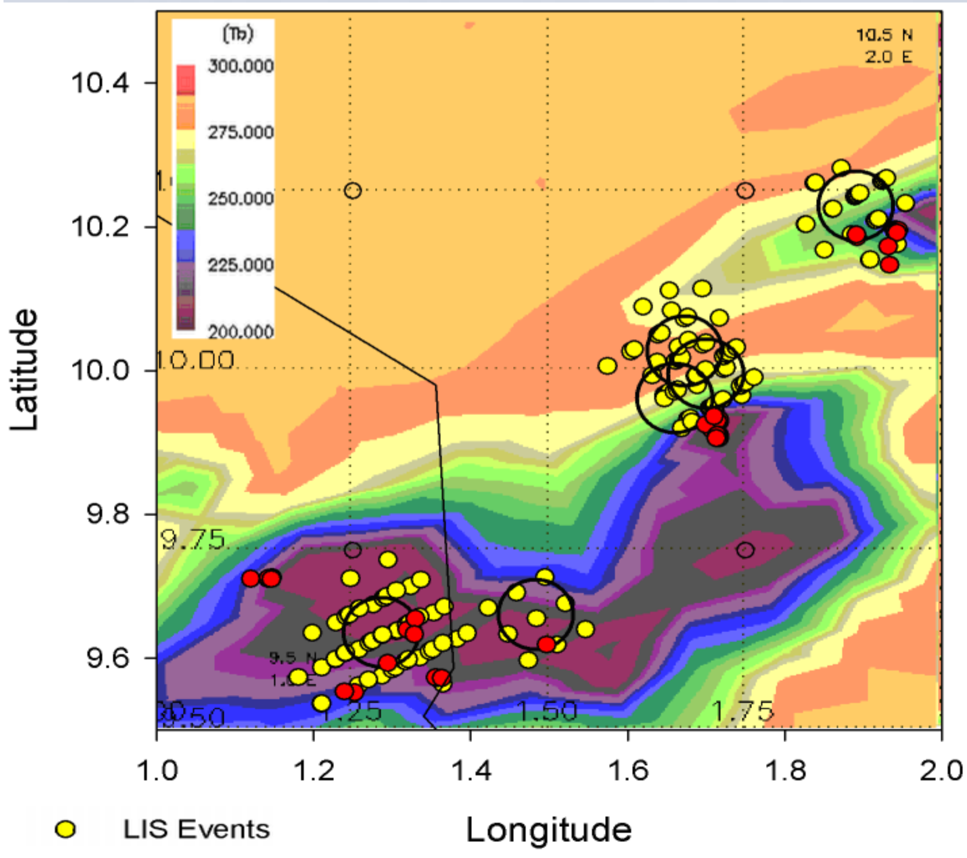
EUMETSAT

MTG Lightning Imager Science Team (LIST)

- The MTG LI Science Team currently consists of the following members:
  - Alec Bennett (MetOffice – UK)
  - 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)
  - Serge Soula (Laboratoire d'Aerologie – France)
- In addition, invited experts contributing in individual meetings.

LIProxy -> LIS-LINET Transfer Function: Comparison 25 July 2006



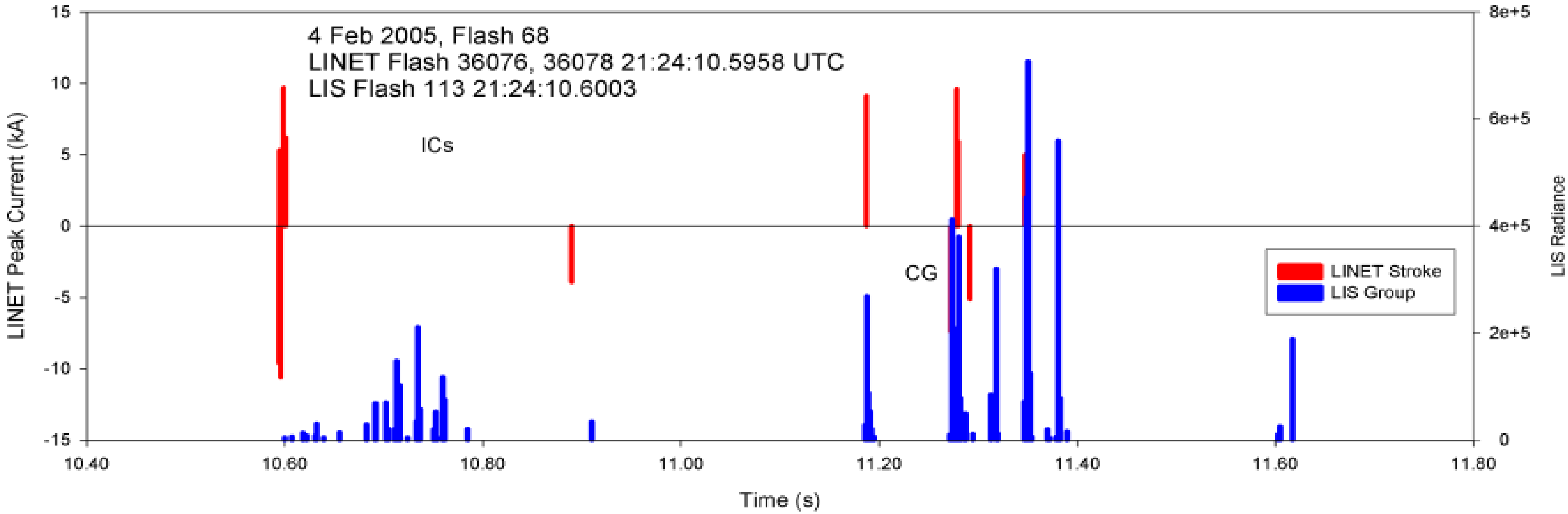


EUM/MTG/VWG/11/0515
September 2011
GLM Science Team, Huntsville

EUMETSAT

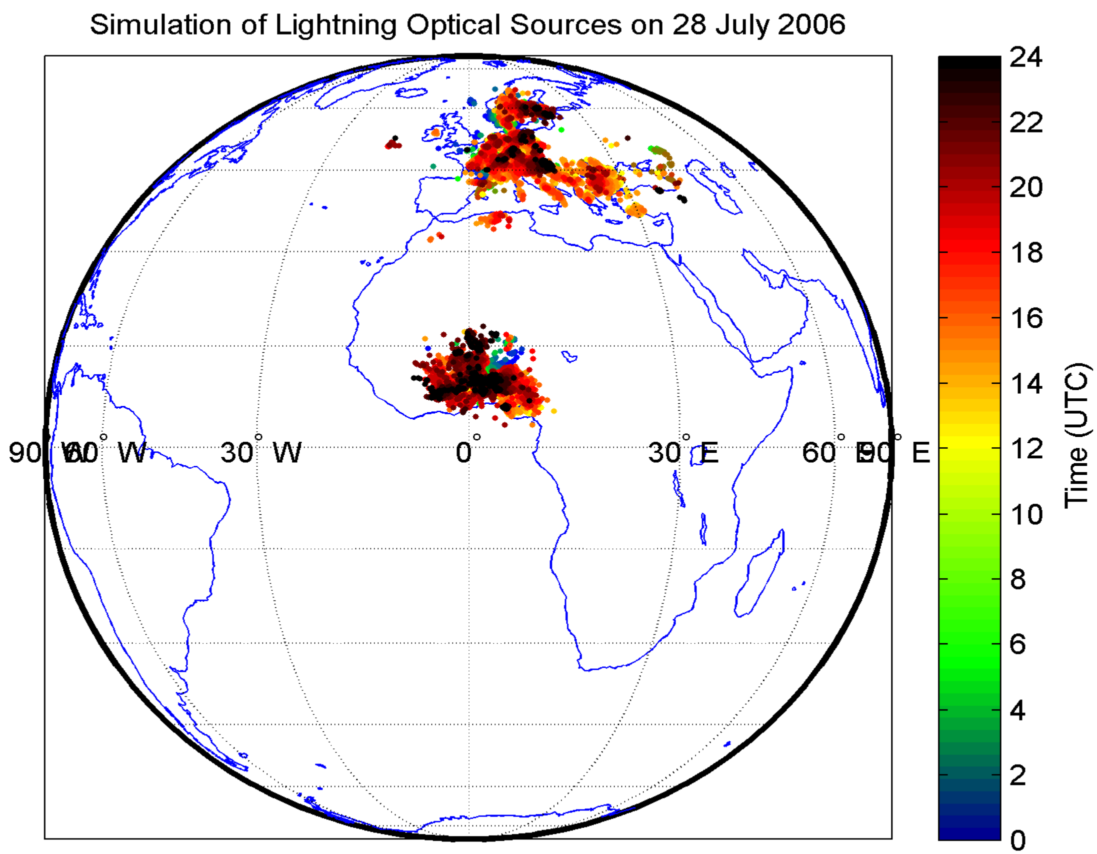
LIProxy -> LIS-LINET Transfer Function:
Inter stroke activity Large variability

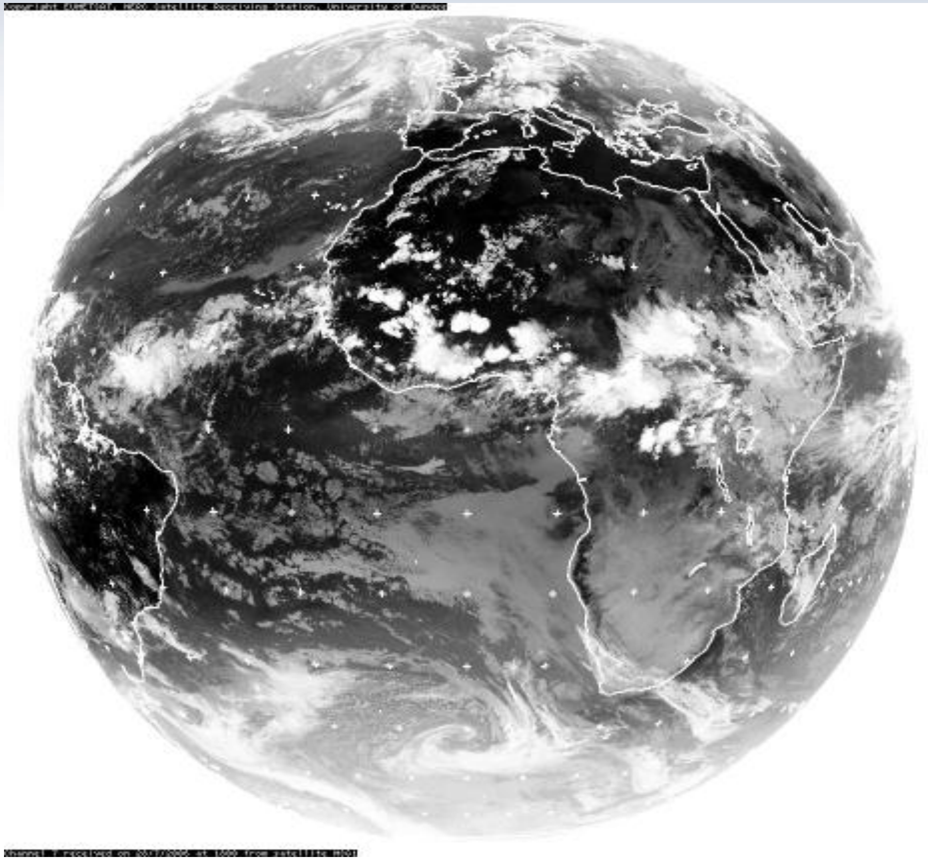
The inter-stroke optical activity is of a much more irregular nature, thus statistical representation will be adequate (post-stroke and pre-stroke predominantly optical or sometimes RF activity)



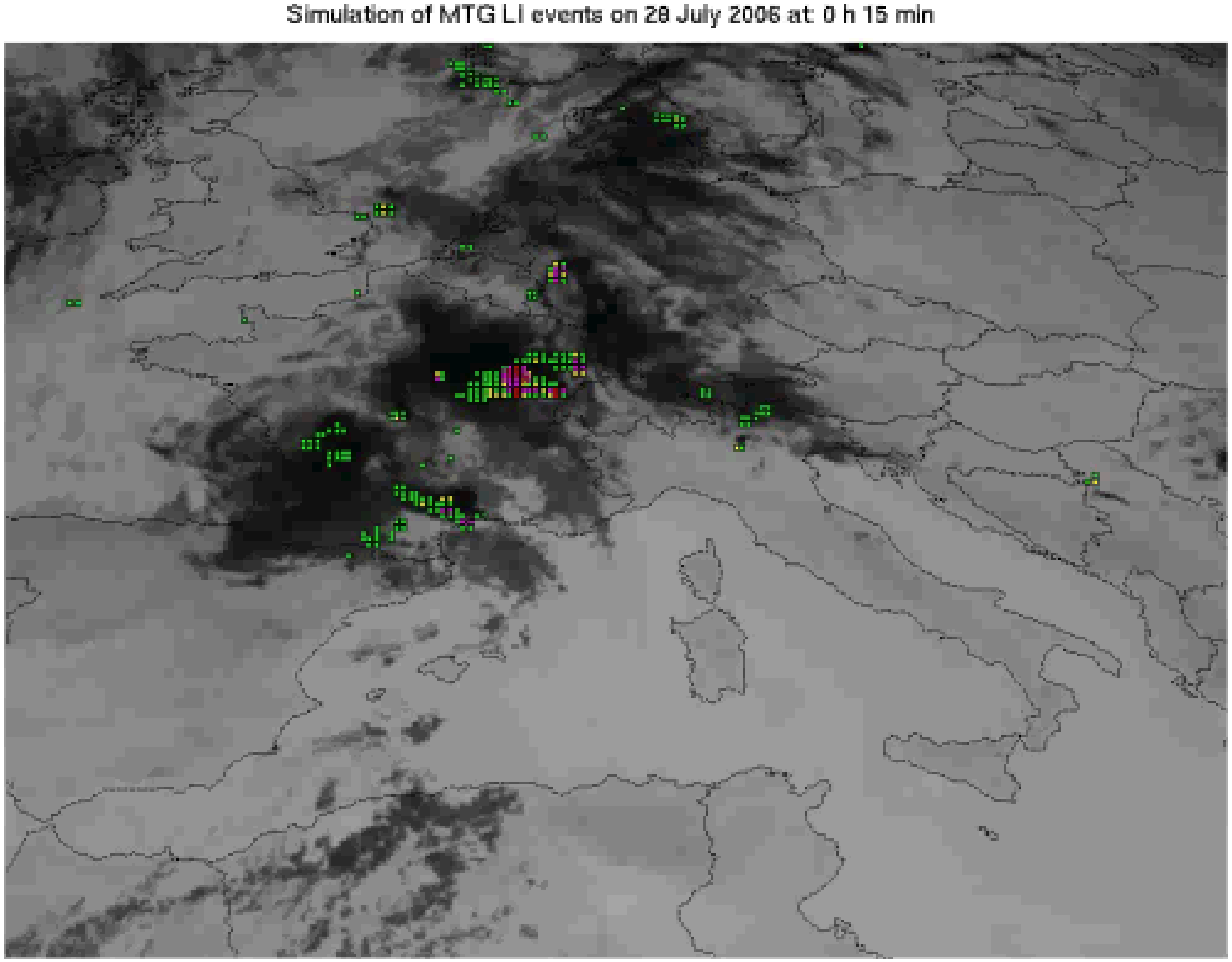
Case Studies - W-Africa + Europe, 28 July 2006

Optical Pulses - simulation for W-Africa and Europe on 28 July 2006





Proxy data development – example



Based on LINET ground-based data over Europe

Colour code indicates the MTG-LI "event" density

Conclusion on MTG Missions

MTG Mission are well defined

- to ensure continuation and improvement of existing services
- to enable new services expected for 2017 – 2037

breakthrough expected exploiting the MTG information on evolution of convective systems from cradle to grave

Thank you!

EUMETSAT