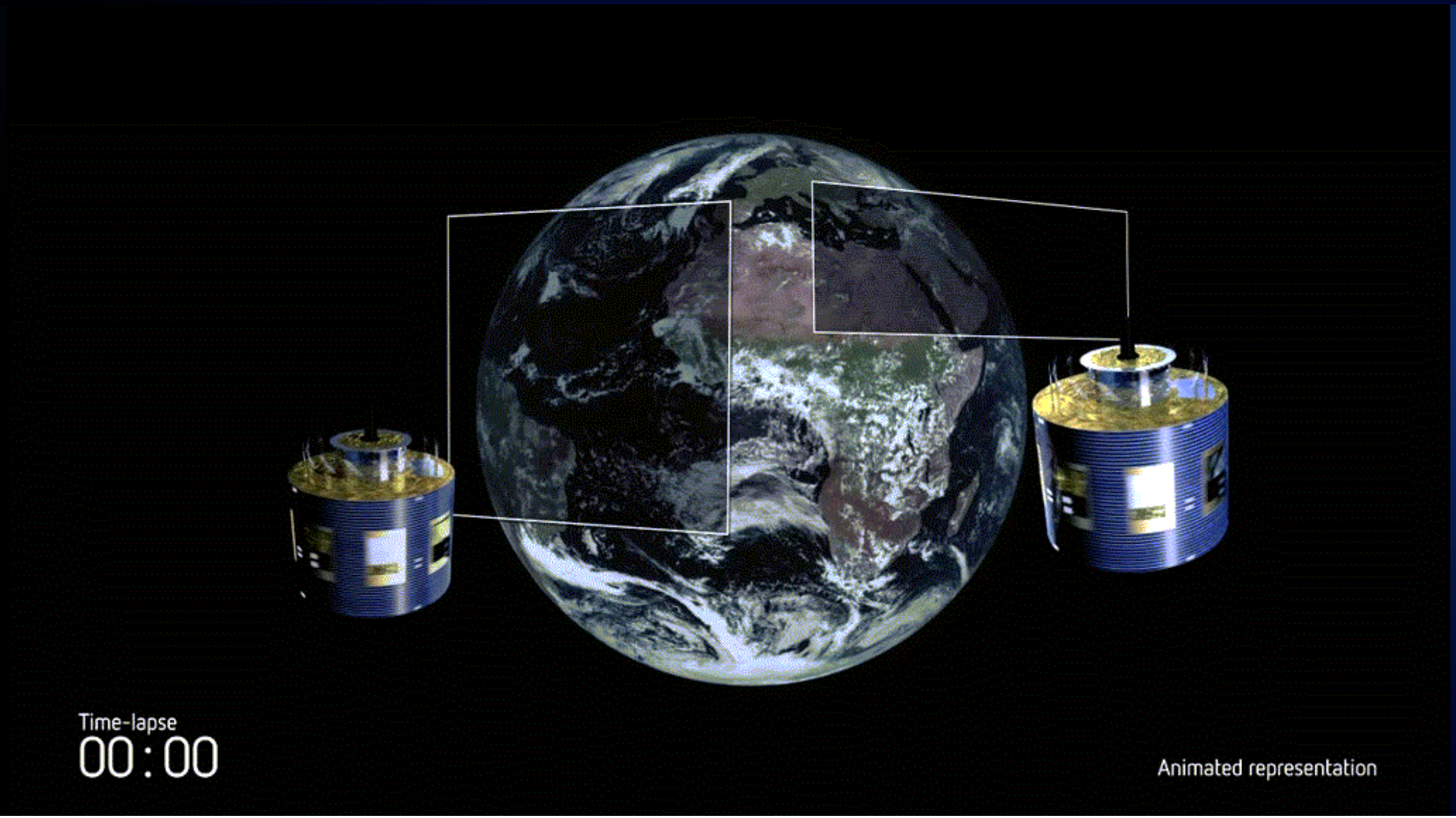
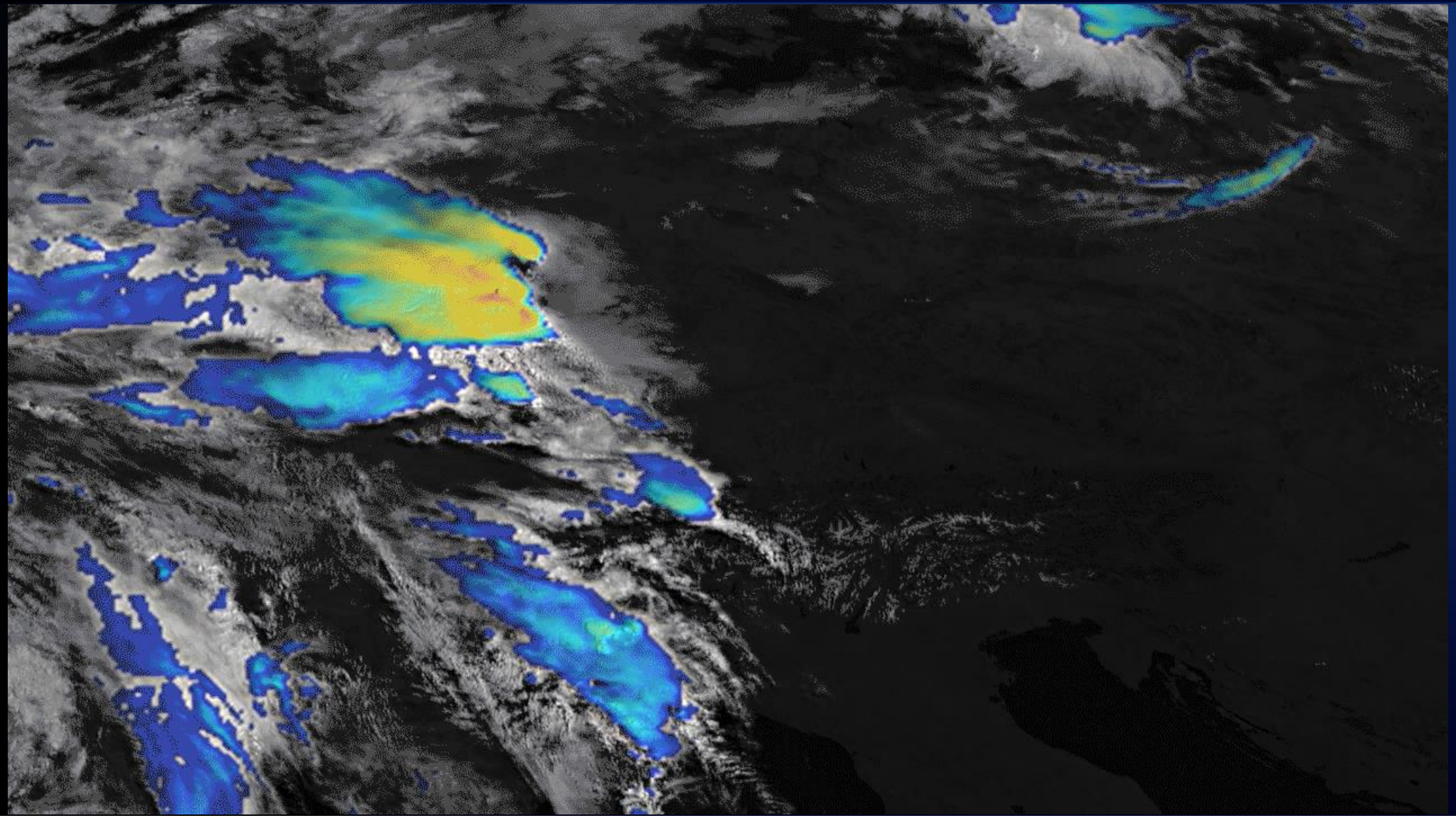
The Meteosat Third Generation satellite mission and its future contribution to nowcasting

Stephan Bojinski, Vesa Nietosvaara, Jochen Grandell (EUMETSAT)

Meteosat Second Generation:
a two-satellite operational system for meteorology



Meteosat Second Generation for nowcasting of severe weather: thunderstorms



Meteosat Third Generation: Imaging mission (MTG-I)

- Imagery mission implemented by two MTG-I satellites
- Full disc imagery every 10 minutes in 16 bands
- Fast imagery of Europe every 2.5 minutes
- New Lightning Imager (LI)

- **Start of operations in 2022**
- **Operational exploitation: 2022-2042**

Meteosat Third Generation: Sounding mission (MTG-S)

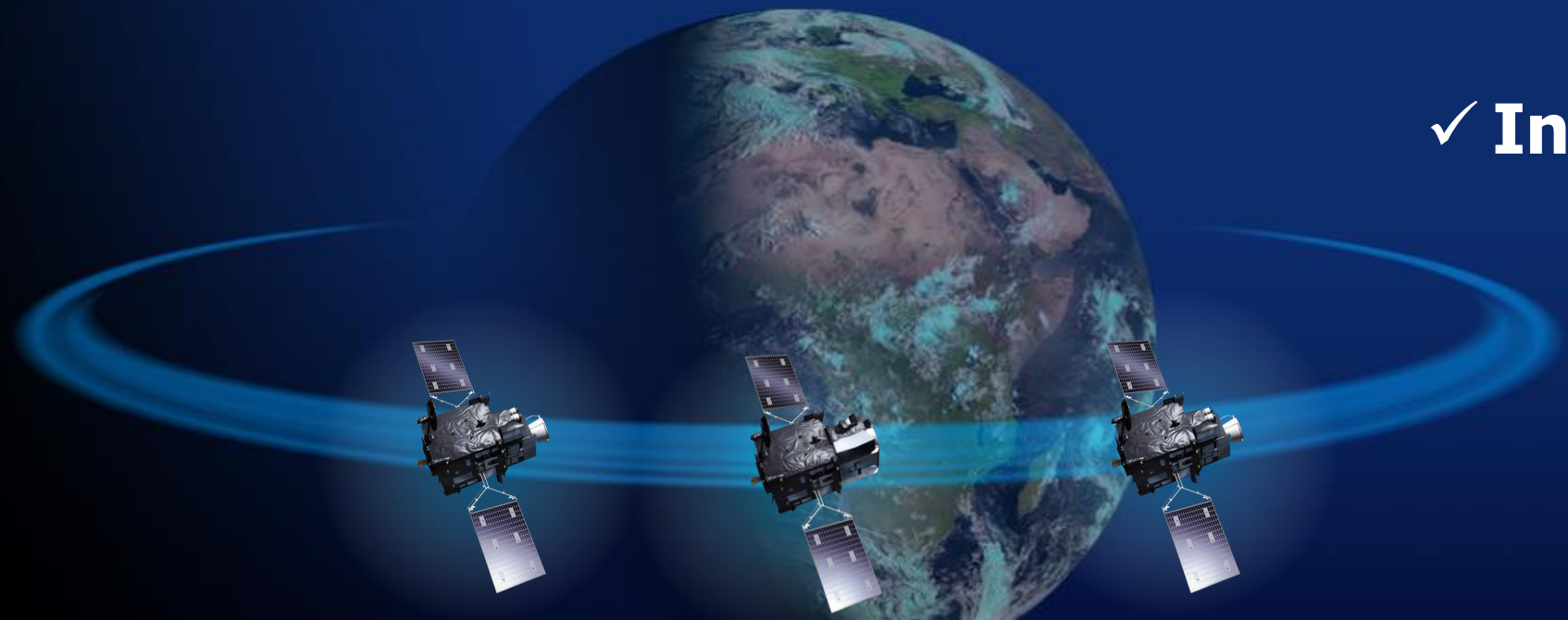
- Hyperspectral infrared sounding mission
- 3D weather cube: temperature, water vapour, O3, every 30 minutes over Europe
- Air quality monitoring and atmospheric chemistry in synergy with Copernicus Sentinel-4 instrument

- **Start of operations in 2024**
- **Operational exploitation: 2024-2043**

Meteosat Third Generation (MTG): Full operational configuration

✓ **Continuity**

✓ **Innovation**



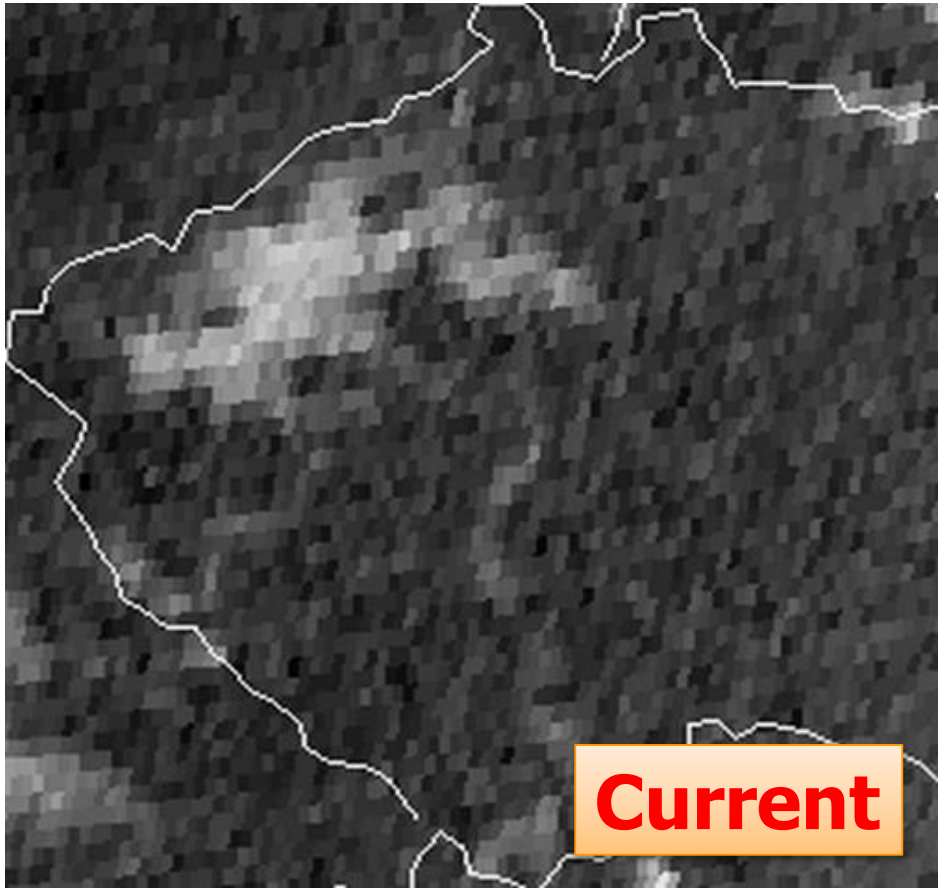
MTG-I
Rapid Scan Service

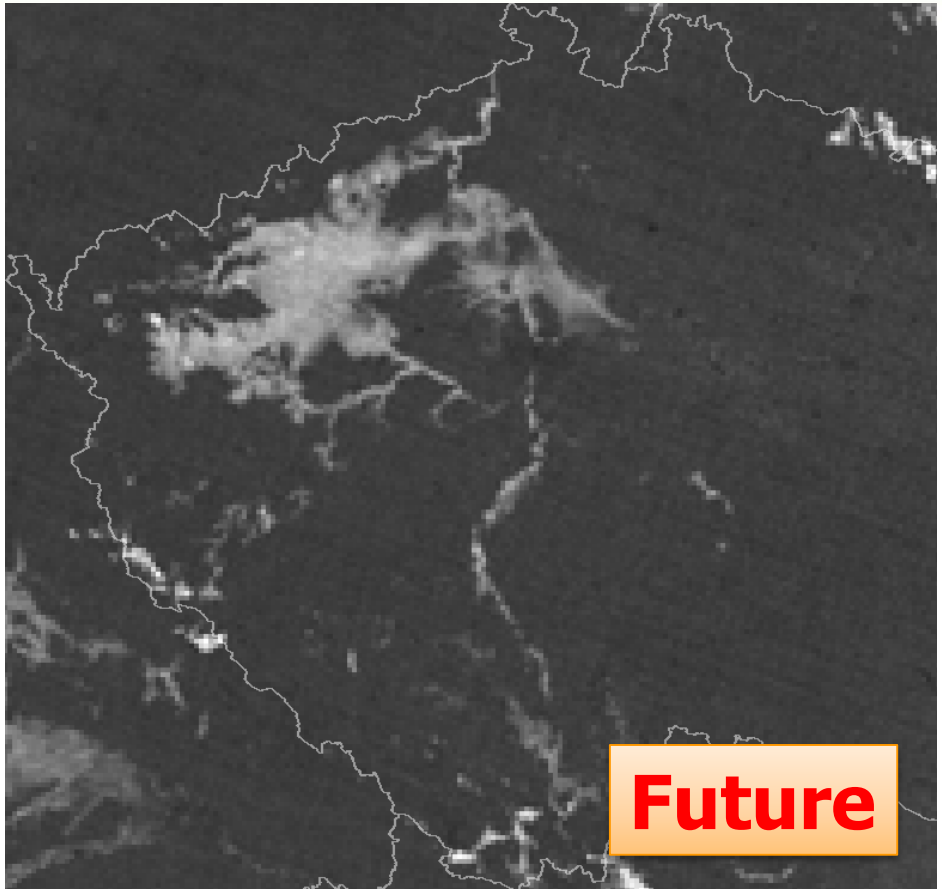
MTG-S
Sounding Service

MTG-I
Full Scan Service

Expected improvements

MTG Imager (FCI): higher spatial resolution imagery

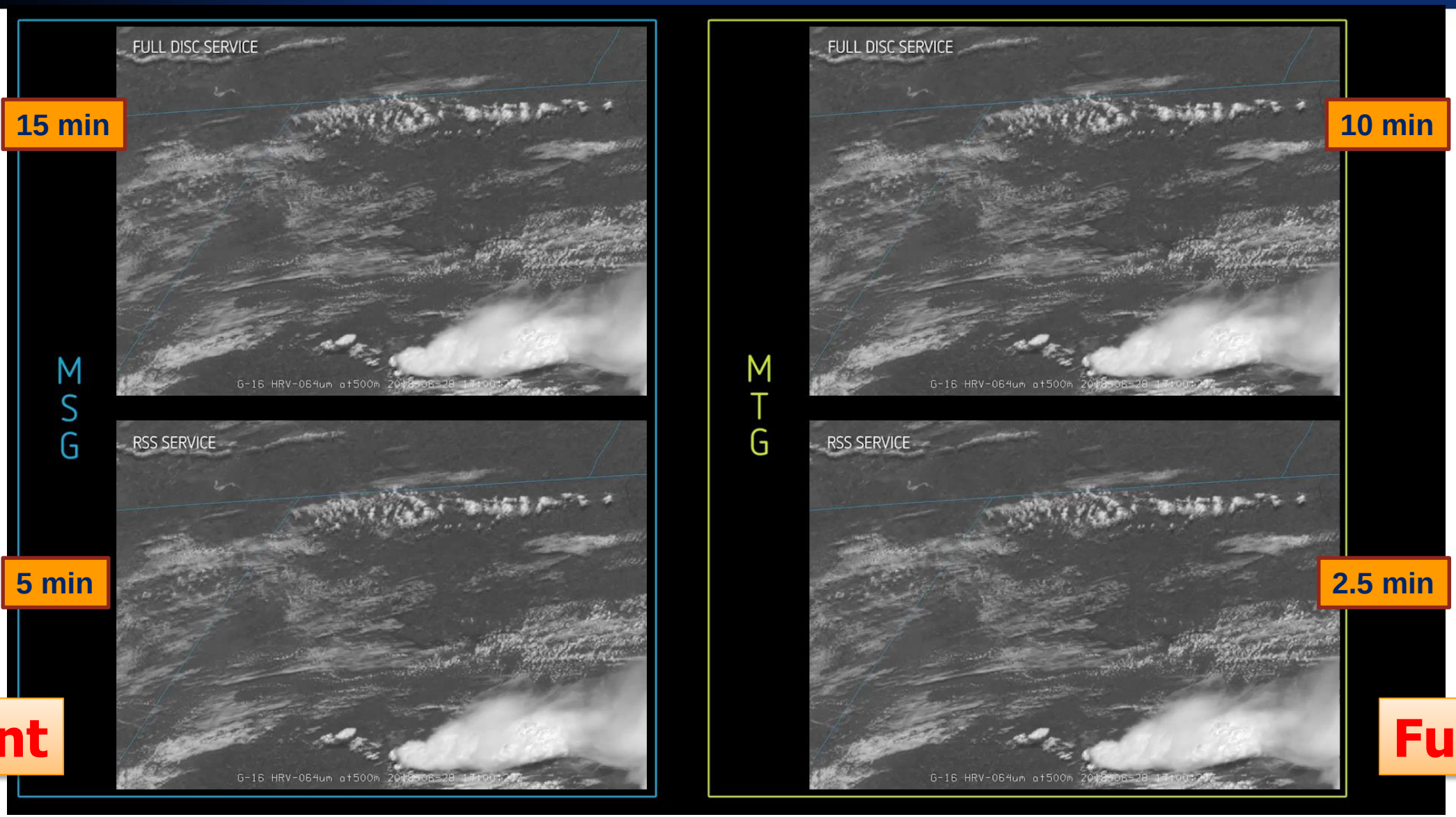




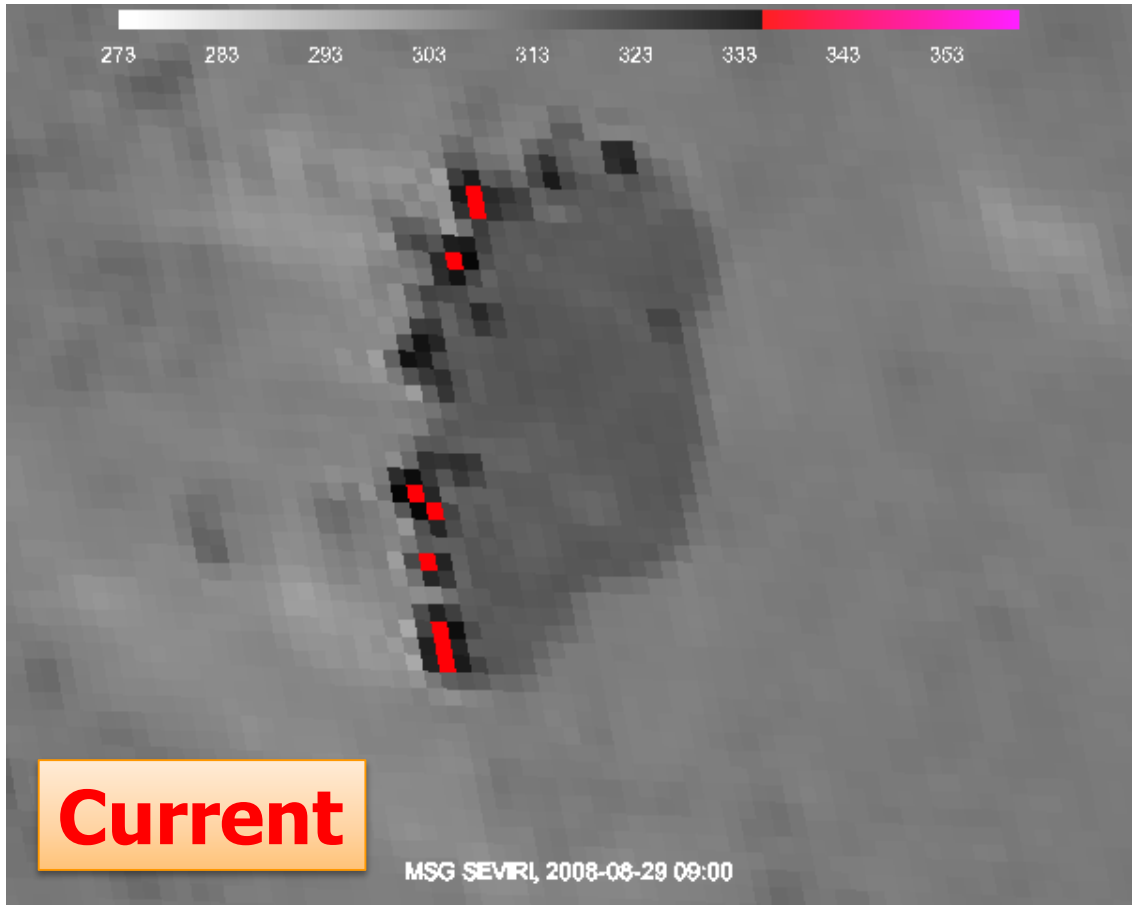
Example of fog detection over Czech Republic

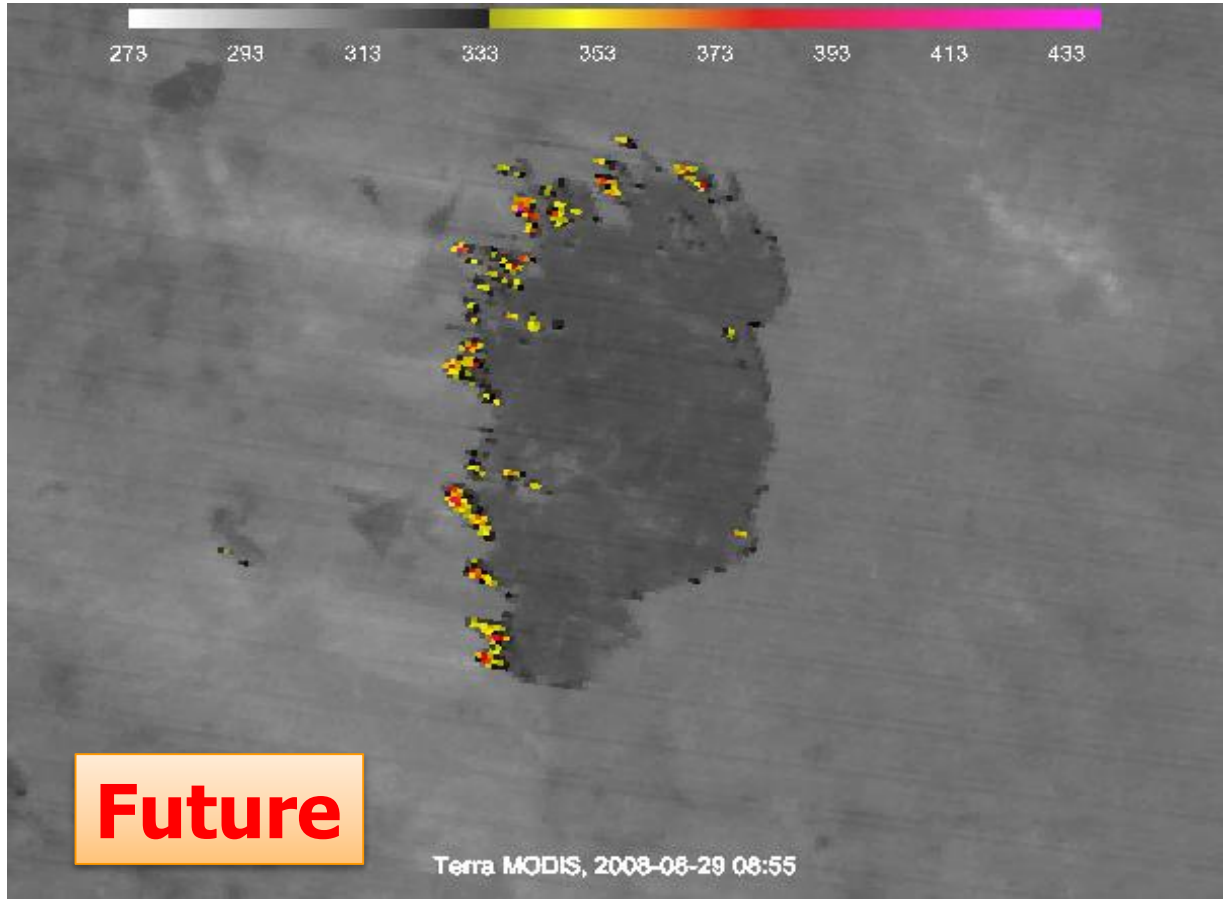
Source: M. Setvak, J. Kerkmann; 16 Nov 2018, 01.37 UTC
Right panel: simulated FCI imagery at ~2 km effective resolution
(1 km nominal), based on NOAA Suomi-NPP VIIRS data
Left panel: MSG SEVIRI imagery at 5 km effective resolution (3 km nominal)

MTG Imager (FCI): New insights through higher temporal resolution



MTG Imager (FCI): New prospects for fire detection and monitoring

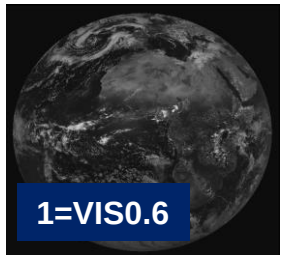


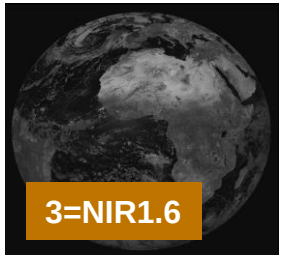


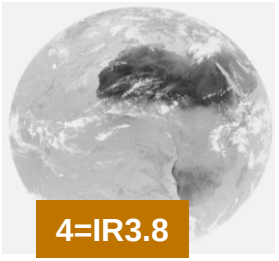
Botswana, August 2008

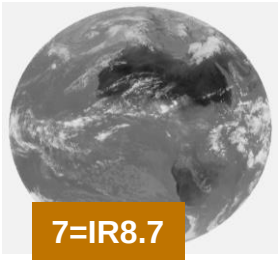
Higher spatial and temporal resolution; new channel for improved fire detection at 2.2 μm

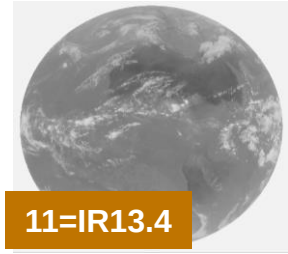
Current and future imagers channels: MSG SEVIRI and MTG FCI





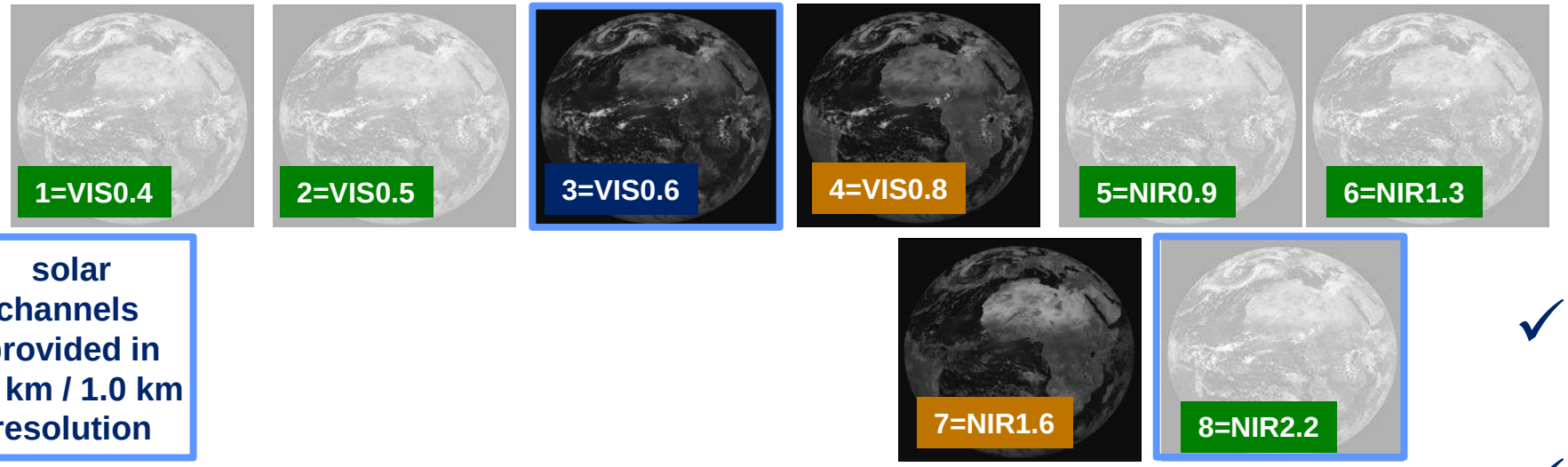






Current SEVIRI

Current and future imagers channels: MSG SEVIRI and MTG FCI



solar channels provided in 0.5 km / 1.0 km resolution

thermal channels provided in 1 km / 2 km resolution

✓ **Continuity**

✓ **Innovation**

Future FCI

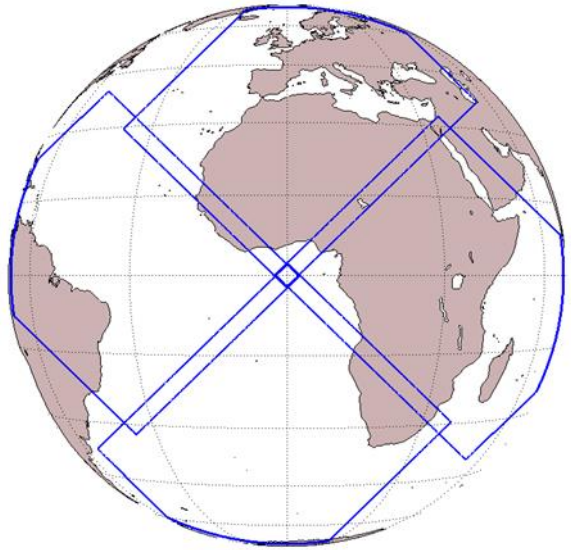
Benefits from the MTG Imager (FCI)

- New channels (0.444 µm and 0.51 µm) will support **true colour images** and permit surpassing current **aerosol retrievals** especially over land – also an important contribution to air quality monitoring.
- The 0.91 µm channel will provide during **daytime total column precipitable water** especially over land surfaces.
- The 1.375 µm channel will improve detection of **very thin cirrus clouds** not seen by the current system. If not detected, errors are introduced in all clear sky products.
- The 2.26 µm channel will provide the capability for an **improved retrieval of cloud microphysics.**
- The higher spatial resolution (1 km and 2 km) of the 3.8 µm channel will **improve fire detection** and, via its extended dynamical range (from 350 K to 450 K), the quality of products.
- To **improve the convection detection** through the shorter repeat cycle and better spatial resolution.

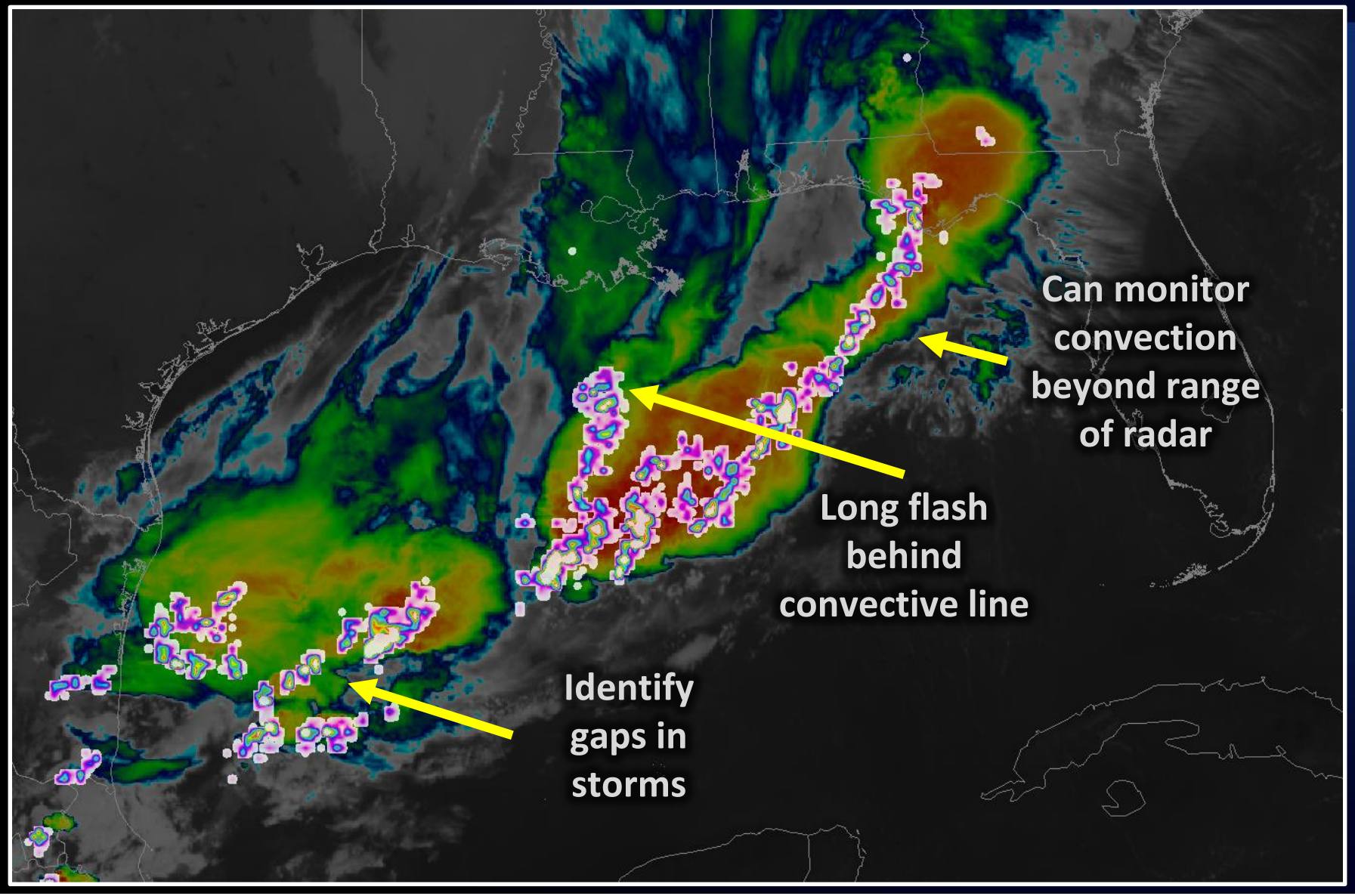
MTG lightning imager mission: *Why do we care?*

- Lightning is a precursor of severe weather, with a lead time of tens of minutes
- Most ground-based lightning location systems are mainly sensitive to cloud-to-ground lightning (CG)
- Often, no increase in CG due to “weather intensification” observable → Total lightning is the parameter of interest

Total lightning = cloud-to-ground + cloud-to-cloud lightning



MTG Lightning Imager (LI): US Proxy Data



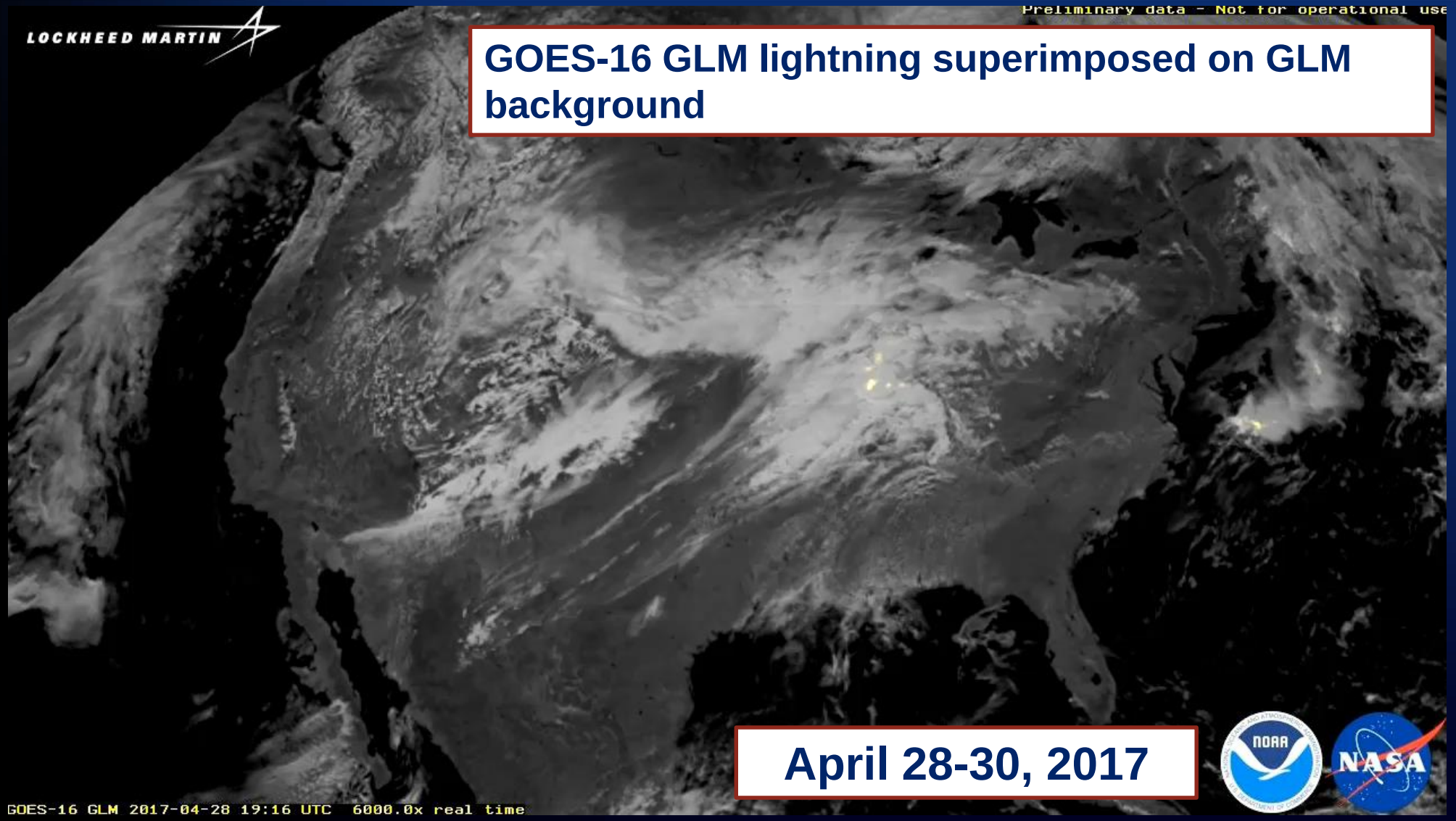
- GOES Lightning Mapper (GLM) Group Density
- Repeat cycle: 1 min
- Horizontal resolution: 8 km

- GOES ABI 11.2 IR
- 4 May 2017

- Source: G. Stano, NASA SPoRT

- MTG LI features:
  Spatial resolution:
  ~ 4.5 km at SSP
  Update cycle: 30s

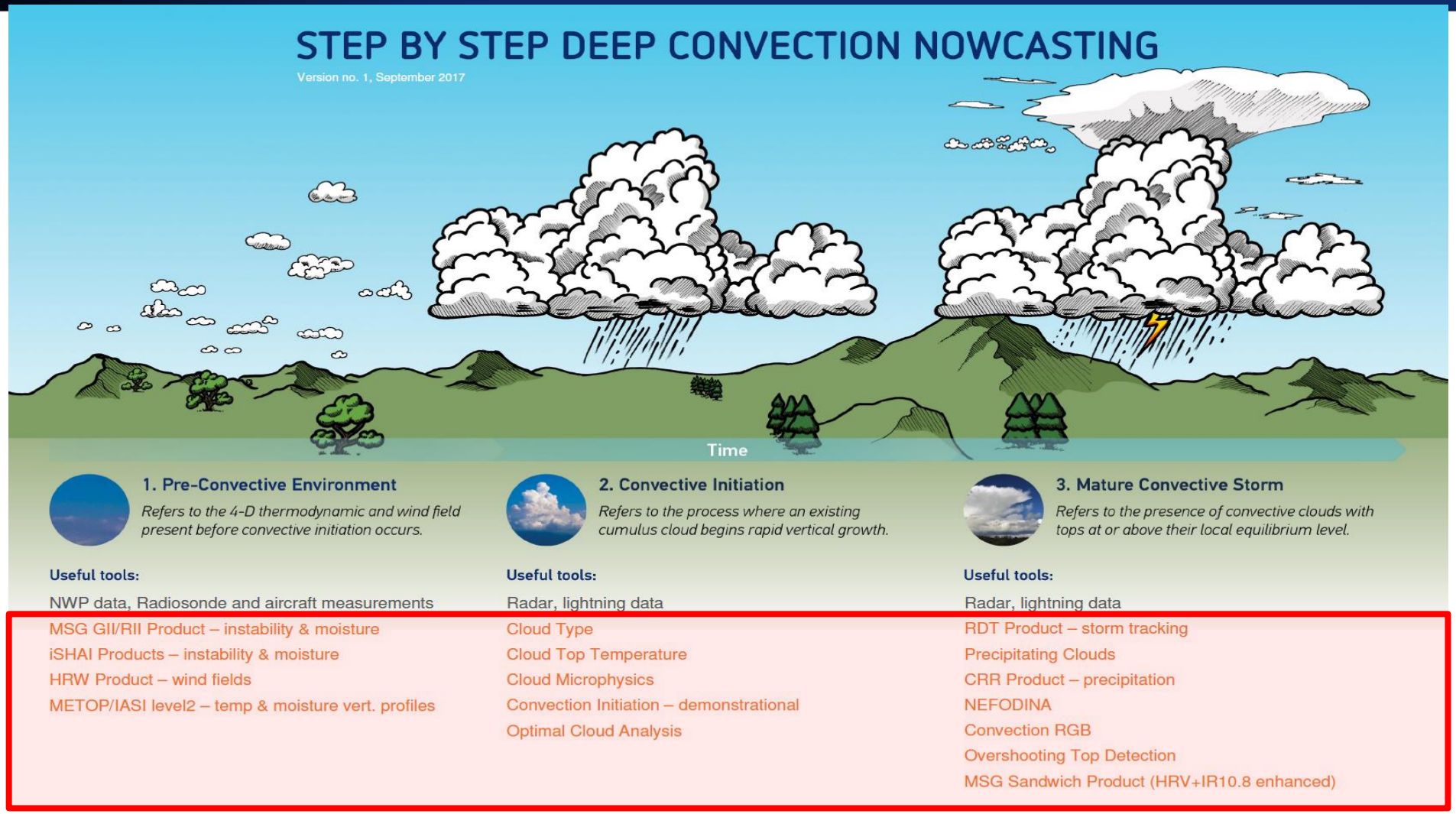
MTG Lightning Imager (LI): US Proxy Data



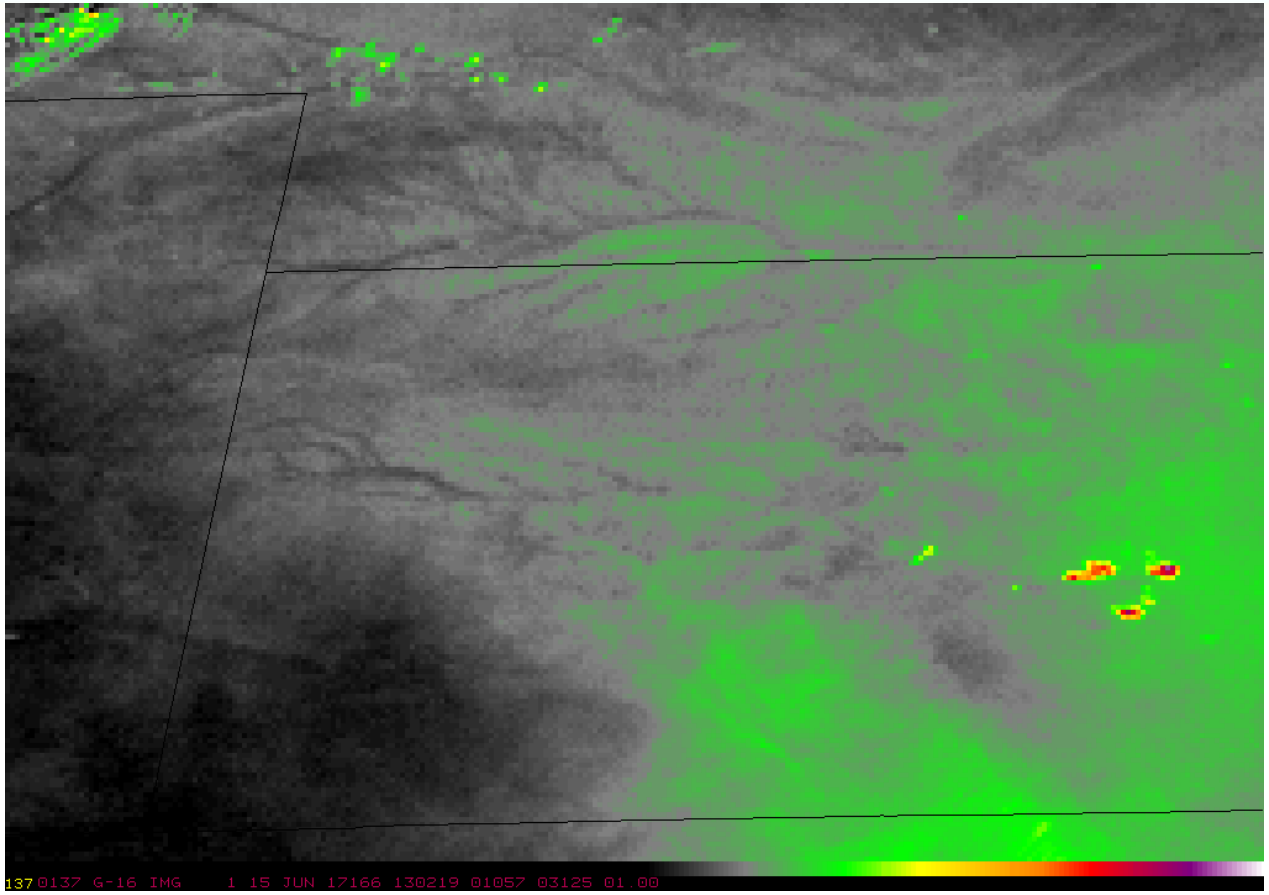
MTG Imager and Sounder: Tools for Nowcasting

Existing satellite products

To be enhanced with MTG data



MTG Imager and Sounder: Tools for Nowcasting

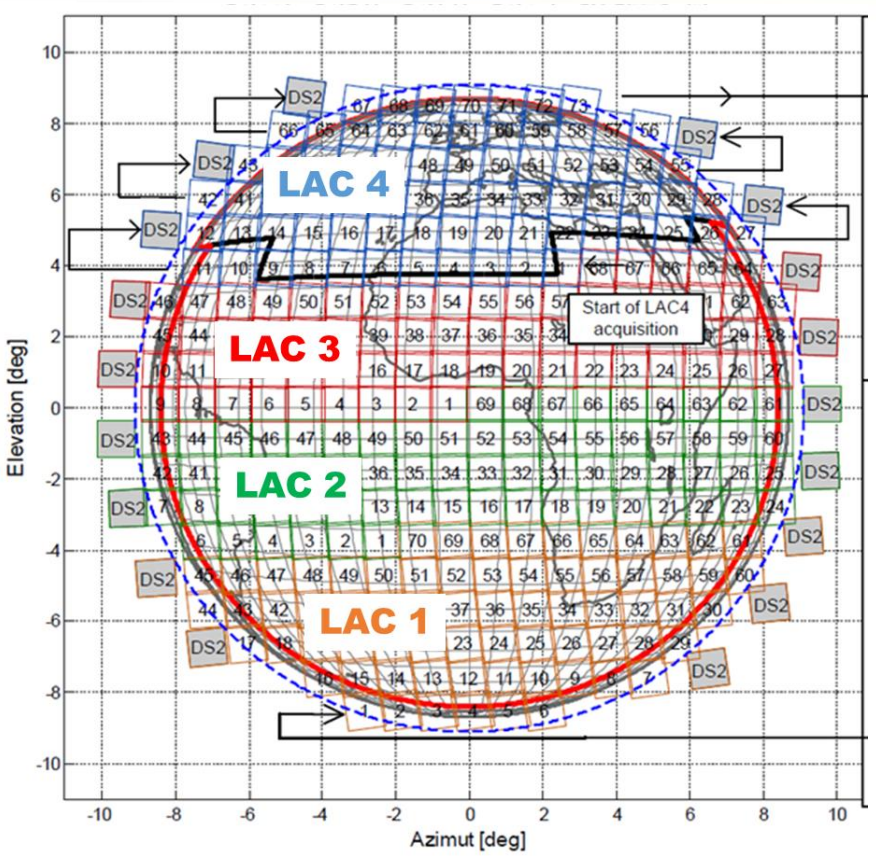


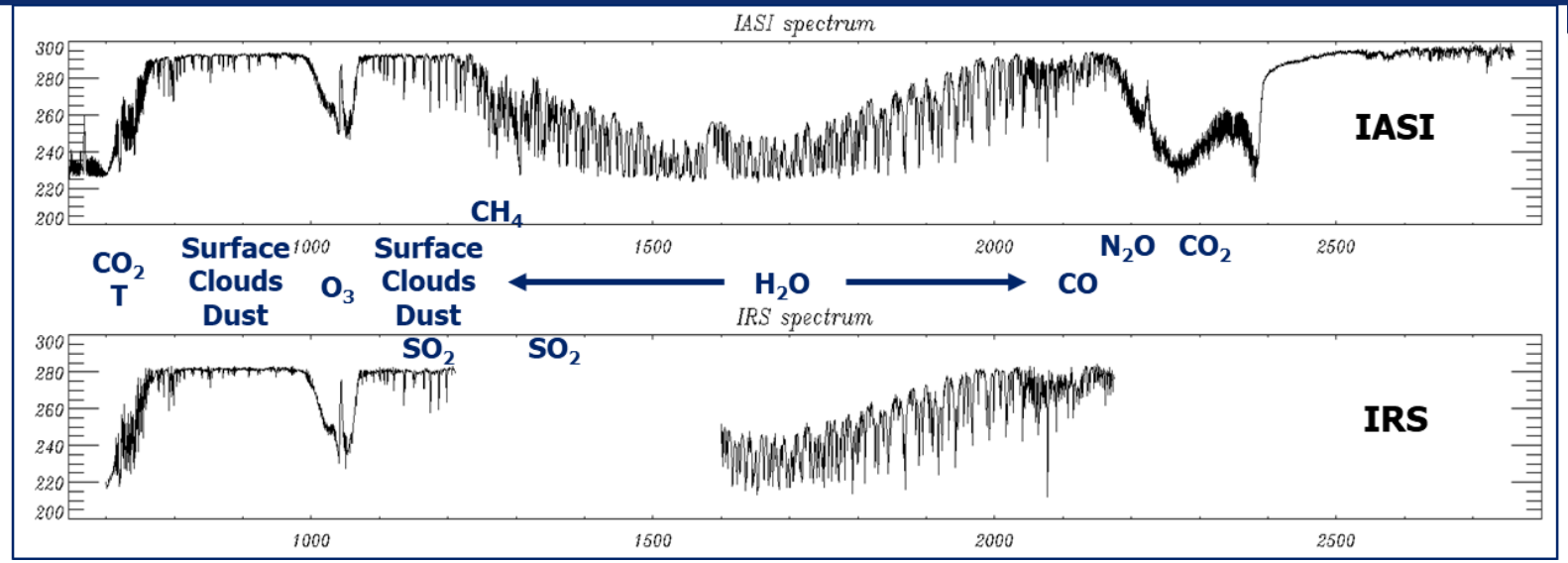
Detection of low-level moisture over Kansas, USA, using the Split Window Difference (10.35 µm minus 12.3 µm) of NOAA GOES-16 ABI data (right panel, in orange-red colours), a precursor for potentially severe storms, while conventional imagery detect no signal (left panel)

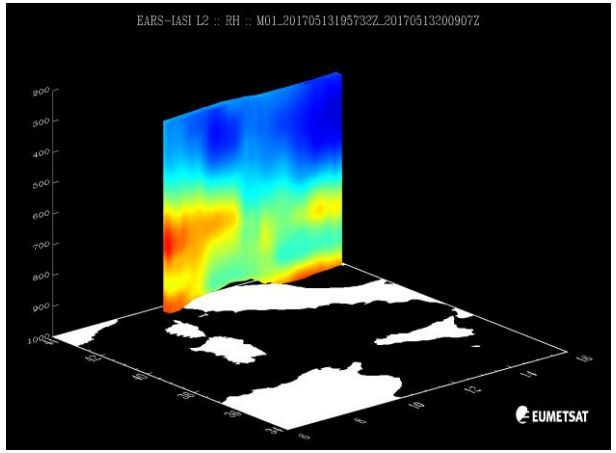
The low-level moisture boundary is evident about 2.5 h before clouds form.

Courtesy: Dan Lindsey (NOAA), 15 June 2017

MTG Infra-Red Sounder (IRS)







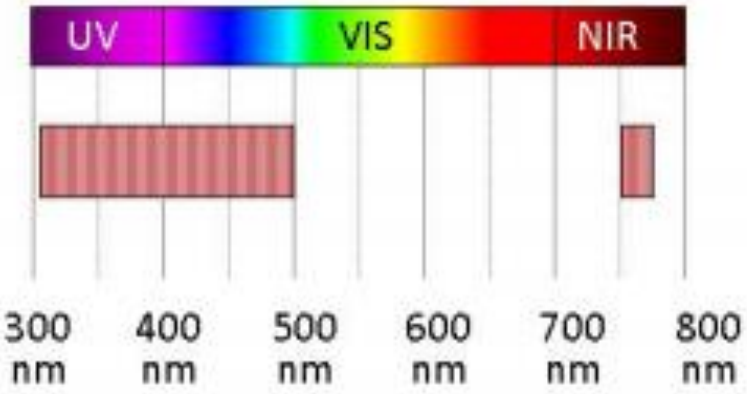
4 Local Area Coverage (LAC):

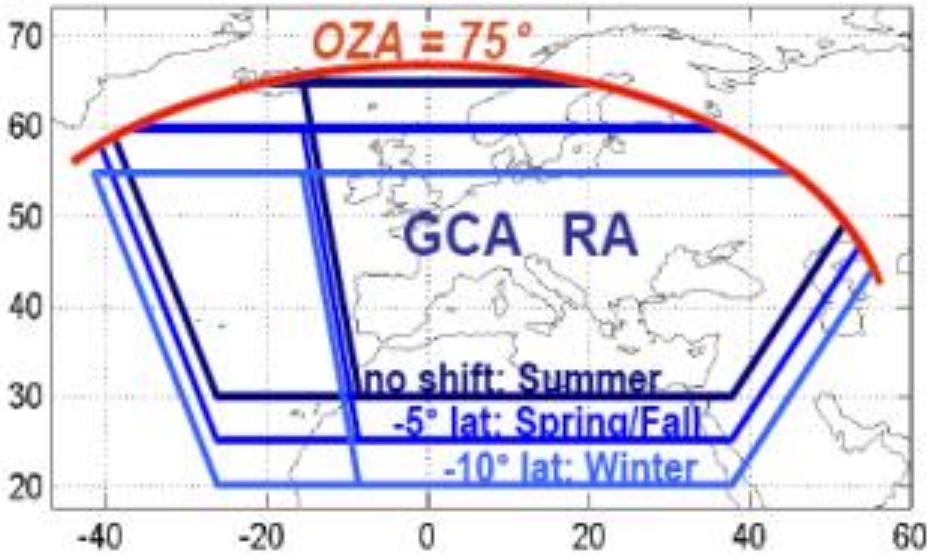
- One LAC acquired within 15’
- Overlapping step & stare dwells
- 160x160 pixels, ~4km at Nadir
- Europe (LAC 4) observed every 30’

Major innovation: Operational spectro-imagery at high spectral, spatial & temporal resolution

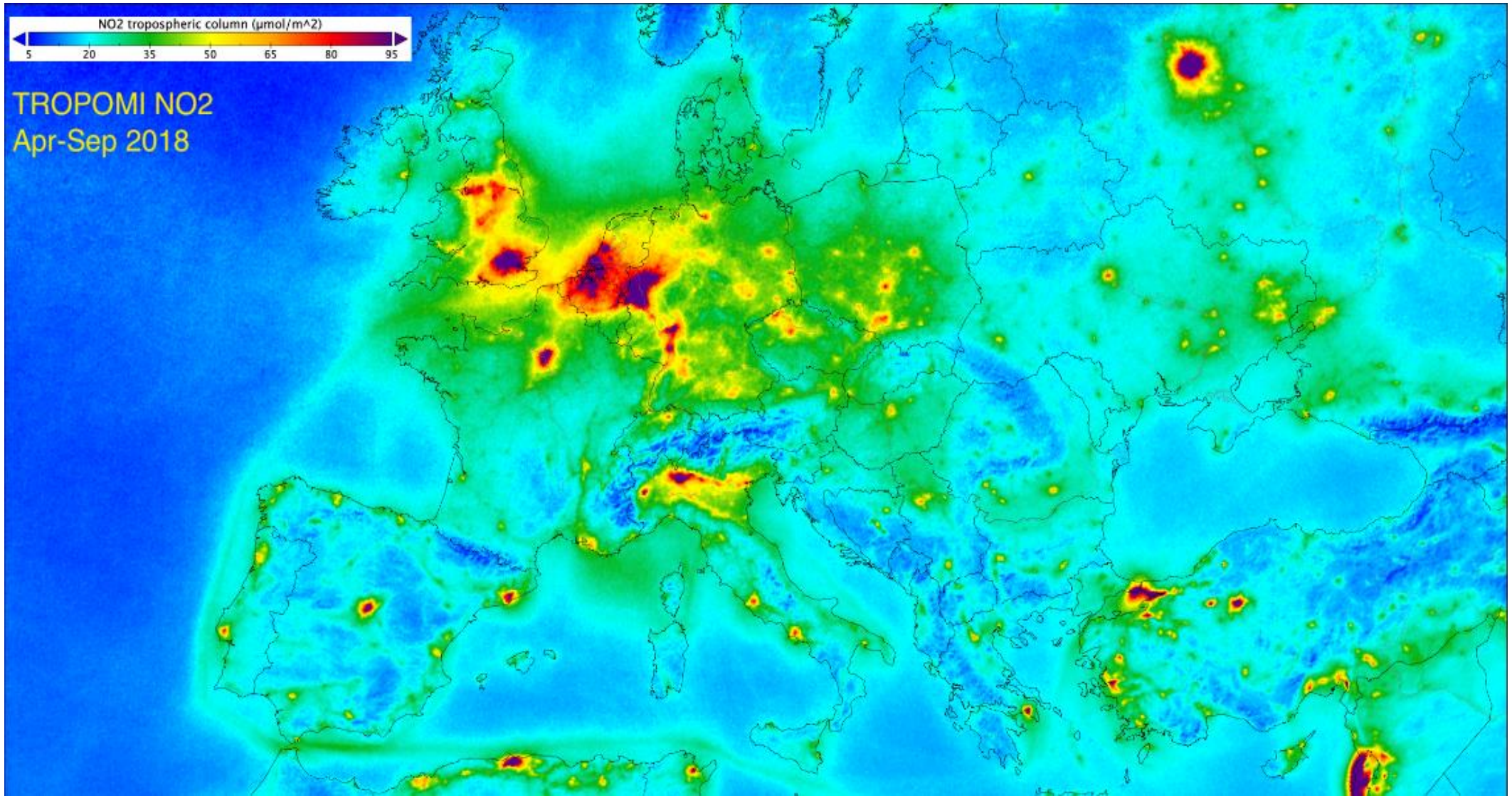
MTG-S: Monitoring atmospheric composition

- The second instrument aboard MTG-S: the Ultraviolet Visible Near-infrared (UVN) spectrometer – *Copernicus Sentinel-4*
- This mission covers the need for continuous monitoring of atmospheric composition / chemistry.
- **Focus on air quality with the main data products being O_3, NO_2, SO_2, HCHO, and aerosol optical depth**.
- Spatial sampling at 45° North: 8 x 8 km²
- Temporal resolution: 60 min.





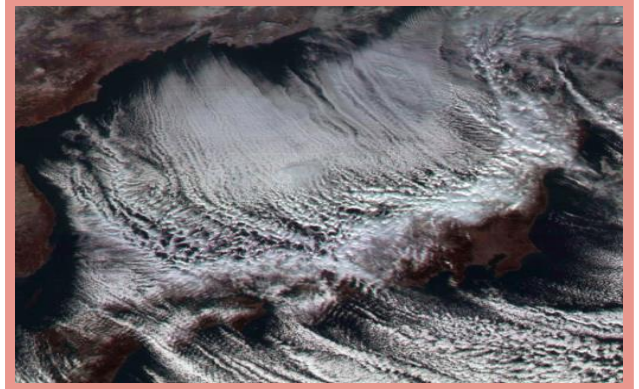
MTG-S: Monitoring air pollution



Meteosat Third Generation: FCI + LI + IRS = 4D

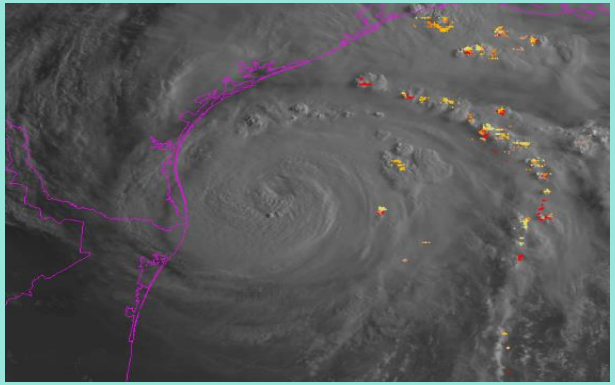
IMAGERY

18 December 2014
(Japan snowstorm)



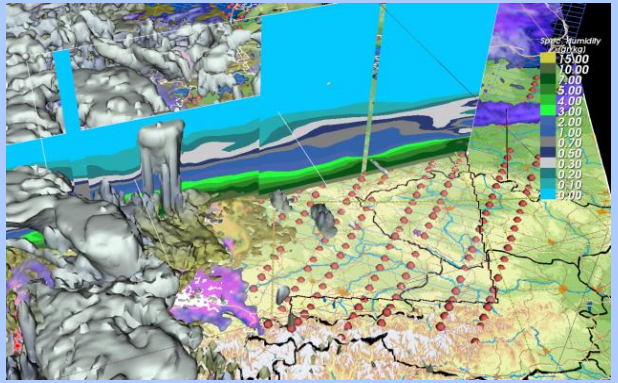
LIGHTNING

12 August 2017
(Hurricane Harvey)

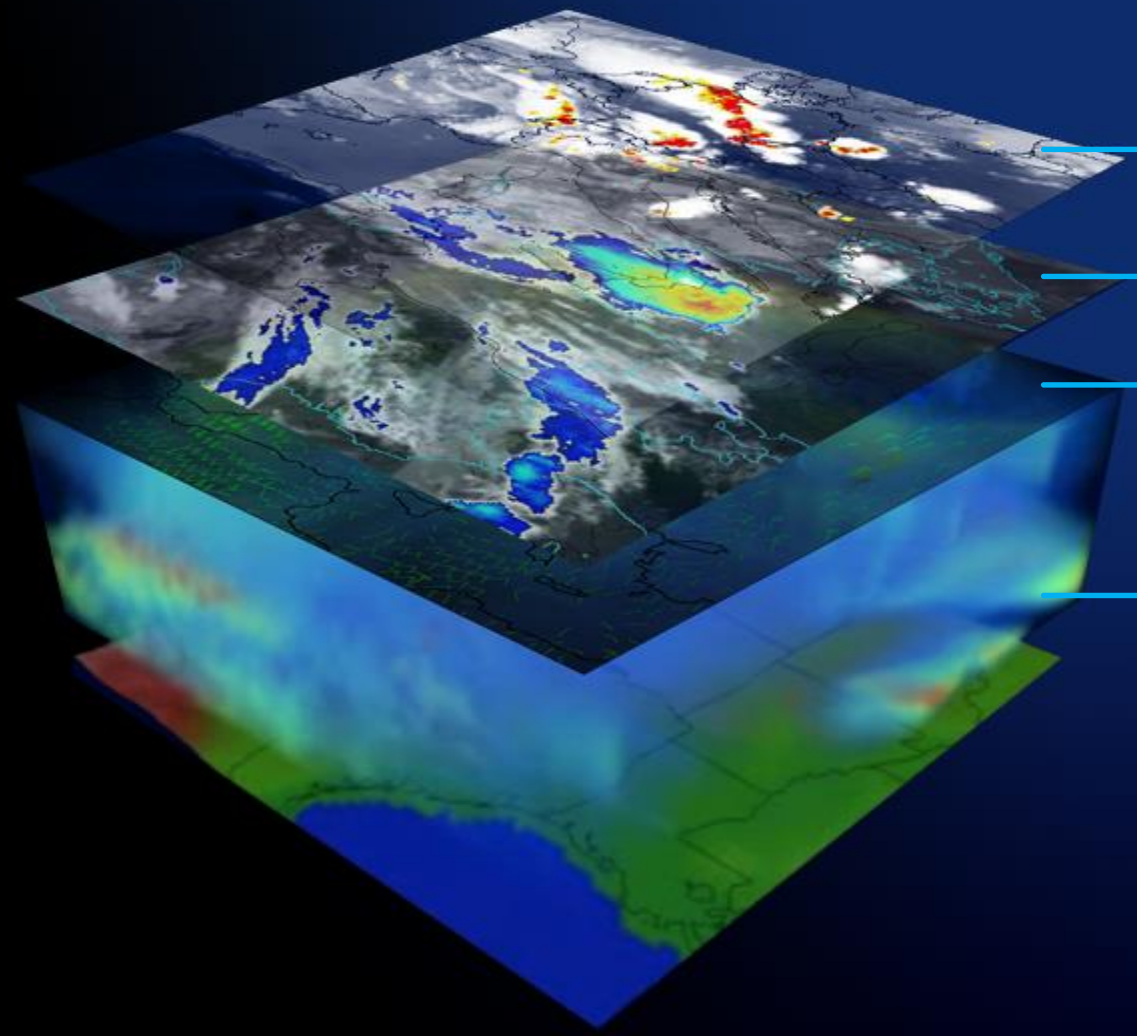


SOUNDINGS

20 June 2013
(IASI vs Harmonie)



Summary: 4D weather cube with MTG-I and MTG-S



- Lightning
- Convection
- Winds
- Atmosphere

Every 30 min over Europe

MTG Geophysical Products (Level-2)*

*excluding products from EUMETSAT Satellite Application Facilities (SAF)

Spectral Imager (FCI)	Lightning Imager (LI)	InfraRed Sounder (IRS)	UV, Visible and Near InfraRed Sounder (UVN)
Atmospheric Motion Vectors	Accumulated	Temperature profile	Ozone Total Column
All Sky Radiance	Flash Area	Humidity profile	Ozone Tropospheric
Clear/Cloud/Dust/Ashes Flag		Instability indices	Column
Clear Sky Reflectance	Accumulated	Ozone profile	Nitrogen Dioxide Total Column
Cloud Analysis	Flash Radiance	Surface temperature	Nitrogen Dioxide Tropospheric
Fire Detection		(land and sea)	Column
Global Instability Indices	Accumulated	Surface emissivity	Sulphur Dioxide
Cloud Drop Effective Radius	Flashes	(land)	Formaldehyde
Outgoing Longwave Irradiance		Cloud products	Glyoxal
at Top of Atmosphere	Lightning Flashes	(detection, fraction,	Aerosol Index
Ozone Total Column		top pressure)	Aerosol Layer Height
Volcanic Ash	Lightning Groups		

Thank you for your attention.

BACKUP

EUMETSAT Mission Planning

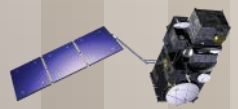
METEOSAT SECOND GENERATION
METEOSAT-8
METEOSAT-9
METEOSAT-10
METEOSAT-11
METEOSAT THIRD GENERATION
MTG-I-1 : IMAGERY
MTG-S-1: SOUNDING
MTG-I-2: IMAGERY
MTG-I-3: IMAGERY
MTG-S-2: SOUNDING
MTG-I-4: IMAGERY

EUMETSAT POLAR SYSTEM (EPS)
METOP-A
METOP-B
METOP-C
EUMETSAT POLAR SYSTEM SECOND GENERATION (EPS-SG)
METOP-SG A: SOUNDING AND IMAGERY
METOP-SG B: MICROWAVE IMAGERY

Mandatory Programmes

JASON (HIGH PRECISION OCEAN ALTIMETRY)
JASON-2
JASON-3
SENTINEL-6 (JASON-CS)

Optional Programmes



COPERNICUS
SENTINEL-3 A/B/C/D
SENTINEL-4 ON MTG-S
SENTINEL-5 ON METOP-SG A

Third Party Programmes

YEAR... 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

YEAR... 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

Information on Meteosat Third Generation (MTG)

- www.eumetsat.int : Satellites : Future Satellites
- MTG User Preparation Project (MTGUP)
- Questions: User Helpdesk
- ops@eumetsat.int

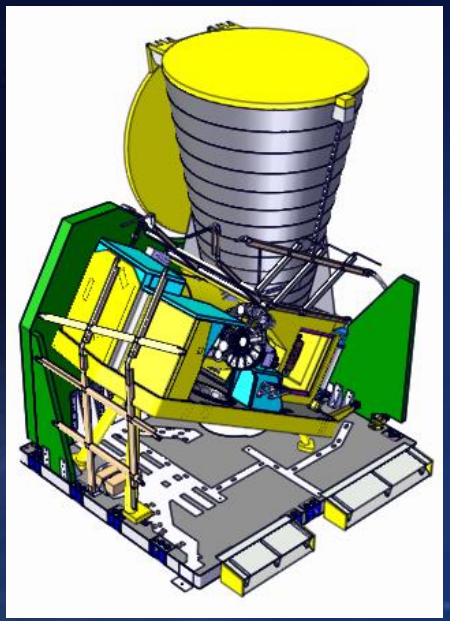
The Flexible Combined Imager (FCI) of MTG-I

- FCI will continue the **Full Disc Scanning Service** (FDSS) and **Rapid Scanning Service** (RSS) currently provided by the MSG SEVIRI instruments.

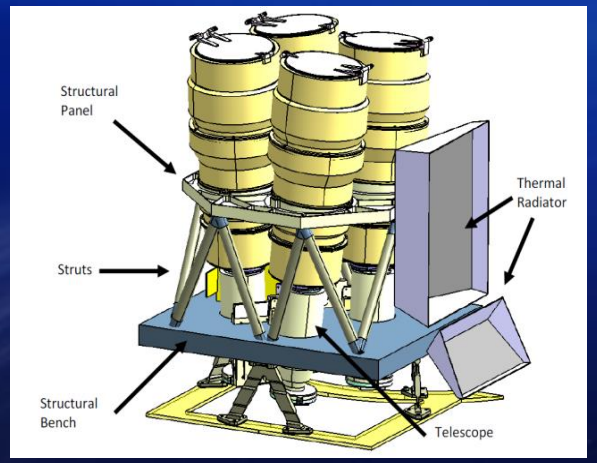
- **Full Disc High Spectral resolution Imagery** (FDHSI) **and High Resolution Fast Imagery** (HRFI) mission requirements are established for FDSS and RSS respectively.

  - **Full Disk Scan Service (FCI-FDSS):**
    - global scales: Full Disk; @ 10 min Repeat Cycle
    - 16 channels at spatial resolution:
      - 1.0 km for the 8 solar channels;
      - 2.0 km for the 8 thermal channels.

  - **Rapid Scan Service (FCI-RSS):**
    - local scales: 1/4th of Full Disk; @ 2.5 min Repeat Cycle



The LI instrument (Lightning imager) of MTG-I

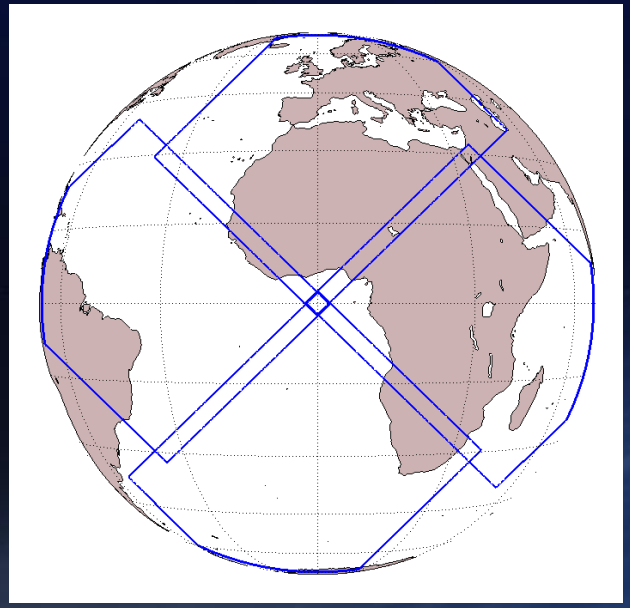


LI Main characteristics:

- Measurements at 777.4 nm
- Coverage close to “visible disc”
- Continuous measurements of (lightning) triggered events
- Spatial resolution ~ 4.5 km at SSP
- Integration time per frame 1 ms
- Background subtraction & event detection in on-board electronics

The baseline for the LI is has 4-Optical sensors:

- 4 identical optical channels with CMOS back-thinned backside illuminated detectors
- 1170 x 1000 pixels per camera

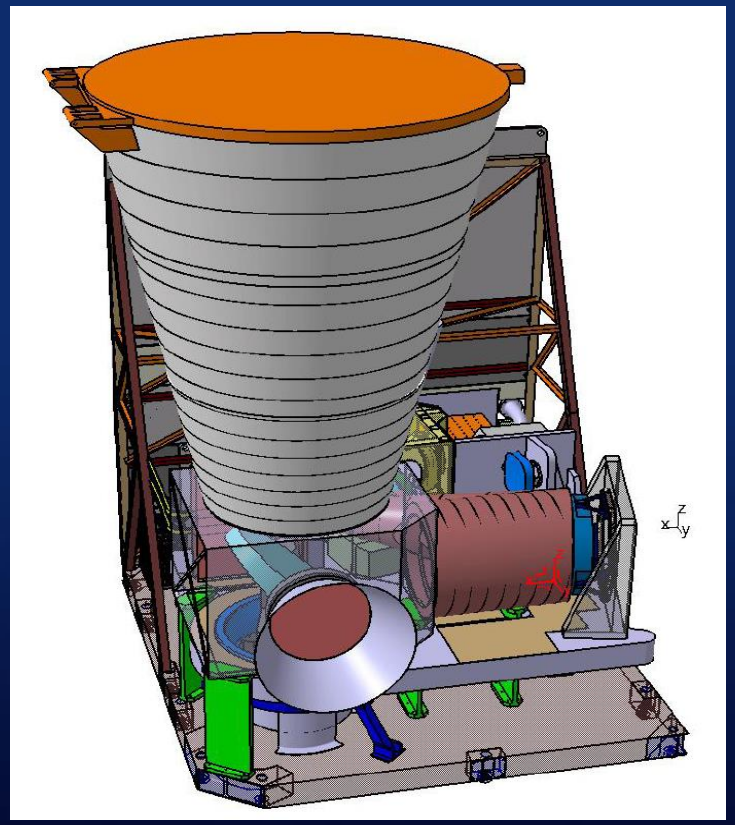


End-users (Level 2) will not see the “detector structure”

MTG-S IRS: Hyperspectral Infrared Sounder

The InfraRed Sounder (IRS):

- Is an imaging interferometer with a hyperspectral spectral sampling of 0.625 cm^{-1} and spectral resolution of 0.754 cm^{-1}
- IRS has 2 detector arrays with each 160 x 160 detectors
- Is taking measurements in two bands:
  - the Mid-Wave InfraRed (MWIR, 1600–2175 cm^{-1} or 6.25–4.6 µm) with 900 spectral channels
  - the Long-Wave InfraRed (LWIR, 700–1210 cm^{-1} or 14.3–8.3 µm) with 800 spectral channels
- Has a spatial resolution of 4 km at nadir and ~10 km at the edges (~7km over Europe)

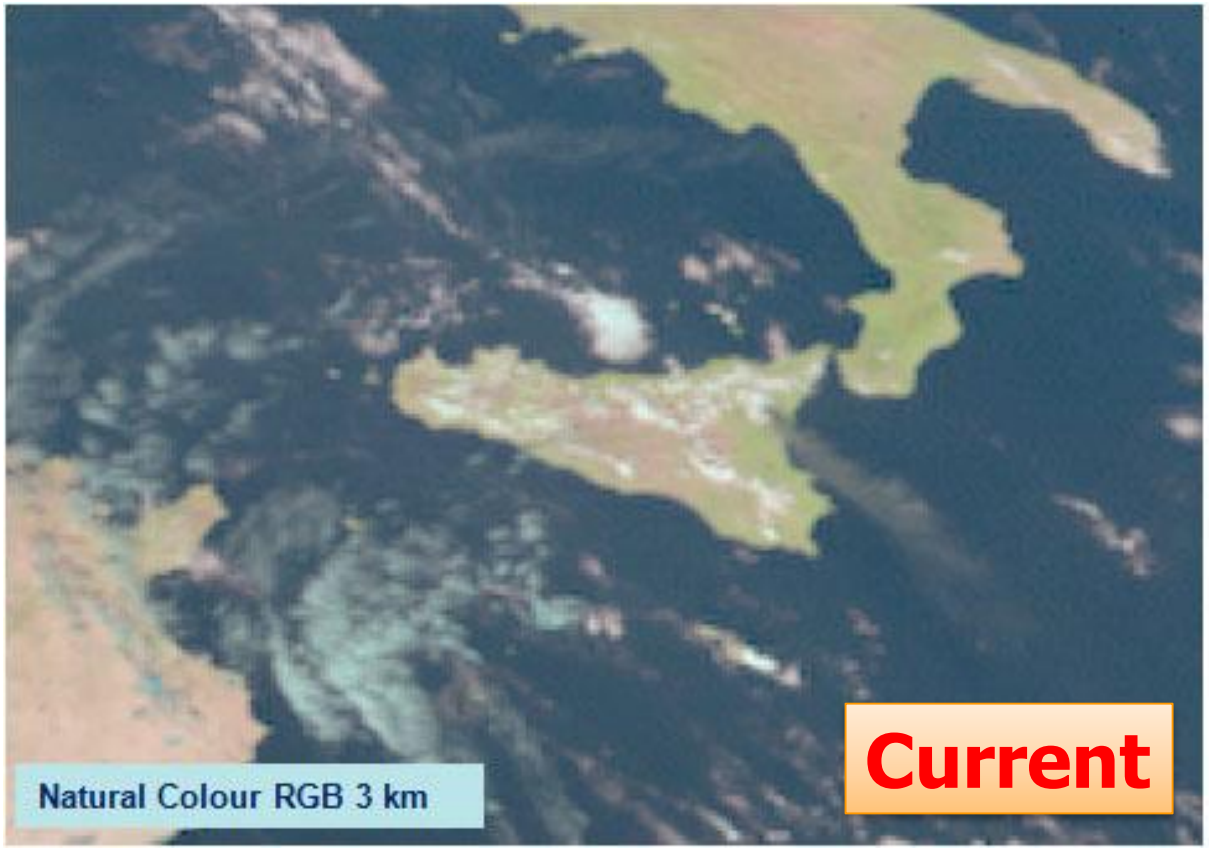


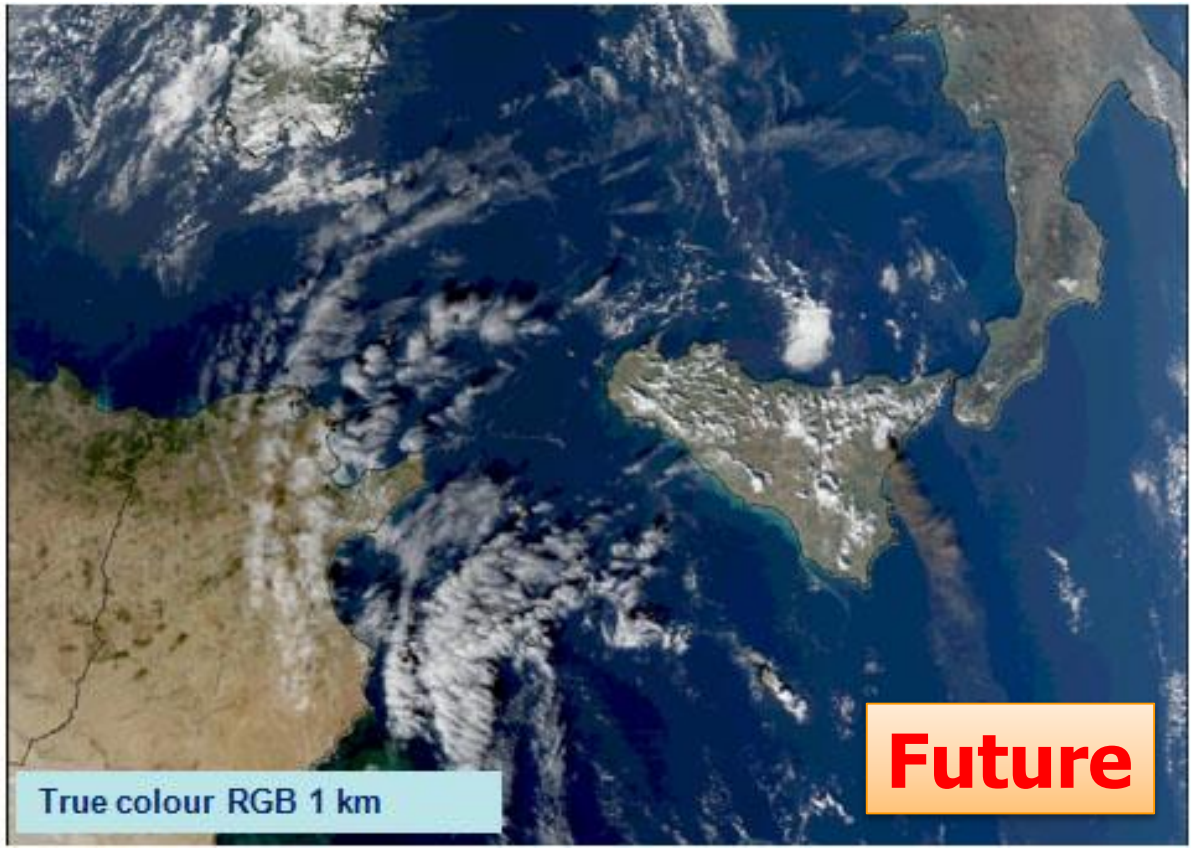
Volume: 1.4 x 1.6 x 2.2 m^3

Mass: 400 kg

Power: 750 W

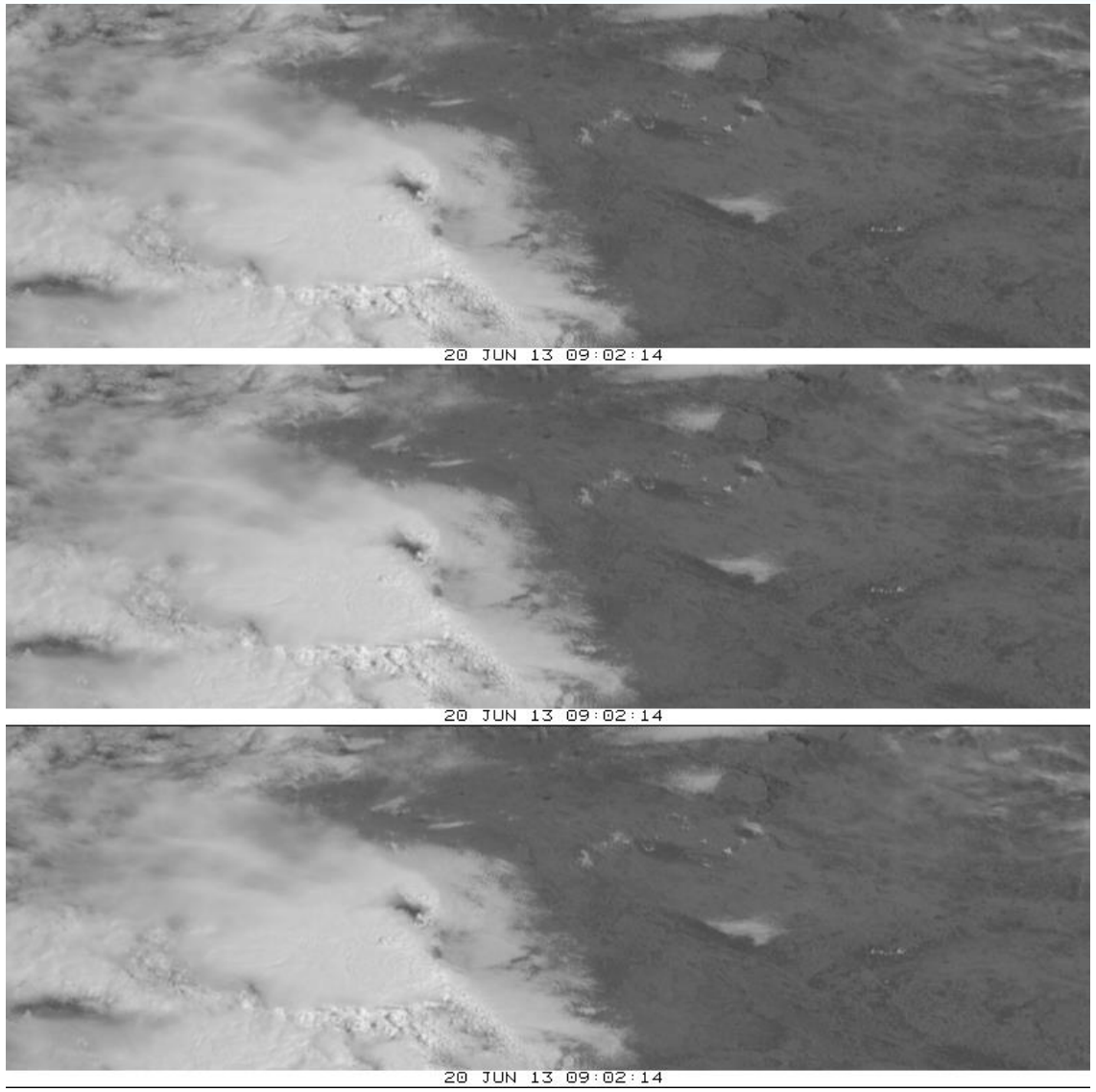
MTG Imager (FCI): higher spatial resolution imagery





Example of ash detection, SEVIRI Natural Colour RGB, 12:15 UTC, 26 November 2006 (left), MODIS True Colour RGB, 12:20 UTC, 26 November 2006

MTG Imager (FCI): New insights through higher temporal resolution

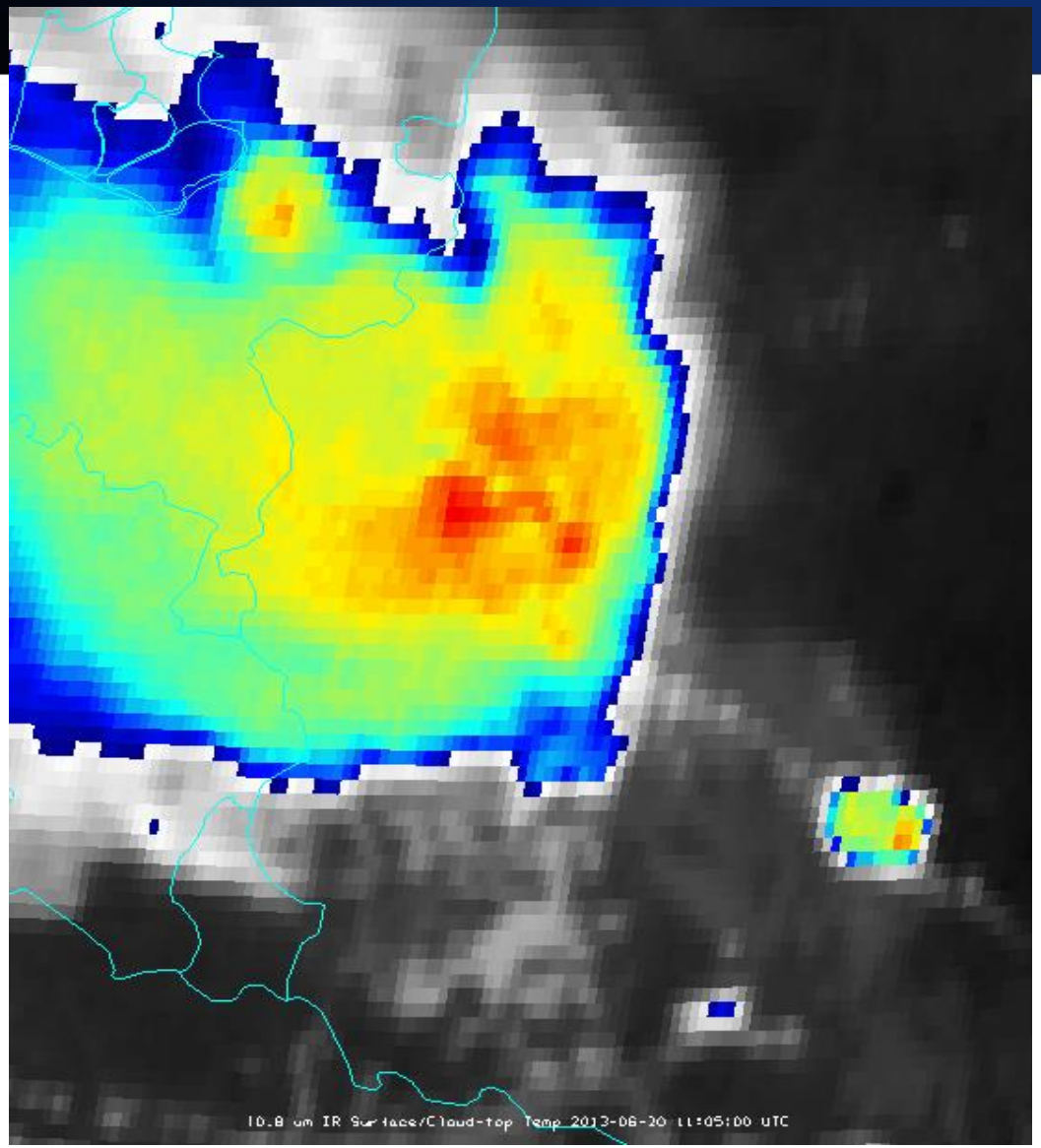


2.5 min resolution

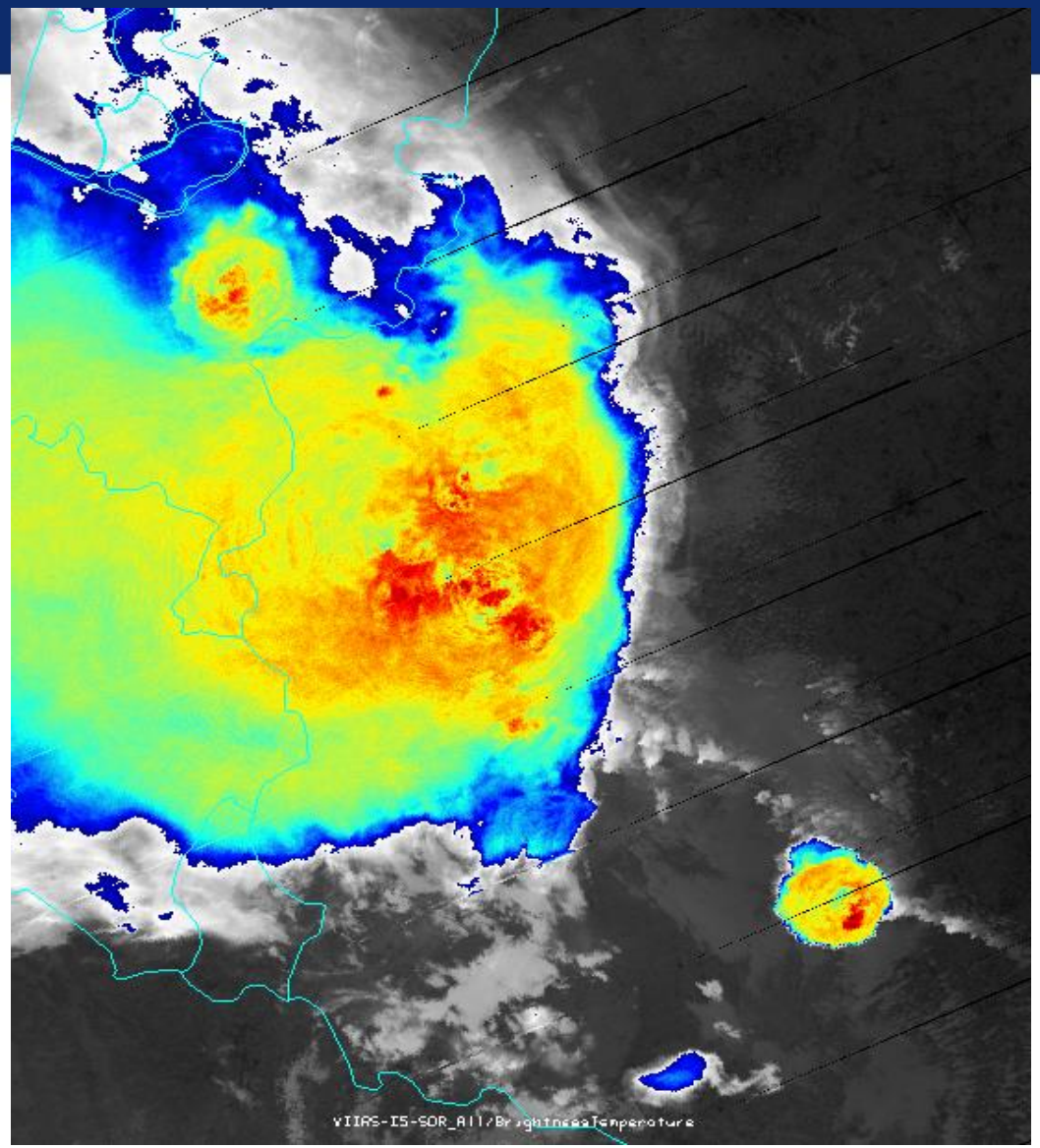
5 min resolution

15 min resolution

Current and future imagers: MSG SEVIRI and MTG FCI



SEVIRI IR10.8 11:05 UTC ~ 3 km

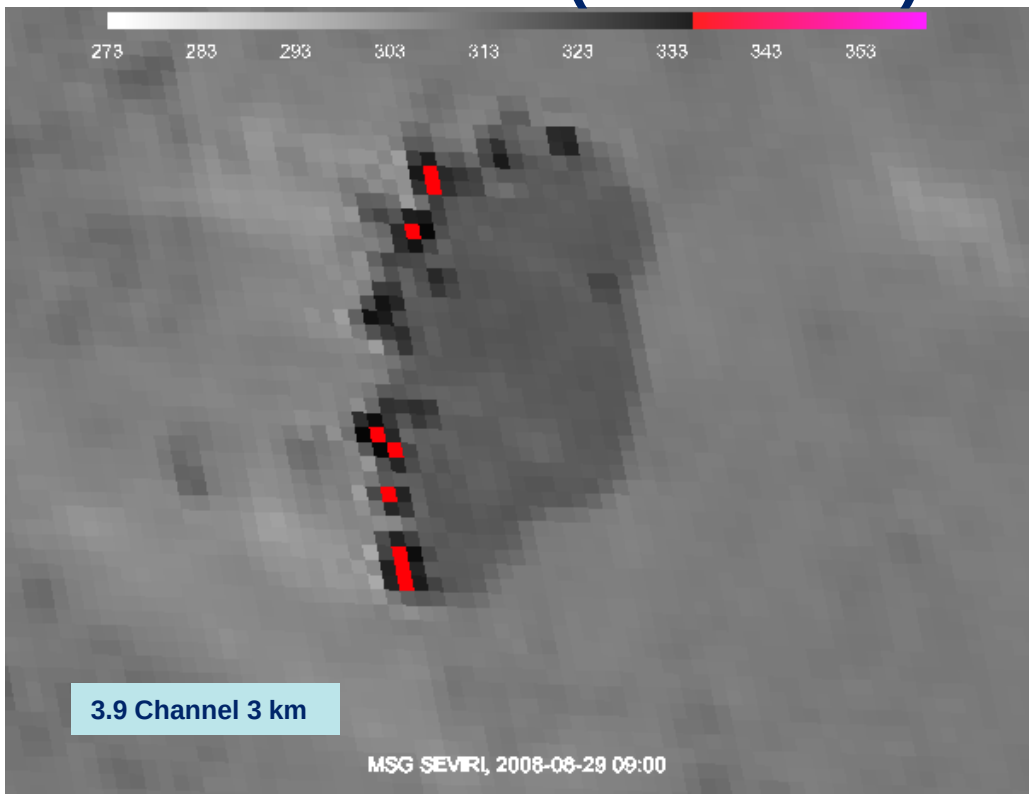


VIIRS band I5 11:05 UTC ~ 375 m

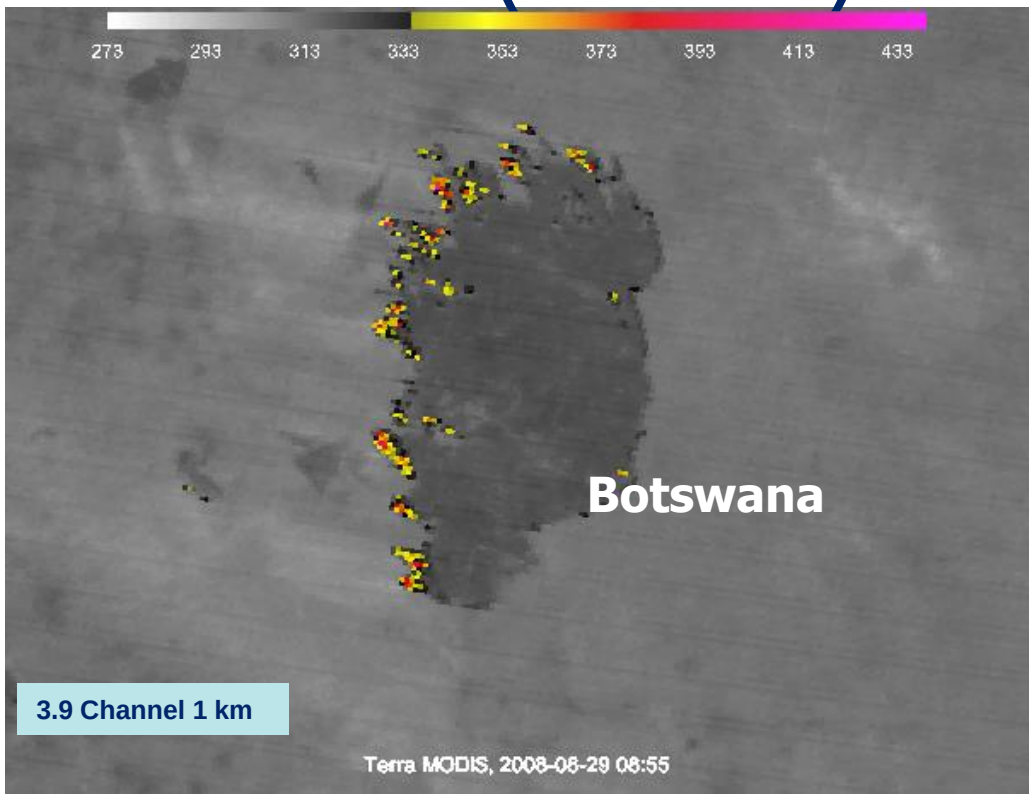
MTG improvements: fire detection

29 August 2008

SEVIRI IR3.9 (09:00 UTC)



MODIS IR3.9 (08:55 UTC)



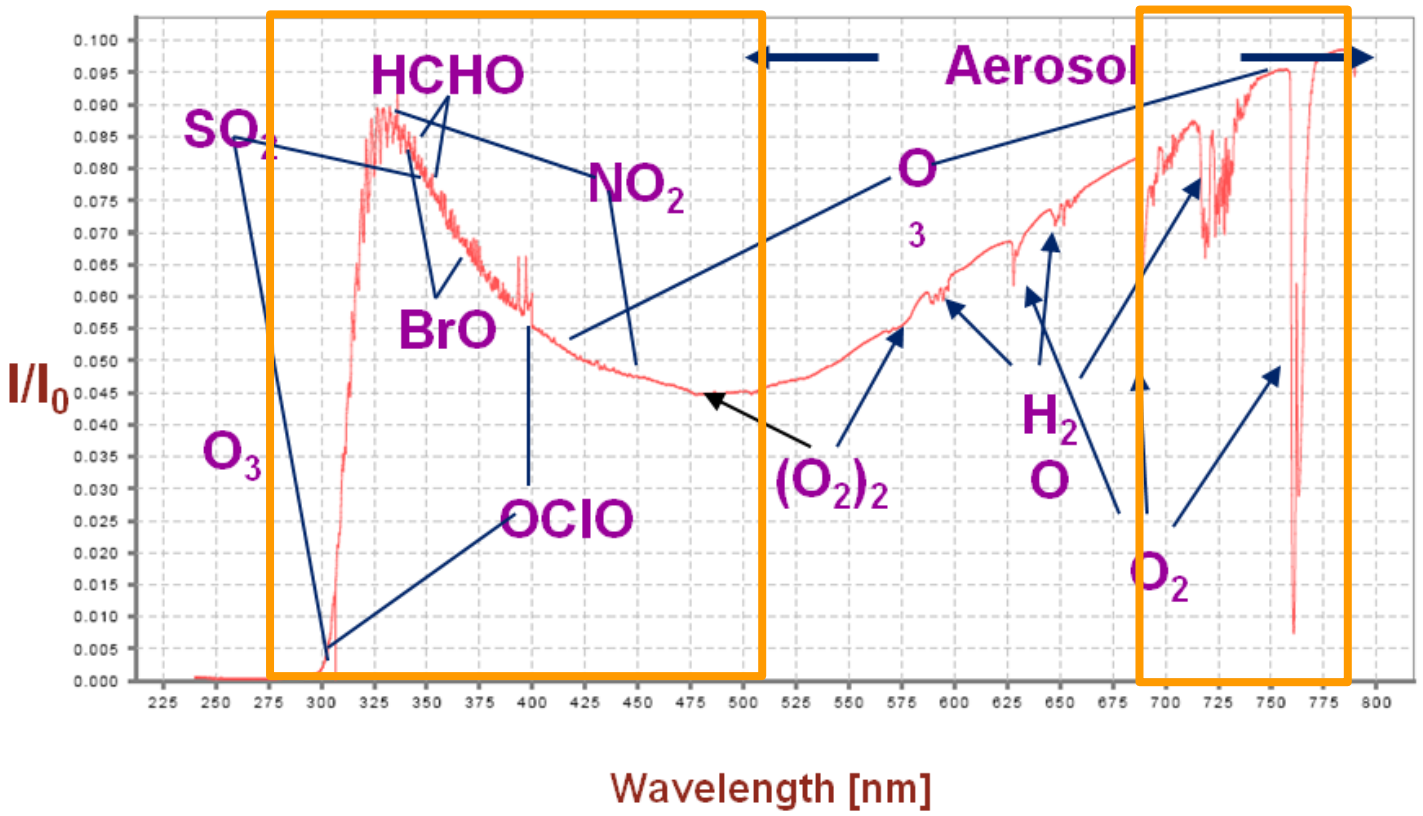
Benefits from the MTG Lightning Imager (LI)

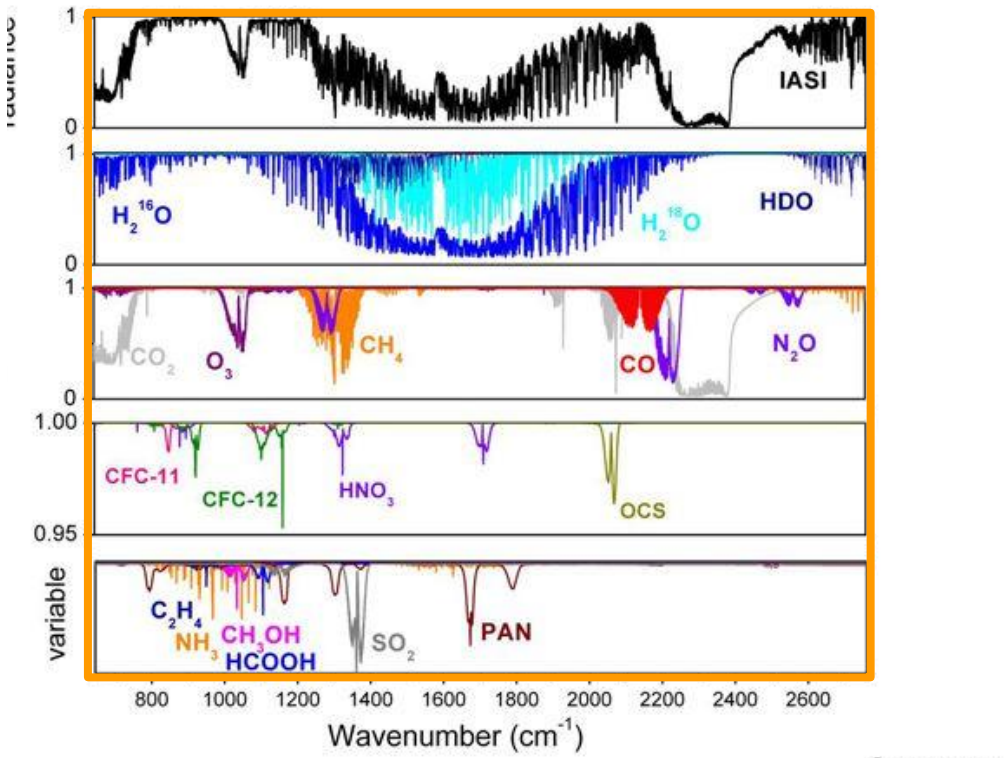
- **Main benefit from GEO lightning observations**:
  - homogeneous and continuous observations delivering information on location and strength of lightning flashes to the users with a timeliness of up to 30 seconds

- **Main objectives are to detect, monitor, track and extrapolate in time:**
  - Development of active convective areas and storm lifecycle
  - Lightning climatology
  - Chemistry (NOx production)

- **Furthermore:**
  - Good coverage in developed countries and around major airports
  - Most areas of the earth are without any good-quality lightning data from ground, but with significant severe weather and lightning causing risks for aviation (e.g. Africa)
  - This situation on the availability of ground-based data is not expected to change in the near future (technical/physical limitations)

MTG synergy: Sentinel-4 and IRS



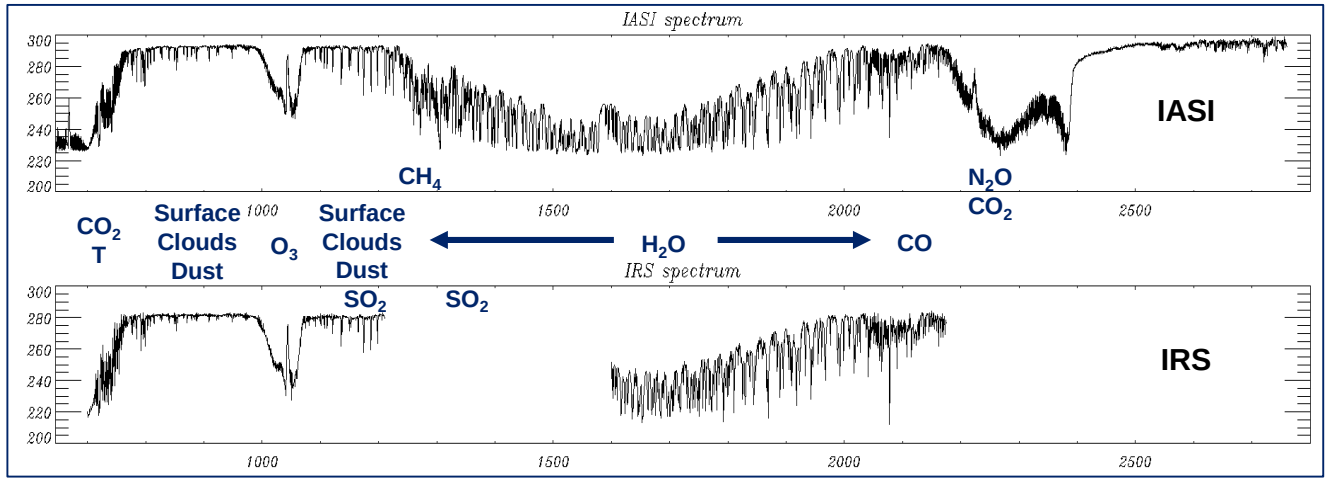


Part 2: Benefits to nowcasting

IRS *and example applications*

IRS has a IASI L2 operational heritage

IRS and IASI → same family of measurements



!! Limitations / Hurdles

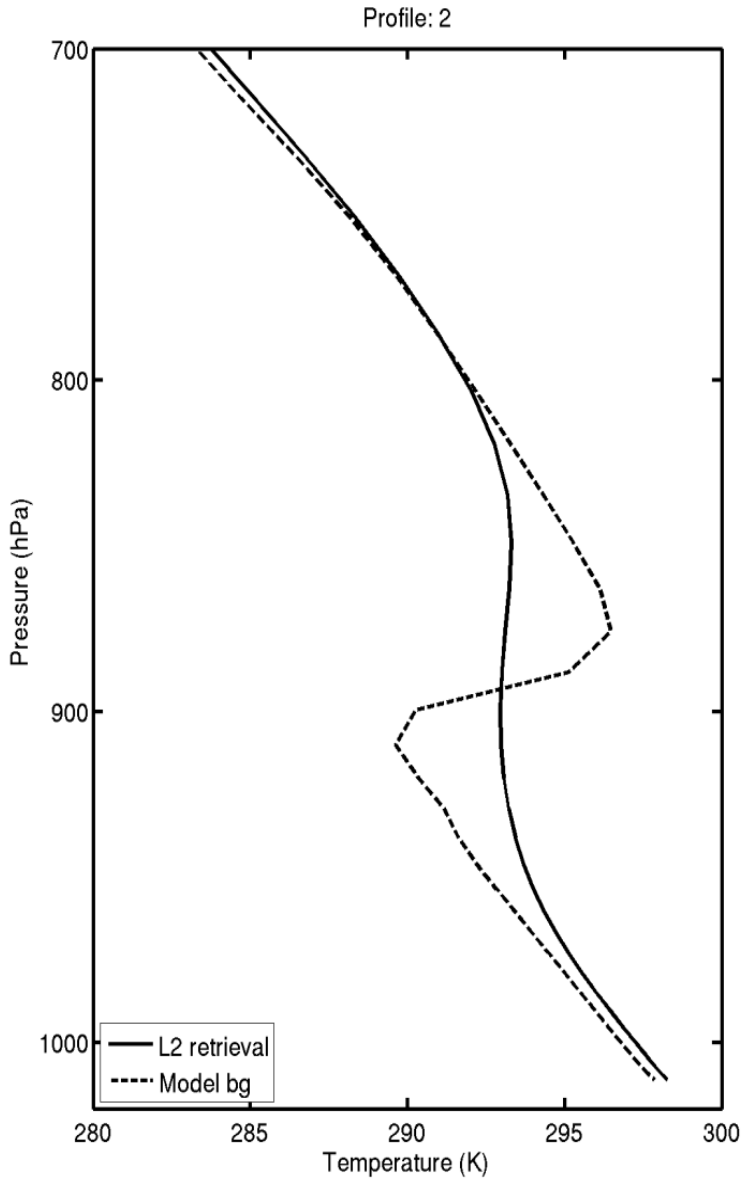
- IR-only, no microwave companion on MTG
- Coarser spectral resolution/coverage
- Viewing geometry (i.e. sat. sza > 58º)
- Data volume: ~100x more than IASI

➔ *Proven CPU-effective processing required*

++ Opportunities

- Spatial resolution *(4km vs. 12km)*
- Temporal repetition *(30' vs. 2x/day)*
- Complementarity GEO/LEO

A note on the vertical resolution



The measurements do not contain information about small low-level inversions or fine-scale vertical variations.

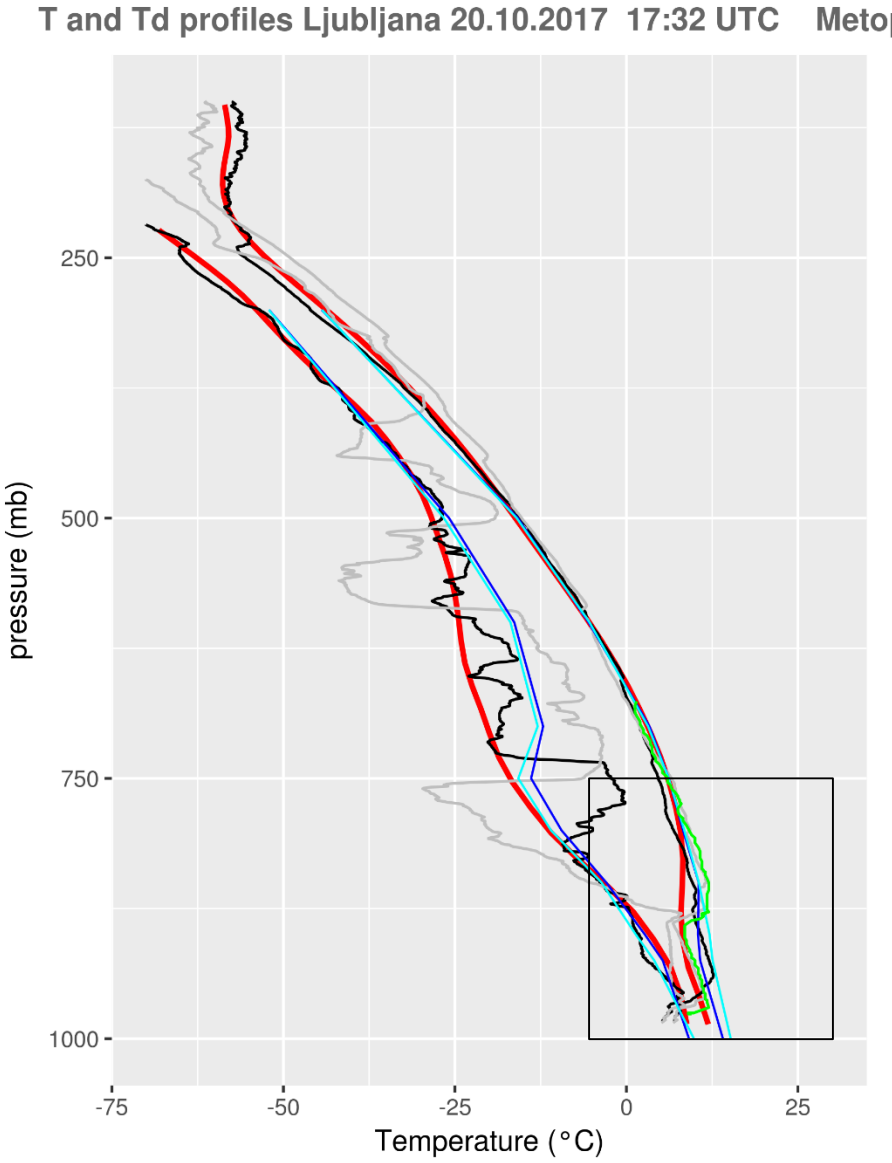
!! Small vertical structures do not affect the radiances at the top of the atmosphere.

!! Sensitivity and resolution of hyperspectral sounder is lower near the surface.

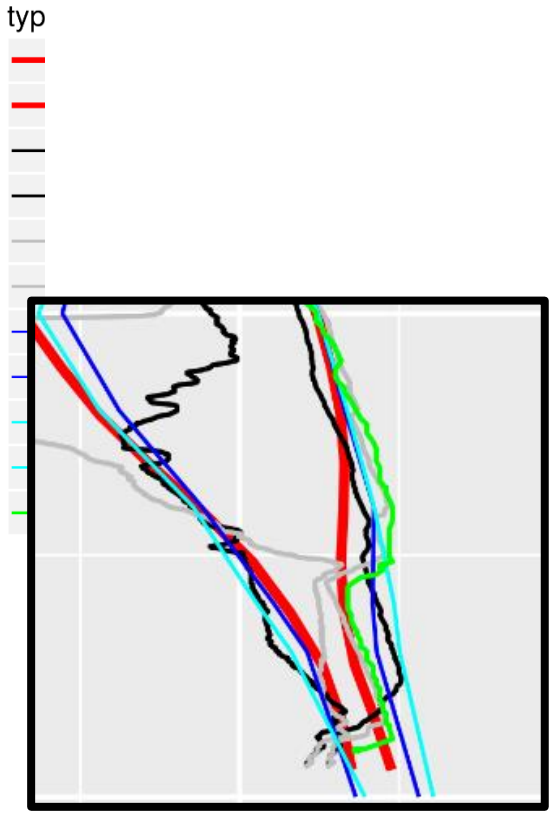
→ What can be retrieved is hence smoother than profiles obtained from radiosondes

NB: req. for IASI: 1K / 1km for T, 10% / 2km for Q

Case study: Ljubljana 20 November 2017



Regional NWP ALADIN analyses (ANA_)**,
NWP ALADIN forecast (15 UTC+3 hours = GUE)
Radiosonde Morning (TEMP) and next day (NEXT_TEMP)*
METOP/IASI level2 (from the archive, over Ljubljana ~19 UTC)
MODE-S Aircraft obs. (only T ~19 UTC) – the most relevant in-situ reference



First results:

IASI/level2 T and Td profiles, do not capture the exact elevated temp. inversion (see MODE-S), however the info on „constant“ temp layer is very well seen and is beneficial for the forecaster. It gives added value to the current NWP info (NWP on the plot is without assimilation of IASI level 1 – but will be soon checked for this case)

*** Please, be aware that radiosonde data are from the morning (5 UTC) and do not represent the time of METOP overpass.**
**** Be aware that ALADIN analyse is available 1-2h after 18 UTC.**

Data: Mateja Irsic, ARSO

AGENCIJA RS ZA OKOLJE

EUMETSAT

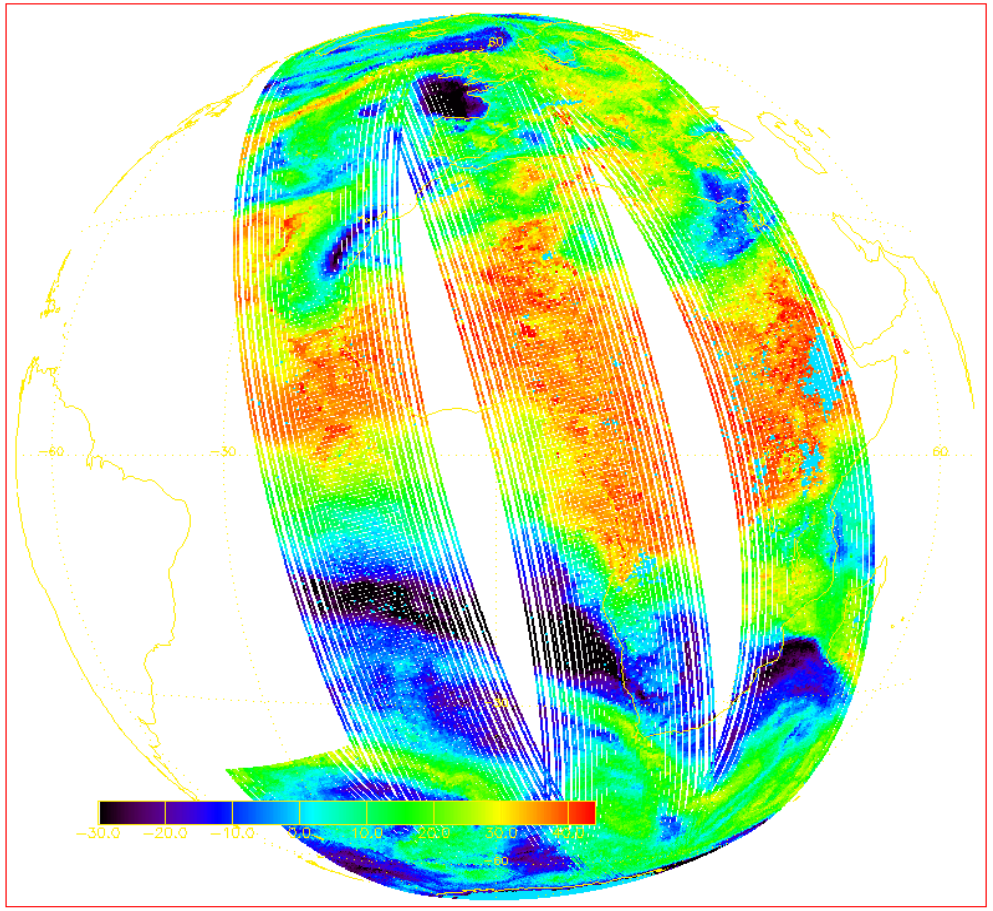
Profiles from satellites – today

IASI Level 2

Satellite derived profiles (and indices)

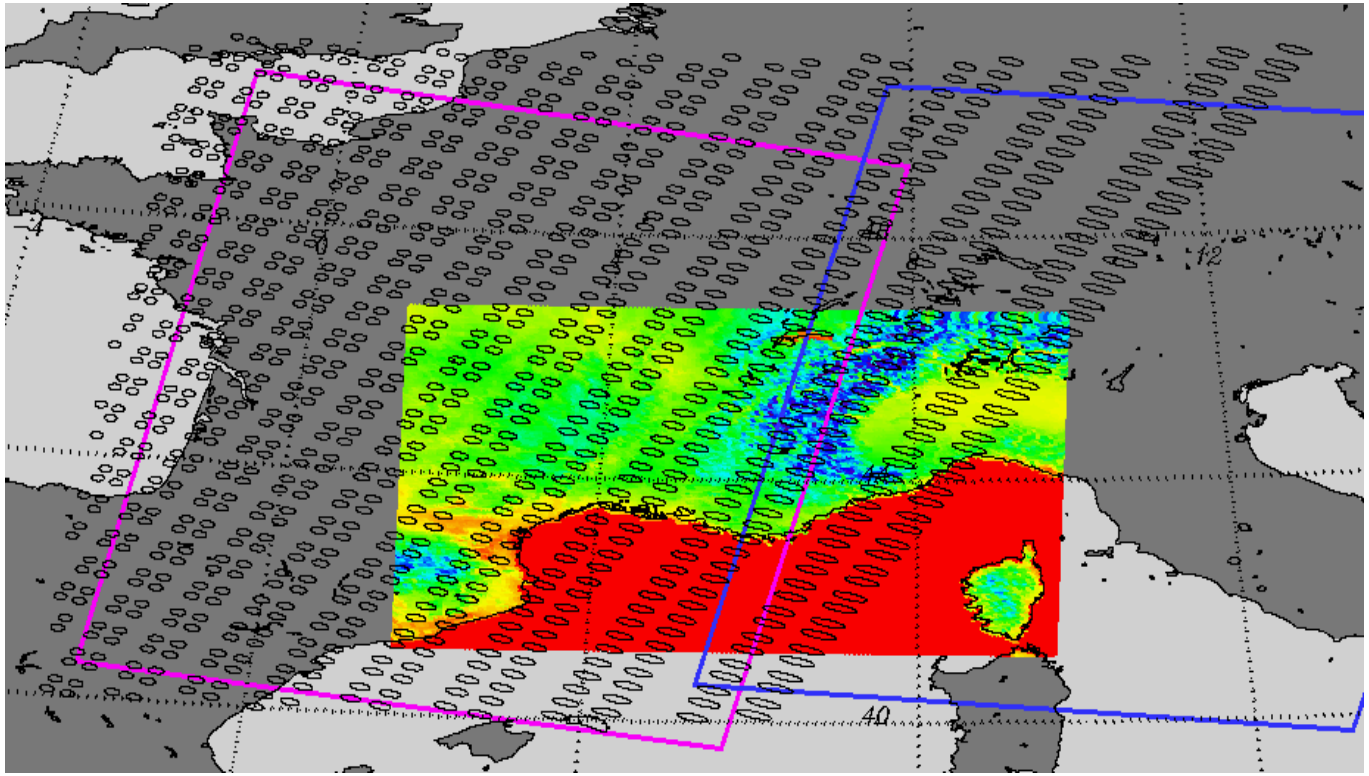
information in cloudy areas (combined MW+IR) and at high latitudes (Polar orbit).

Some users are starting to use IASI L2 to prepare for MTG-IRS and the knowledge base of application is growing

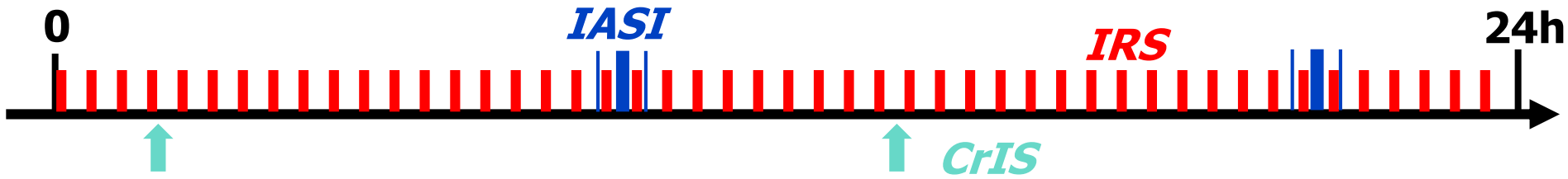


IRS: atmospheric sounding - high spatial/temporal resolution

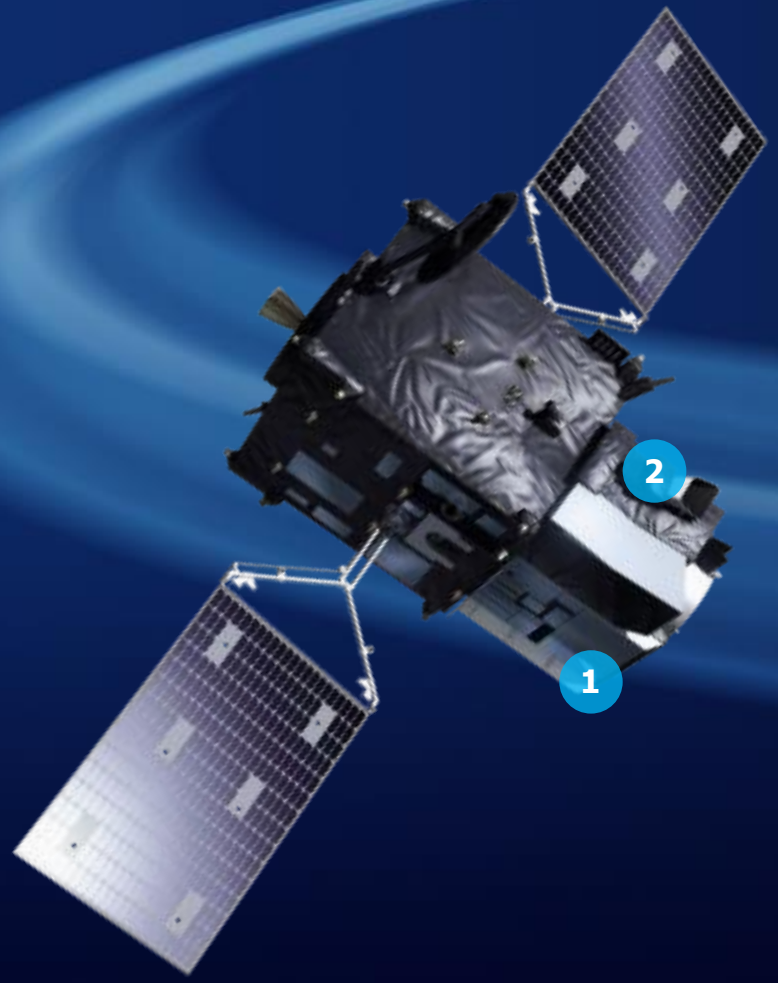
IASI footprints 12-40km Not-contiguous 2x per day



IRS pixels ~7km Contiguous Every 30'



MTG: Sentinel-4 and IRS



1. **IRS**
   Infrared Sounder
2. **Copernicus Sentinel-4**
   Ultra-violet, Visible and Near-Infrared Sounder

MTG: synergy between IRS and Sentinel-4

IRS on MTG-S

O_3

CO

NO_2

SO_2

VOC(H_2CO, CHOCHO)

Aerosol/PM

S4-UVN on MTG-S