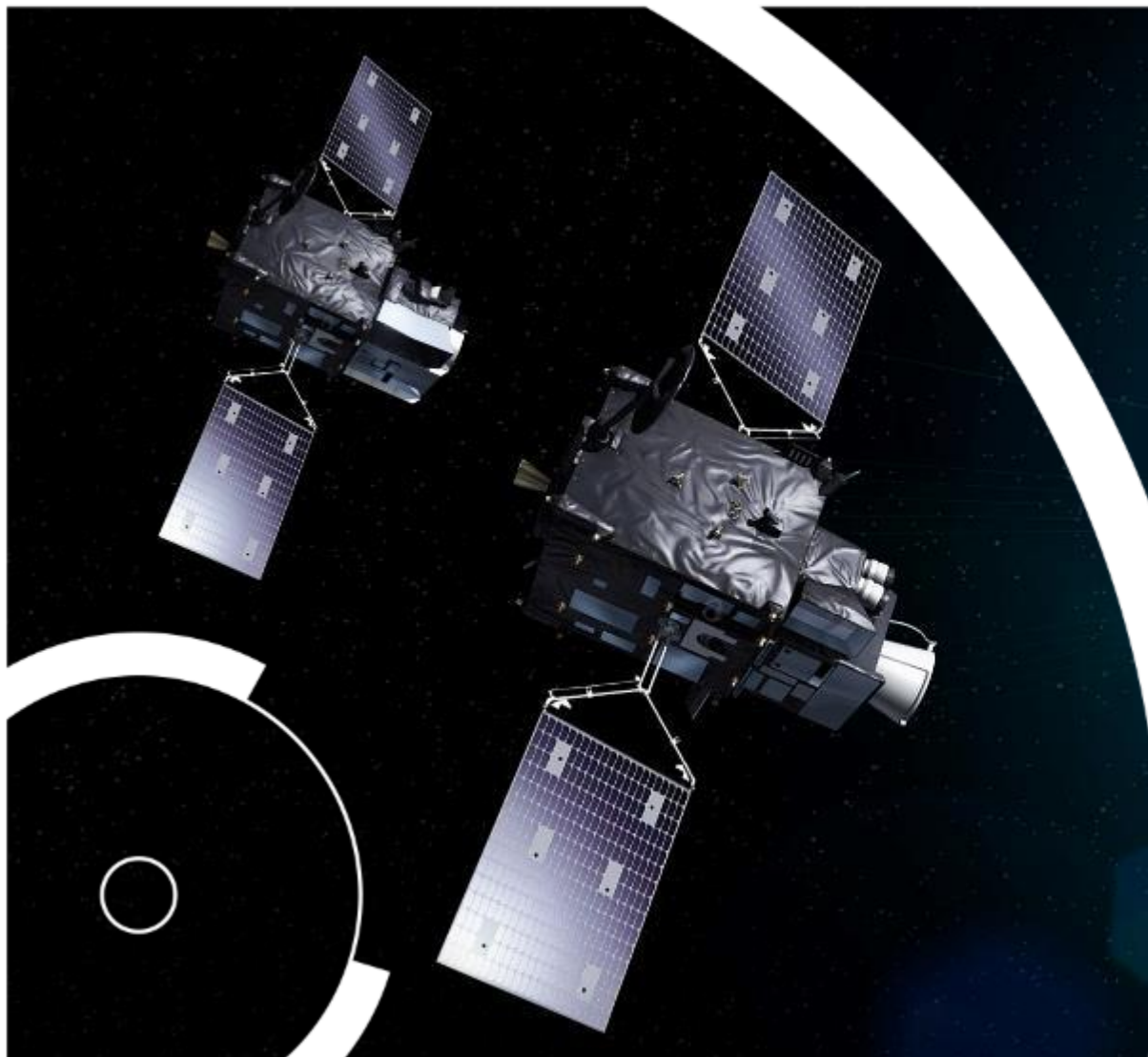




Nowcasting severe storms using full-constellation Meteosat Third Generation satellite data

Natasa Strelec Mahovic, Stephan Bojinski
EUMETSAT

ECSS 2025, Utrecht, Netherlands, 17-21 November 2025

Initial Joint Polar System

In commissioning

Copernicus satellites delivering marine data services from 814km altitude

Copernicus ocean surface topography mission (shared with CNES, NOAA, NASA and Copernicus)

Copernicus ocean surface topography mission (shared with NASA, NOAA, ESA and Copernicus with support from CNES)

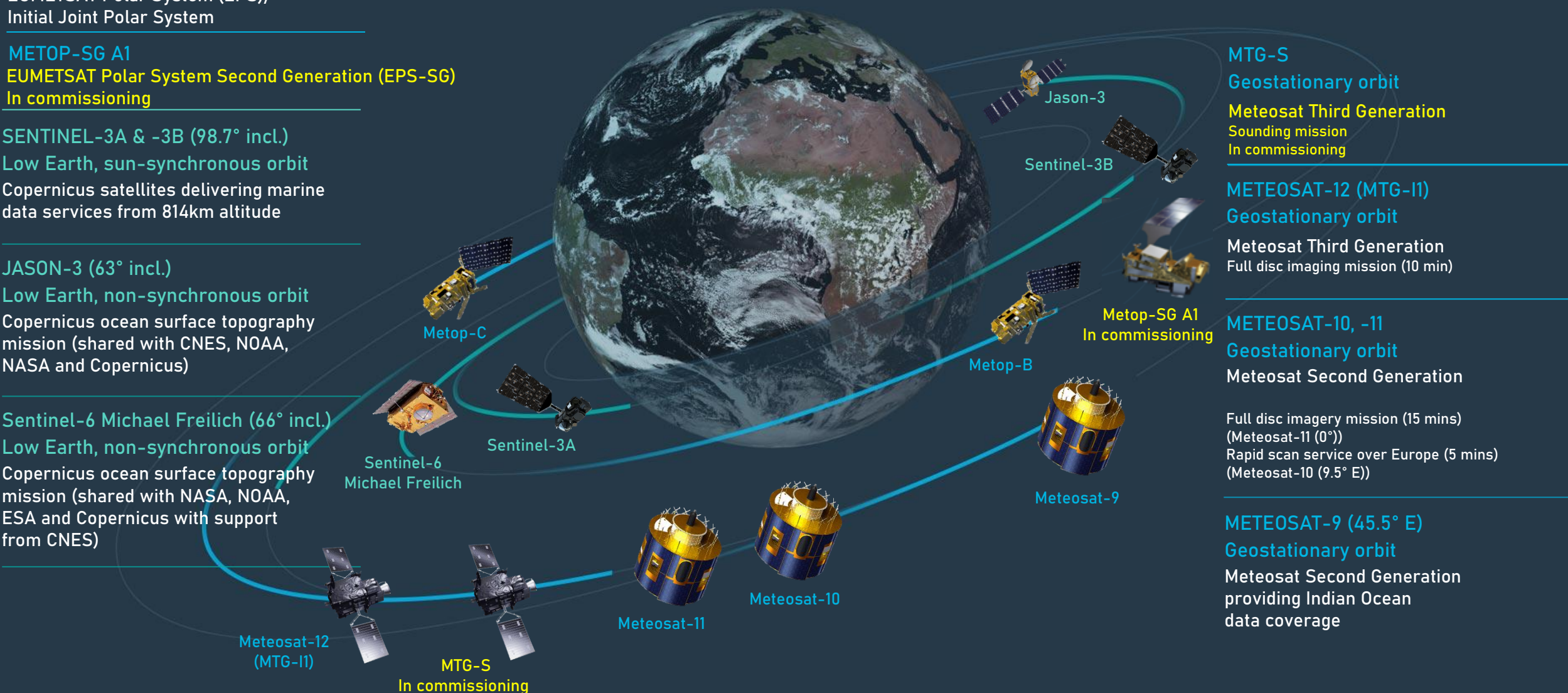
In commissioning

Full disc imaging mission (10 min)

Meteosat Second Generation

(Meteosat-10 (9.5° E))

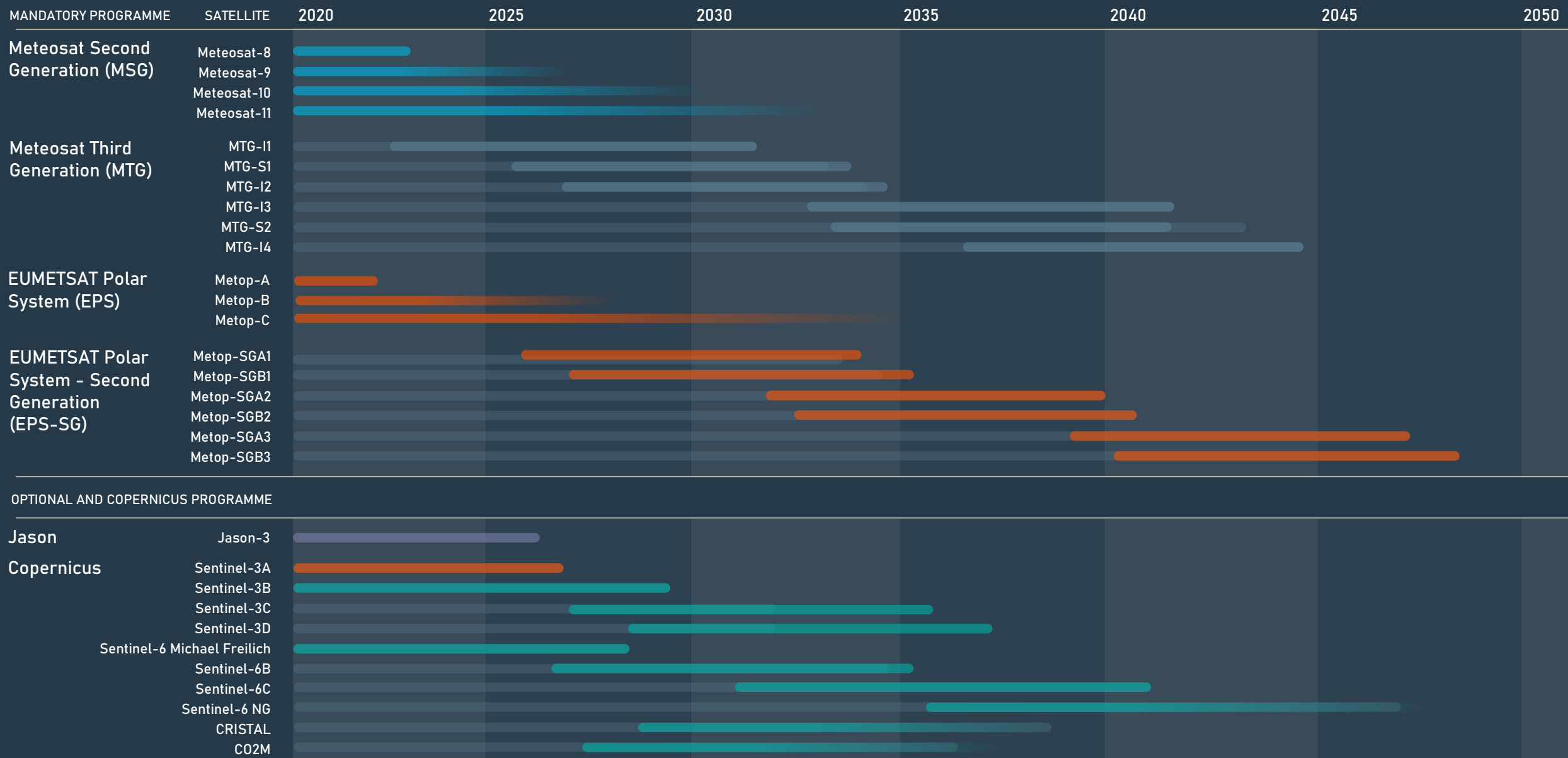
Meteosat Second Generation providing Indian Ocean data coverage





EUMETSAT mission planning

www.eumetsat.int





MTG Mission Objectives

www.eumetsat.int

MTG-I

Full Disc image service

- 16 spectral channels over Europe and Africa every 10 minutes
- Lightning Imager

MTG-S

Full Disc sounding service

- Hyperspectral Infrared Sounder
- Copernicus Sentinel-4 UVN

MTG-I

Rapid Scanning Service

- 16 spectral channels over Europe every 2.5 minutes

Primary mission:

- **Support Nowcasting/ Short Range Forecasting of high impact weather**
 - This is achieved through:
 - Continuity and enhancement of MSG imagery
 - Addition of a new lightning imaging capability
 - New, innovative infrared hyper-spectral sounding

Secondary mission:

- **Air quality monitoring over Europe**
 - This is achieved through:
 - Synergy between Sentinel-4, Infrared Sounder and Imagery



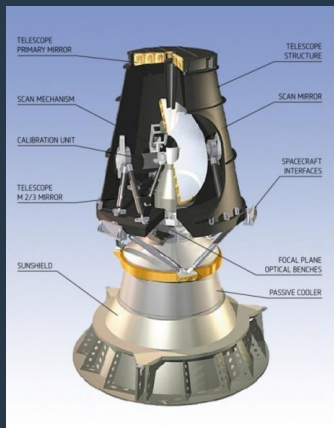
- Flexible Combined Imager (FCI)
 - Full disc imagery every 10 minutes in 16 bands (MTG-I1)
 - Fast imagery of Europe every 2.5 minutes (MTG-I2)
- Lightning Imager (LI)
- MTG-I1 launched 13 December 2022, operational 4 December 2024 (Meteosat-12)



MTG-I imaging mission

www.eumetsat.int

SEVIRI



SEVIRI on current Meteosat Second Generation satellites

15 min full disc repeat cycle

SNR 1.2 to 10.1

NEdT 0.25-1.8K

IR3.9 up to 335K

11 x 3.0 km non-HRV channels

1.0 km High-Res Visible channel

FCI on new Meteosat Third Generation satellites

10 min full disc repeat cycle

SNR 12 to 40

NEdT 0.1-0.3K

IR3.8 up to 450K

Normal resolution (FDHSI):

- 8 x 1.0 km channels
- 8 x 2.0 km channels

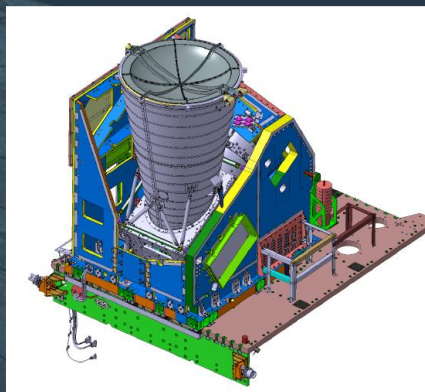
High resolution (HRFI):

- 2 x 0.5 km channels
- 2 x 1 km channels

New channels

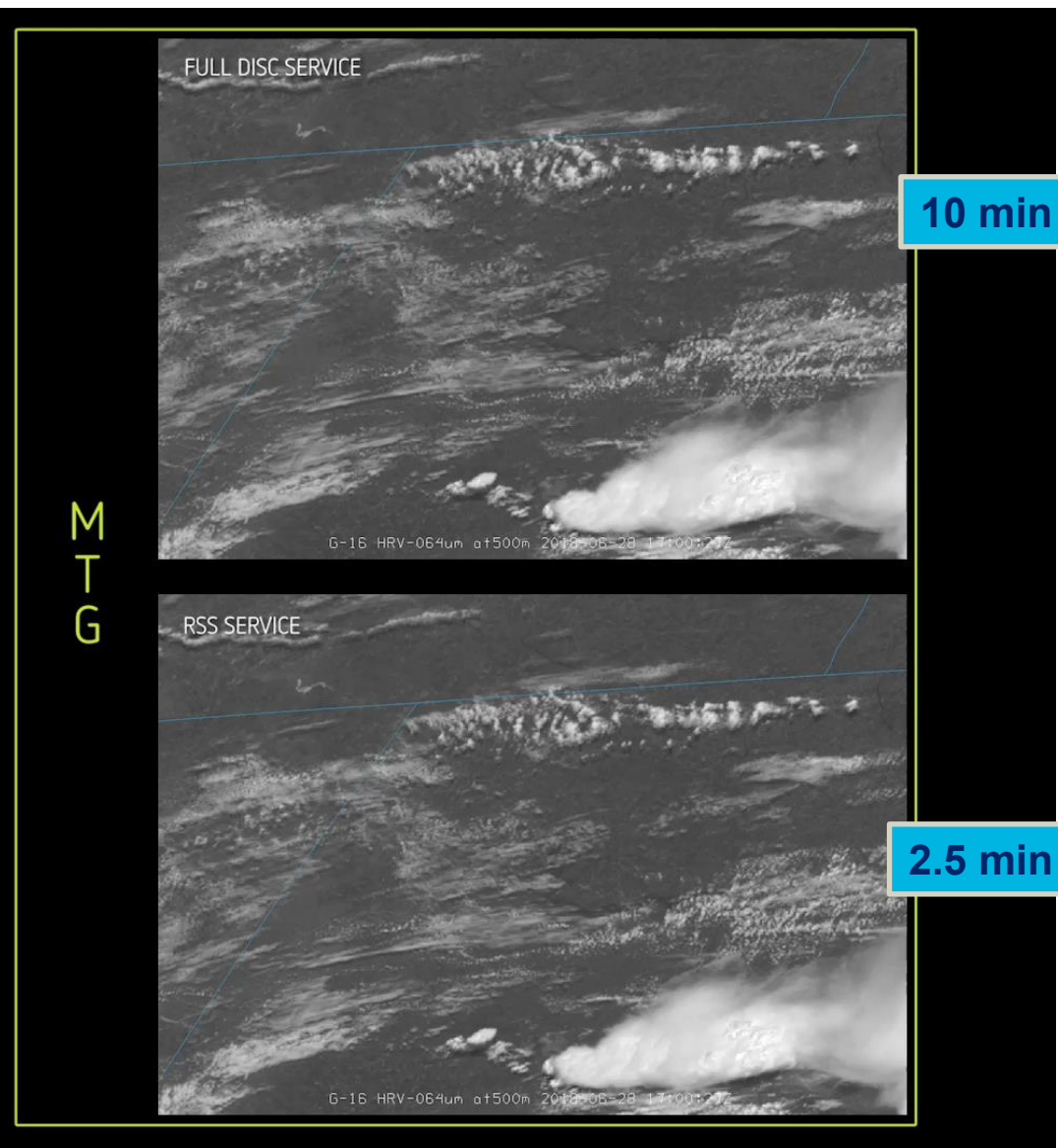
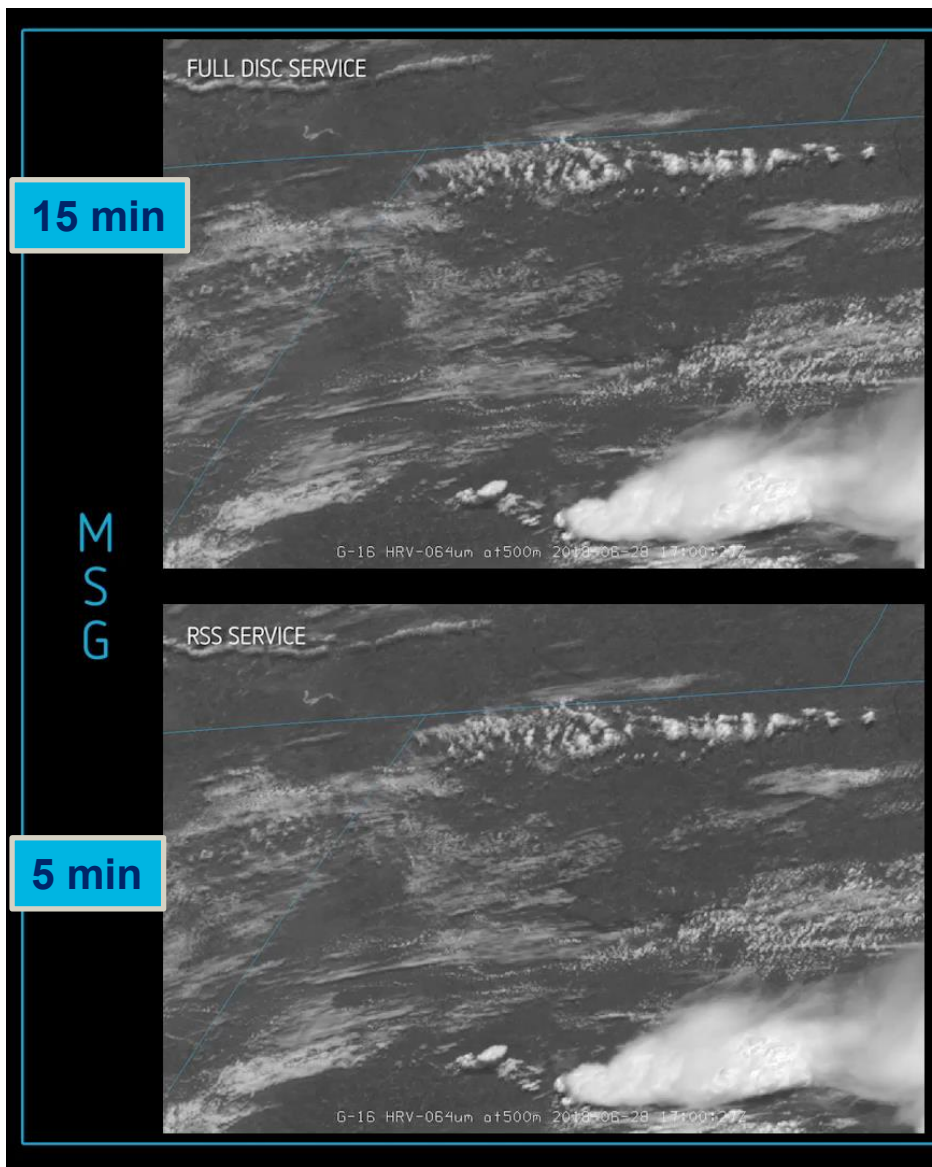
- VIS0.4
- VIS0.5
- VIS0.9
- NIR1.3
- NIR2.2

FCI





Temporal resolution

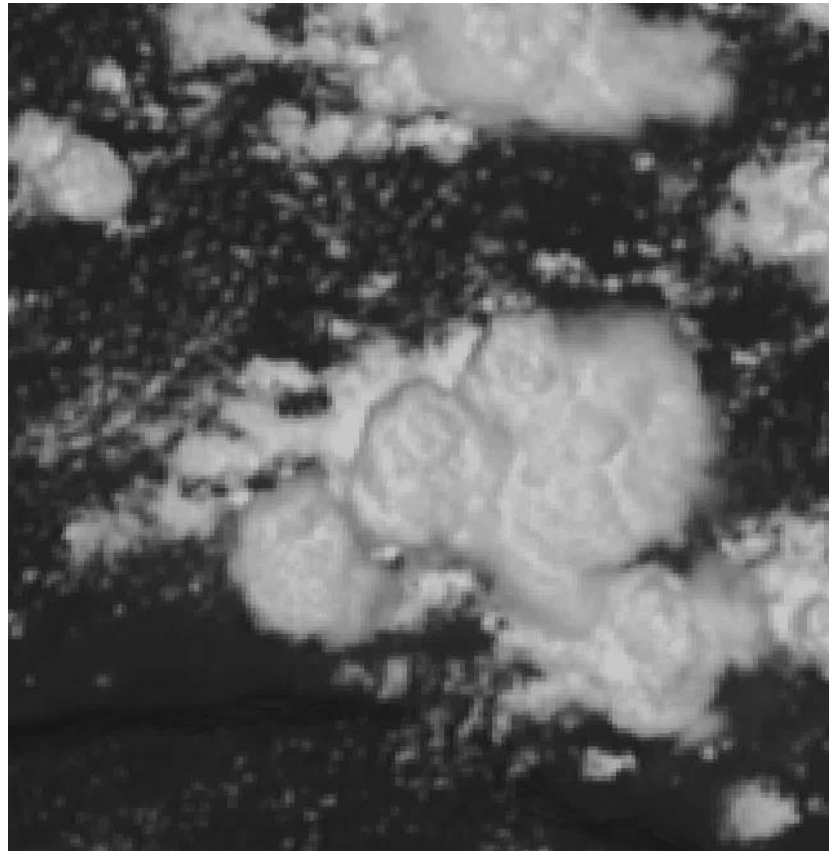




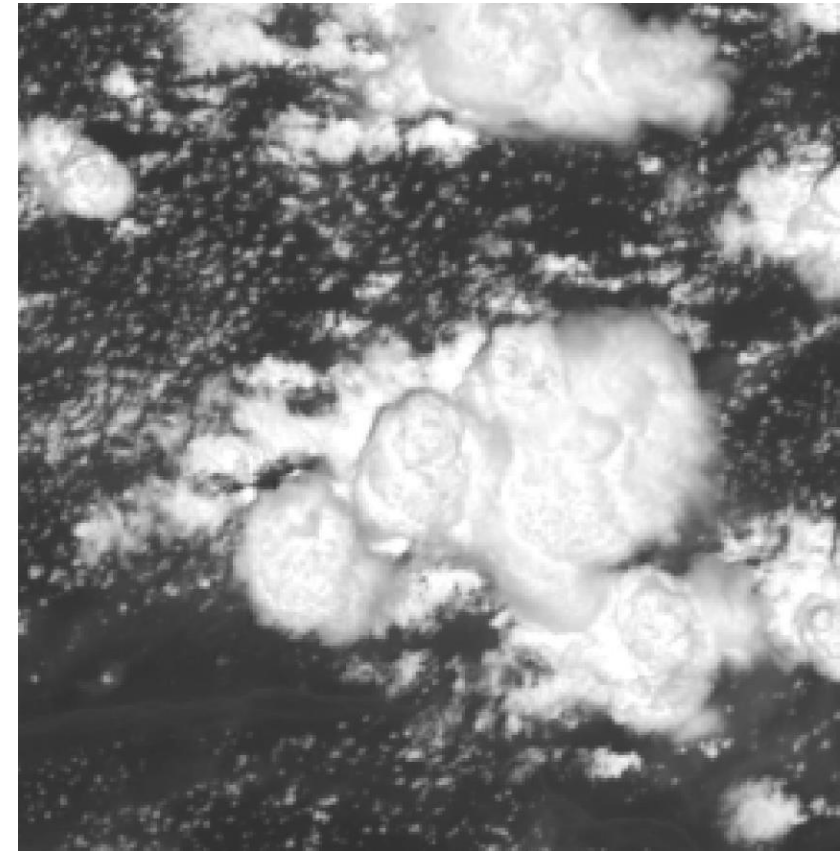
Spatial resolution



SEVIRI VIS0.6
3 km



SEVIRI HRV
1 km



FCI VIS0.6
500 m



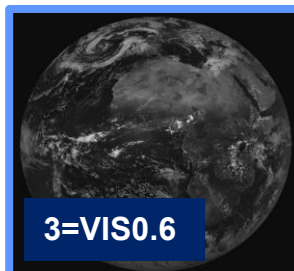
MTG FCI – channels



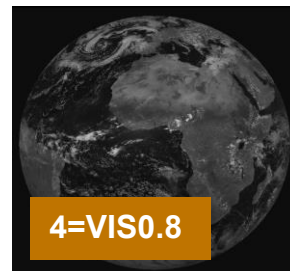
1=VIS0.4



2=VIS0.5



3=VIS0.6



4=VIS0.8

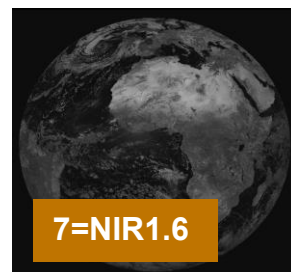


5=NIR0.9



6=NIR1.3

Solar channels
available with
1.0 km (& 0.5 km)
resolution

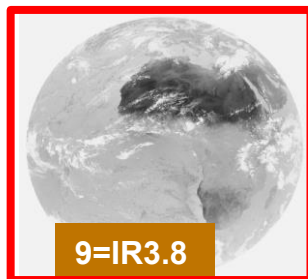


7=NIR1.6

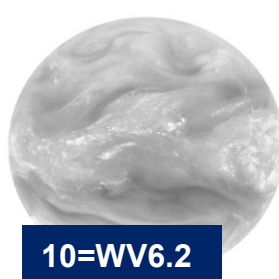


8=NIR2.2

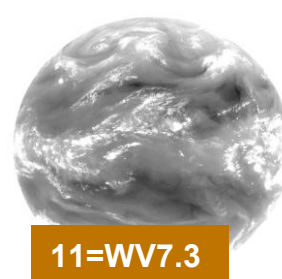
Thermal channels
available with
2 km (& 1 km)
resolution



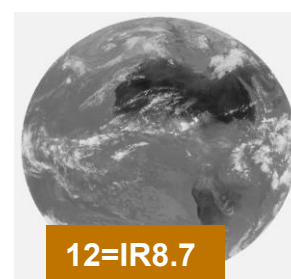
9=IR3.8



10=WV6.2



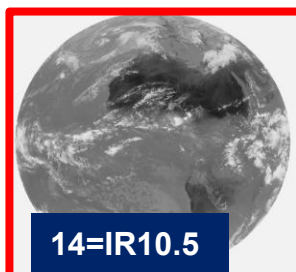
11=WV7.3



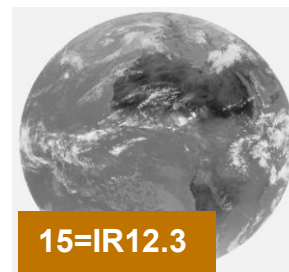
12=IR8.7



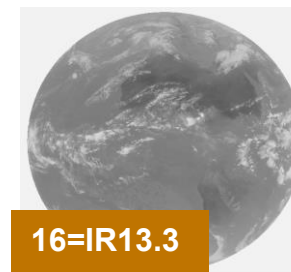
13=IR9.7



14=IR10.5



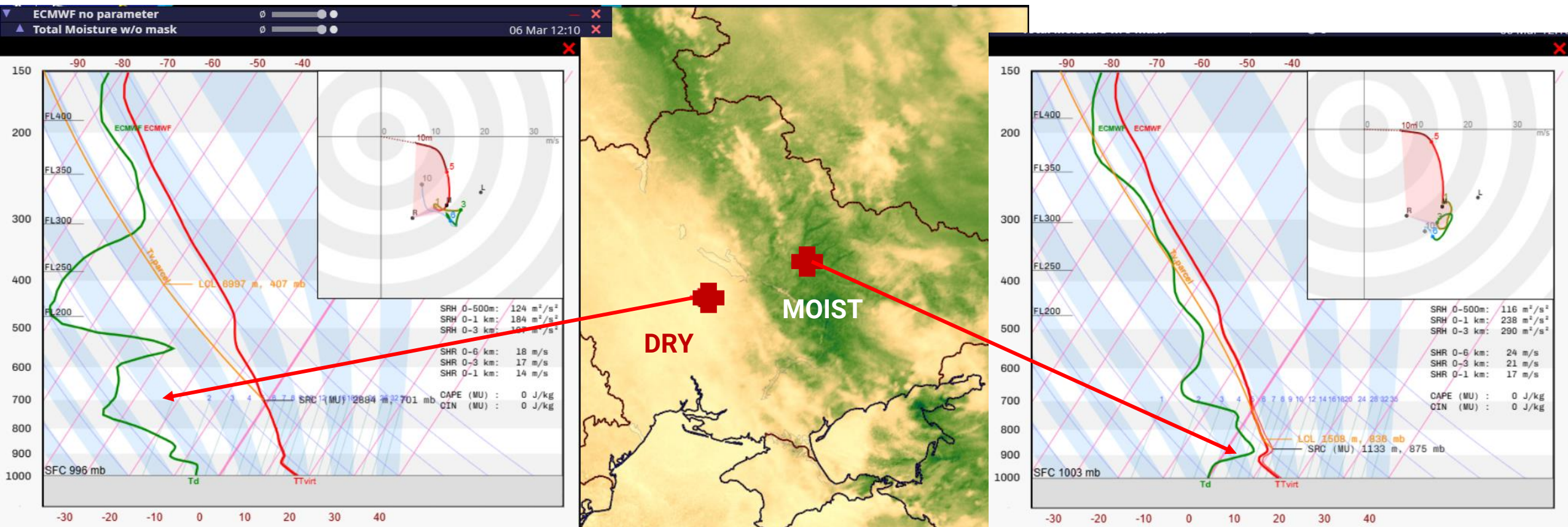
15=IR12.3



16=IR13.3



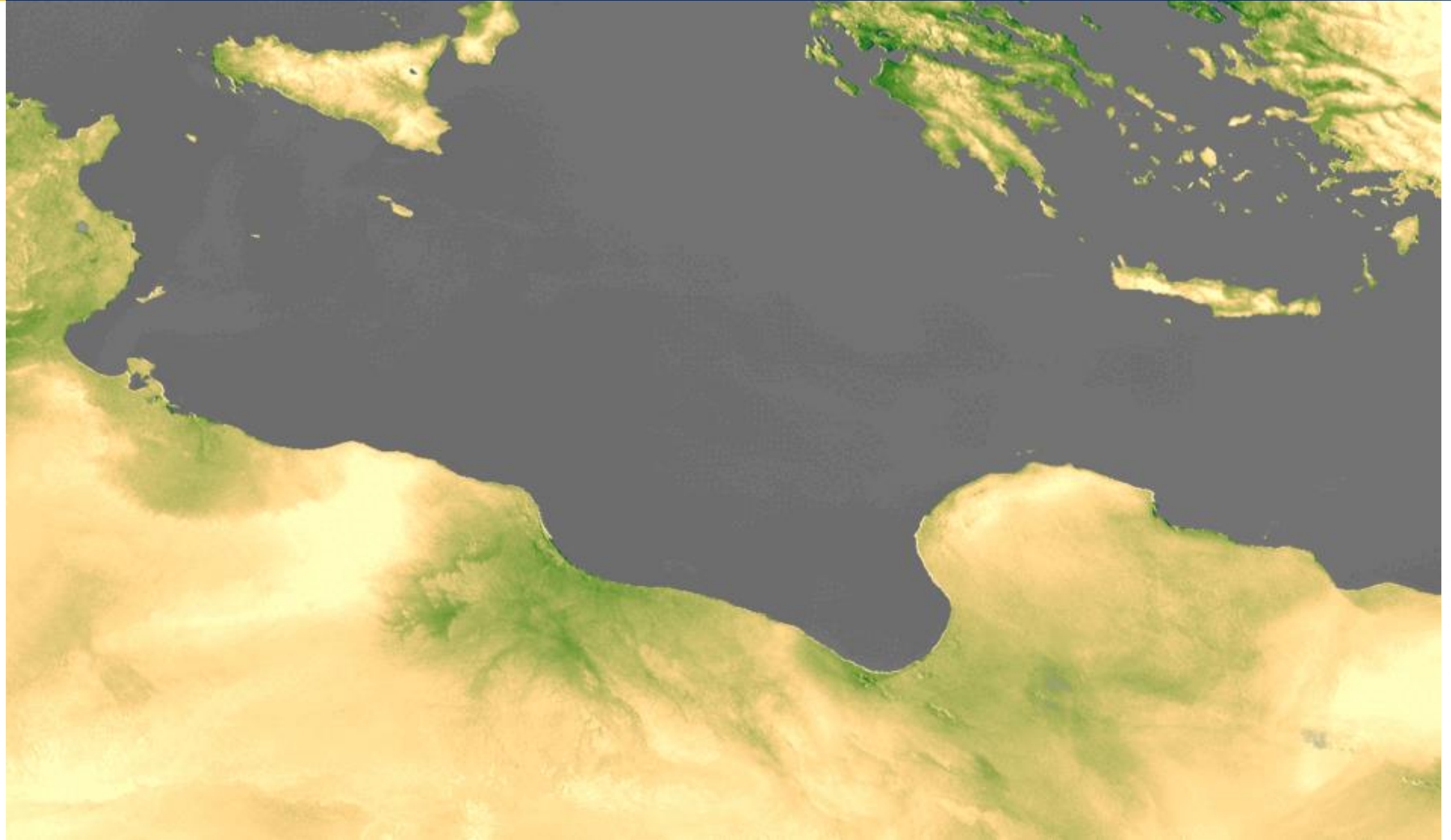
VIS0.9 channel – humidity assessment



Ratio between VIS0.9 and VIS0.8 offers view of the total column moisture content – important for pre-convective conditions assessment.

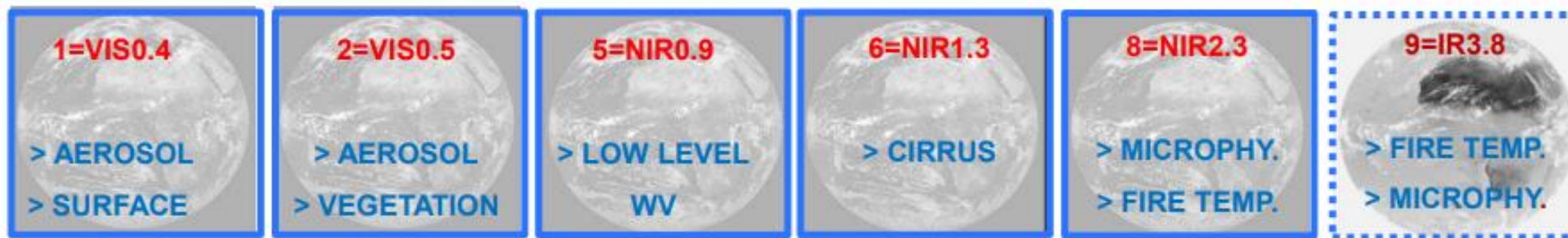


VIS0.9 channel – humidity assessment: sea breeze



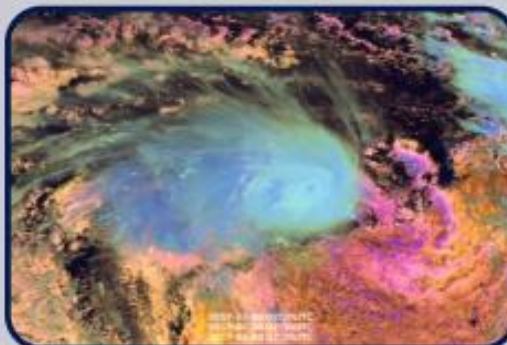


MTG FCI new RGBs



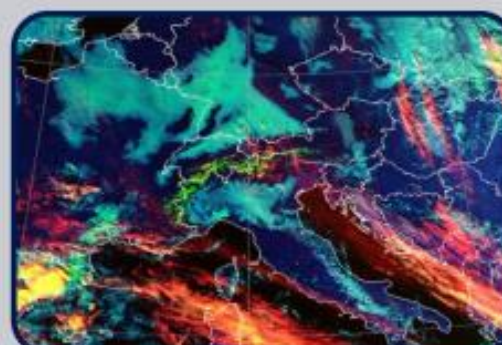
Cloud Phase RGB

R NIR1.6
G NIR2.3
B VIS0.5/VIS0.6



Cloud Type RGB

R NIR1.3
G VIS0.8
B VIS1.6





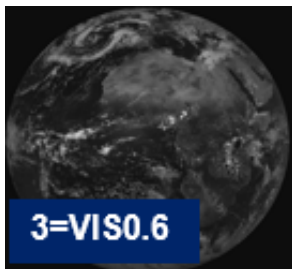
Cloud Phase RGB



7=NIR1.6



8=NIR2.2



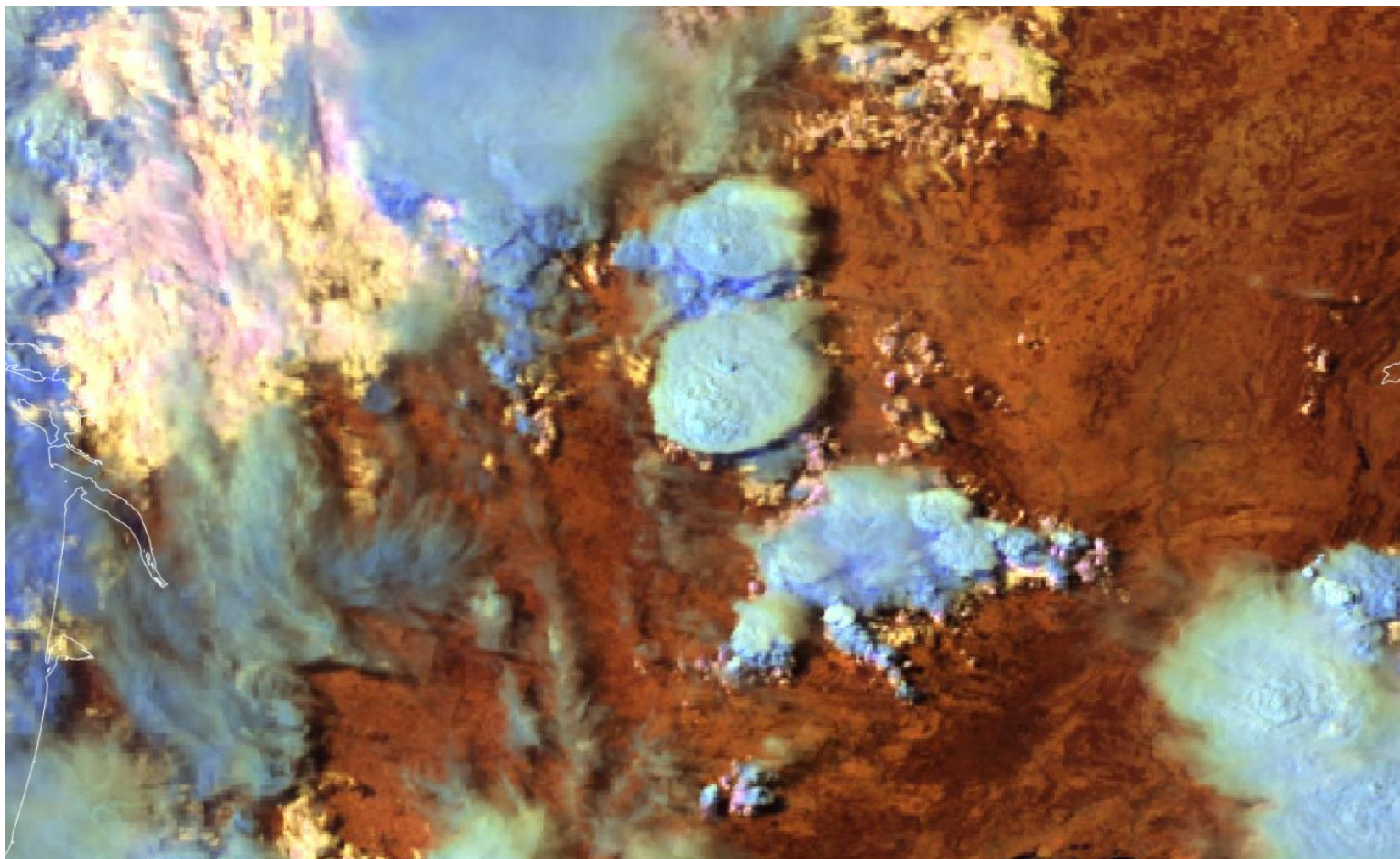
3=VIS0.6



- Cloud phase
- Particle size
- Snow/ice
- Vegetation

13 August 2025, 14:50 UTC

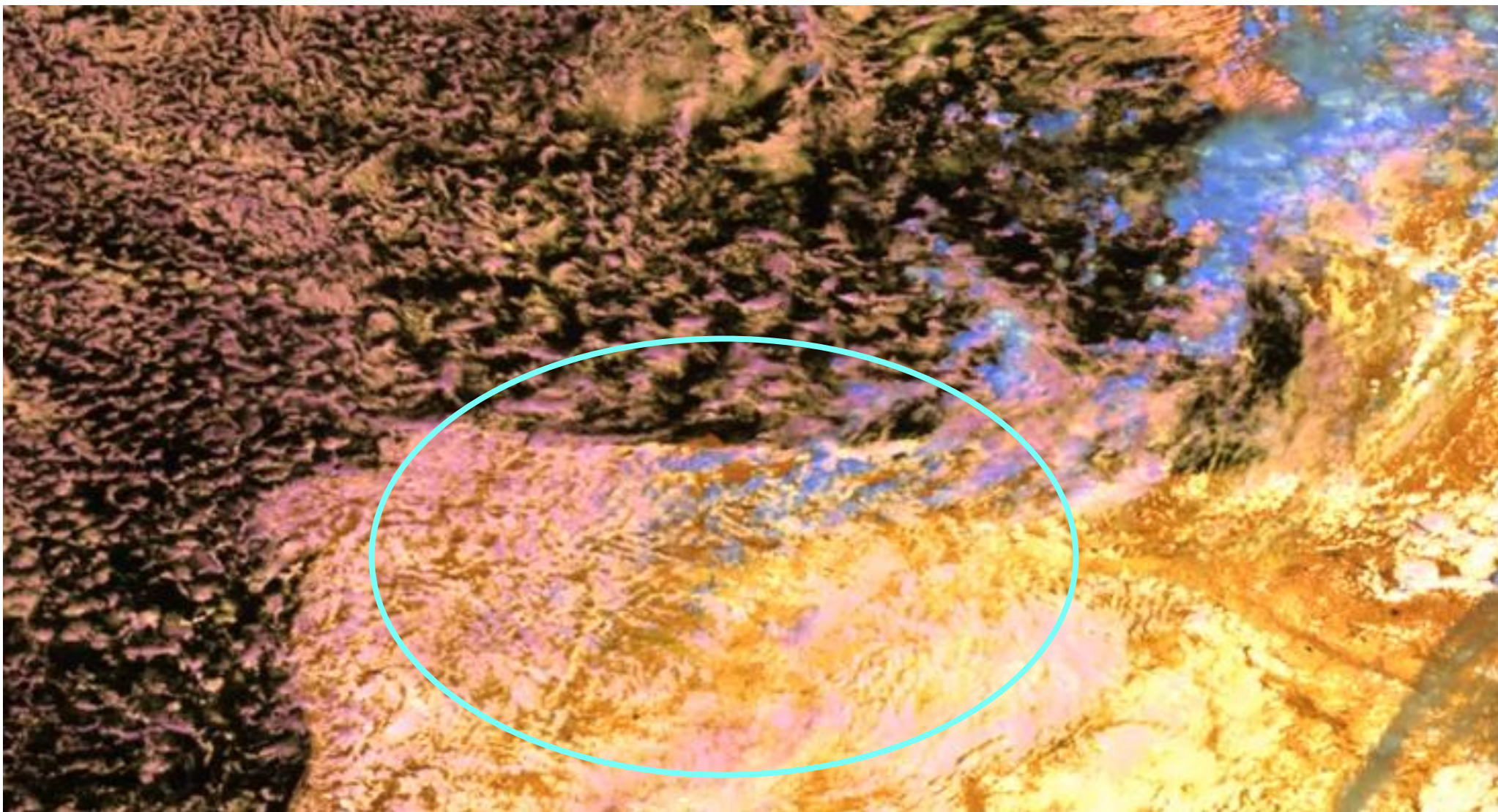
- 1 Thick ice clouds, large particles
- 2 Thick ice clouds, small particles
- 3 Thin ice clouds
- 4 Thick water clouds, small droplets
- 5 Thick water clouds, larger droplets (larger the droplets are darker pink)
- 6 Thick water clouds, extreme large droplets (or thick mixed phase clouds)
- 7 Thin water clouds over sea
- 8 Vegetated land (snow free)
- 9 Sea (ice free)
- 10 Desert
- 11 Snow on ground or sea ice





Cloud Phase RGB - cloud growth and glaciation

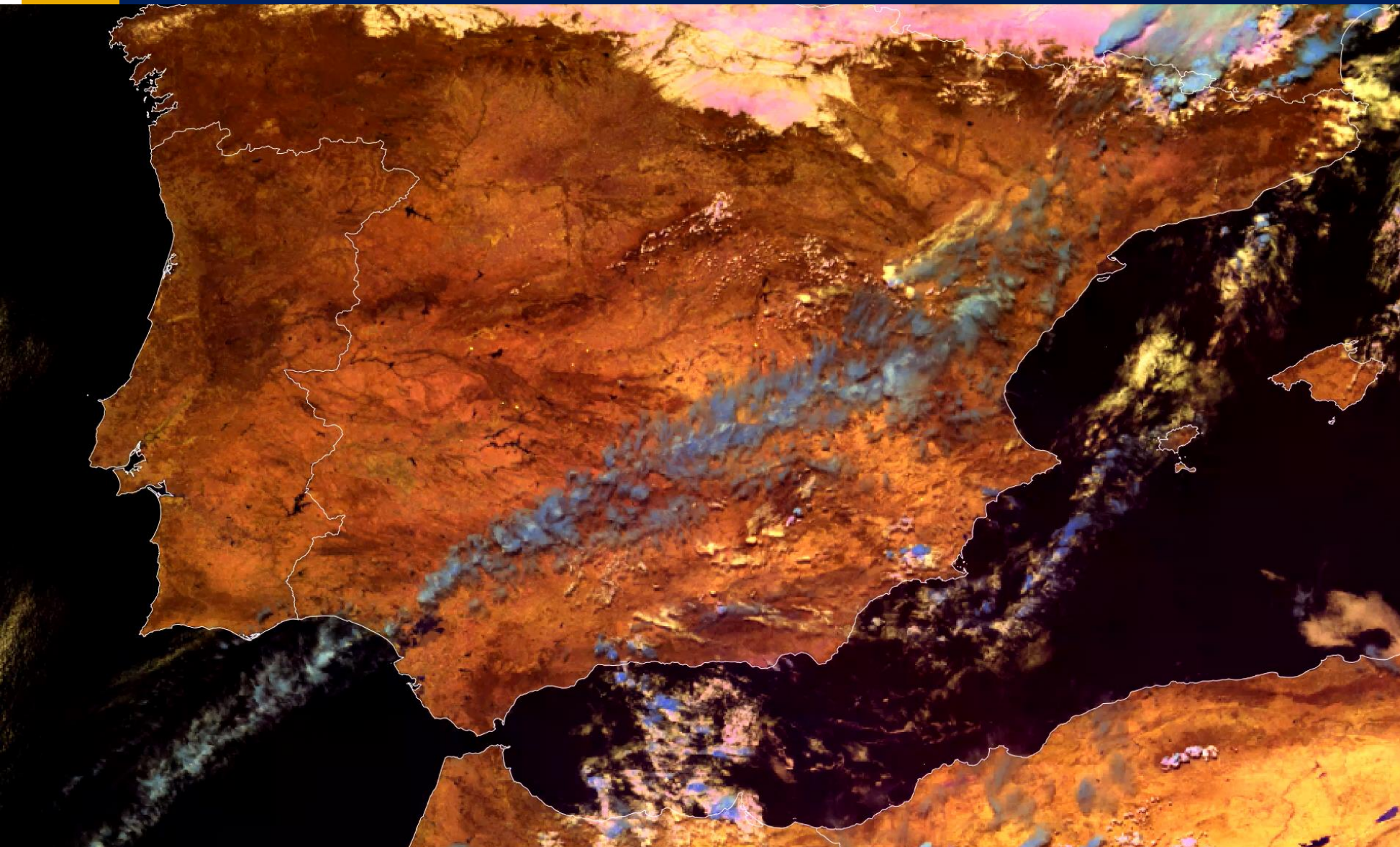
MTG-I1 Cloud Phase RGB - 18 March 2023, 12.00 – 14:30 UTC



Change of
colour from
pink to blue
shades –
freezing of
cloud tops



Cloud Phase RGB – cloud top features

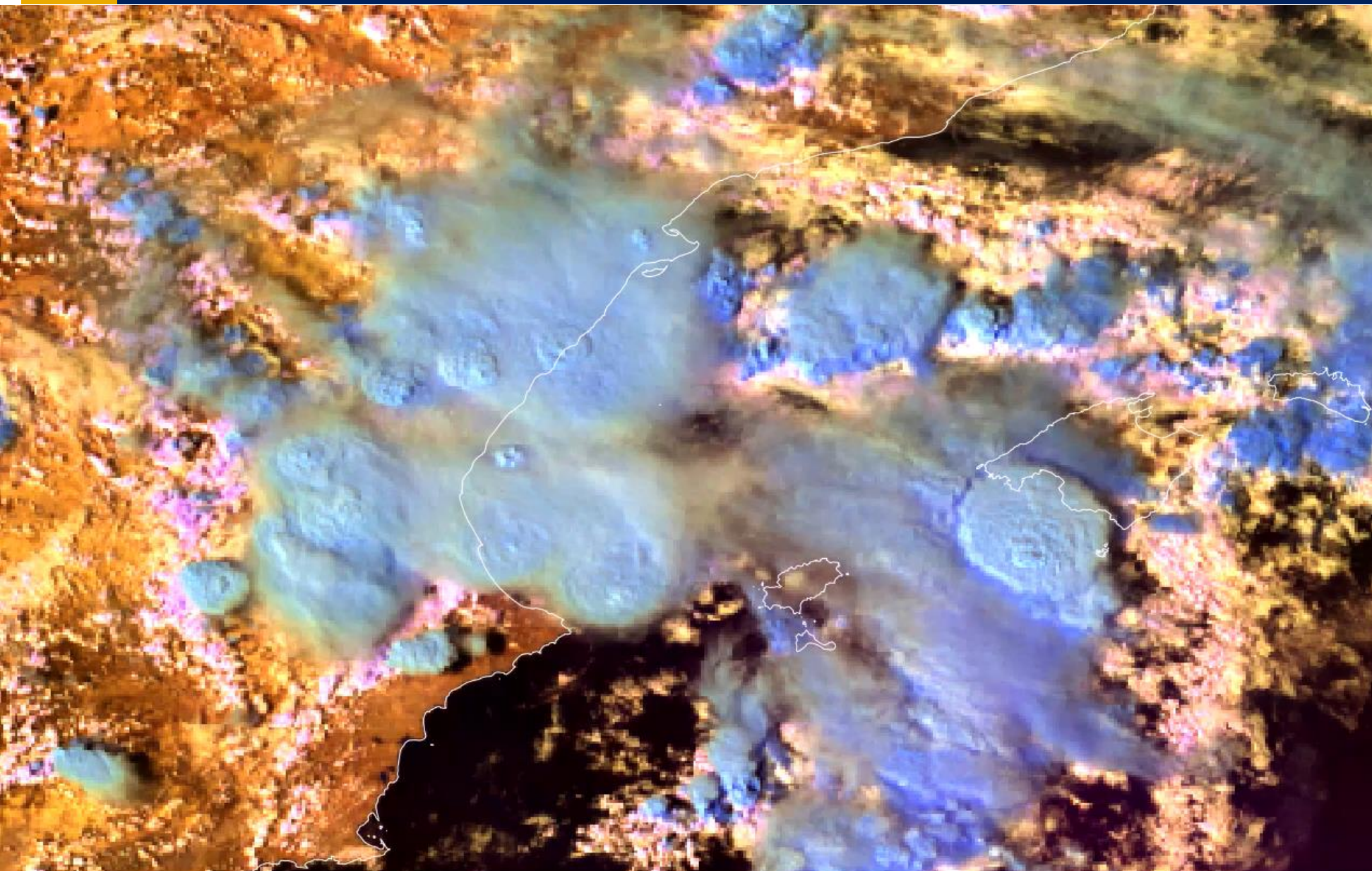


Onset of the storms

OT and new updrafts in the existing storm

Direction of upper-level wind seen from the spread of the anvils

Storm outflow



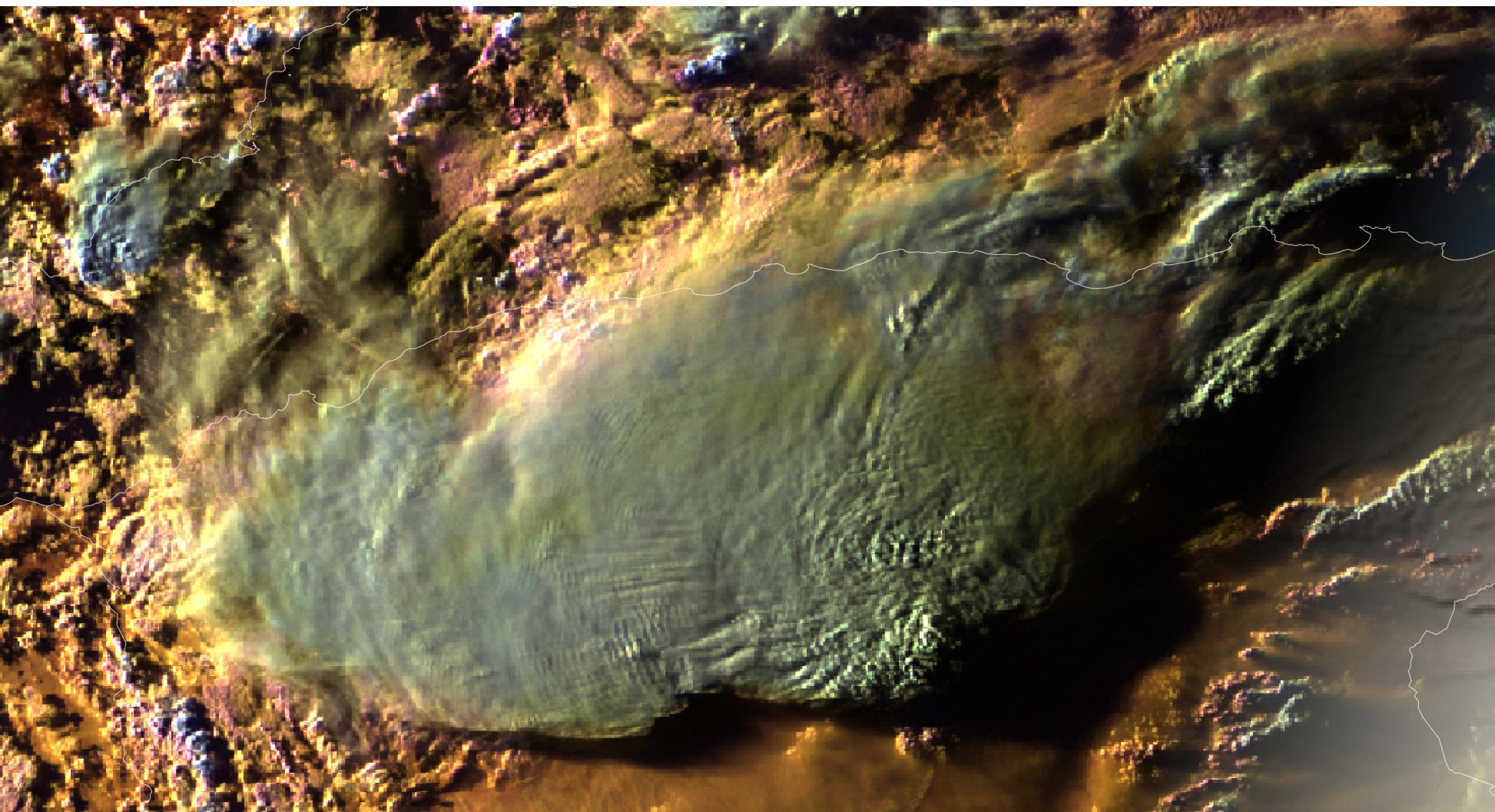
Mature storms

Overshooting tops

Above anvil cirrus
plums

Difference between
small and large
particle ice clouds
> light blue vs darker
blue

Radial spreading cirrus
clouds – divergent
flow



Cloud Phase RGB

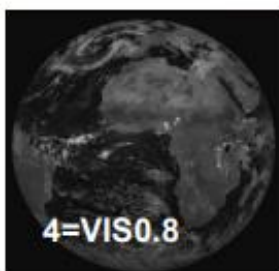
New RGB most
favoured among the
forecasters



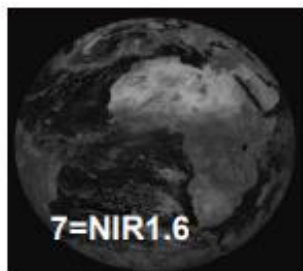
Cloud type RGB



6=NIR1.3



4=VIS0.8



7=NIR1.6



- Cloud optical depth
- Cloud phase
- Snow/ice
- Vegetation

1 Thin cirrus clouds over land and sea (darker red over the seas)

2 Thick ice clouds (multi-layered clouds with ice on top)

3 Land

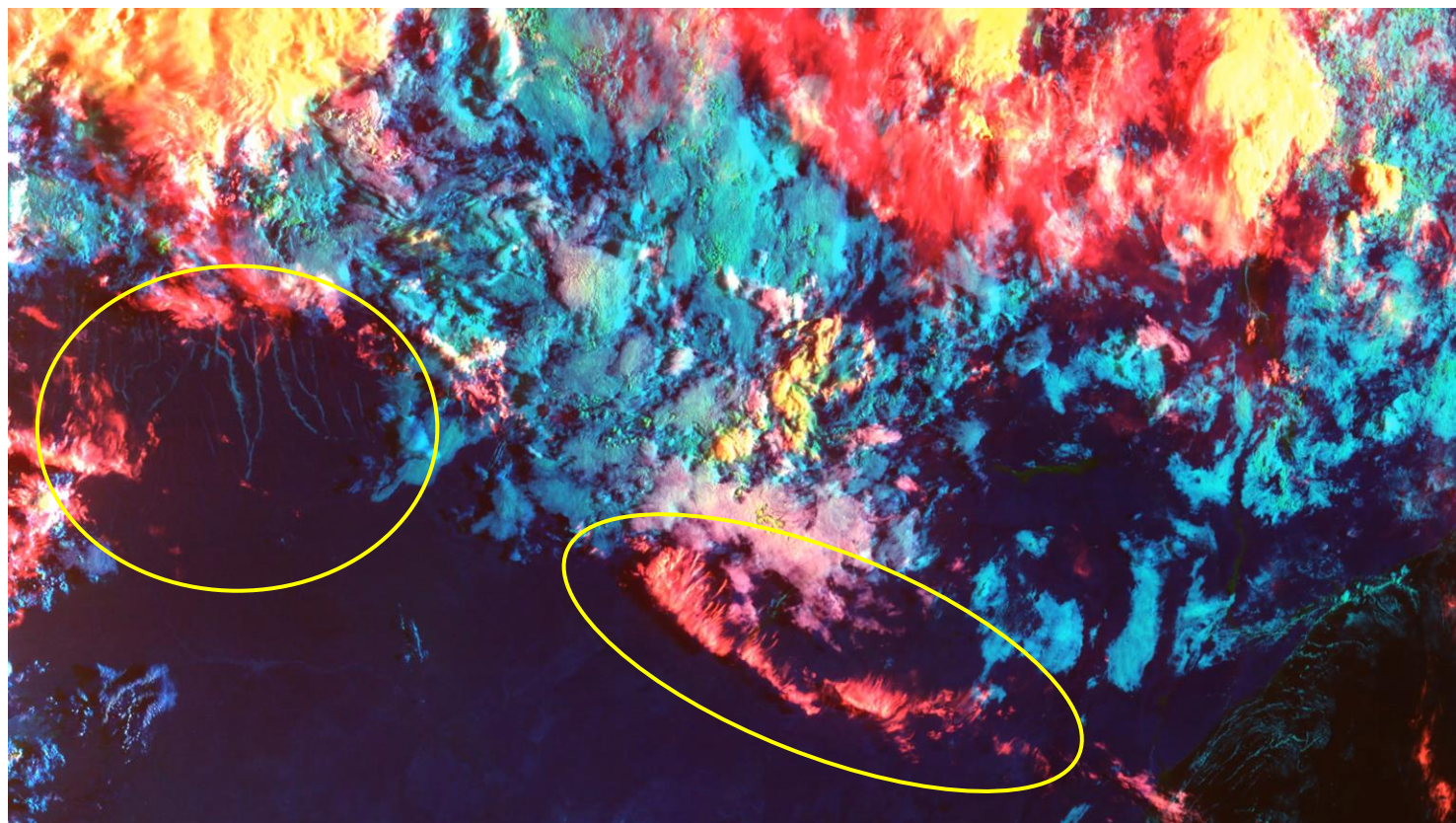
4 Low to mid-level water clouds

5 Mixed phase clouds (at low and mid-levels)

6 High and thin water clouds (more orange if ice is present)

7 Super-cooled water clouds

8 Snow and ice on the ground

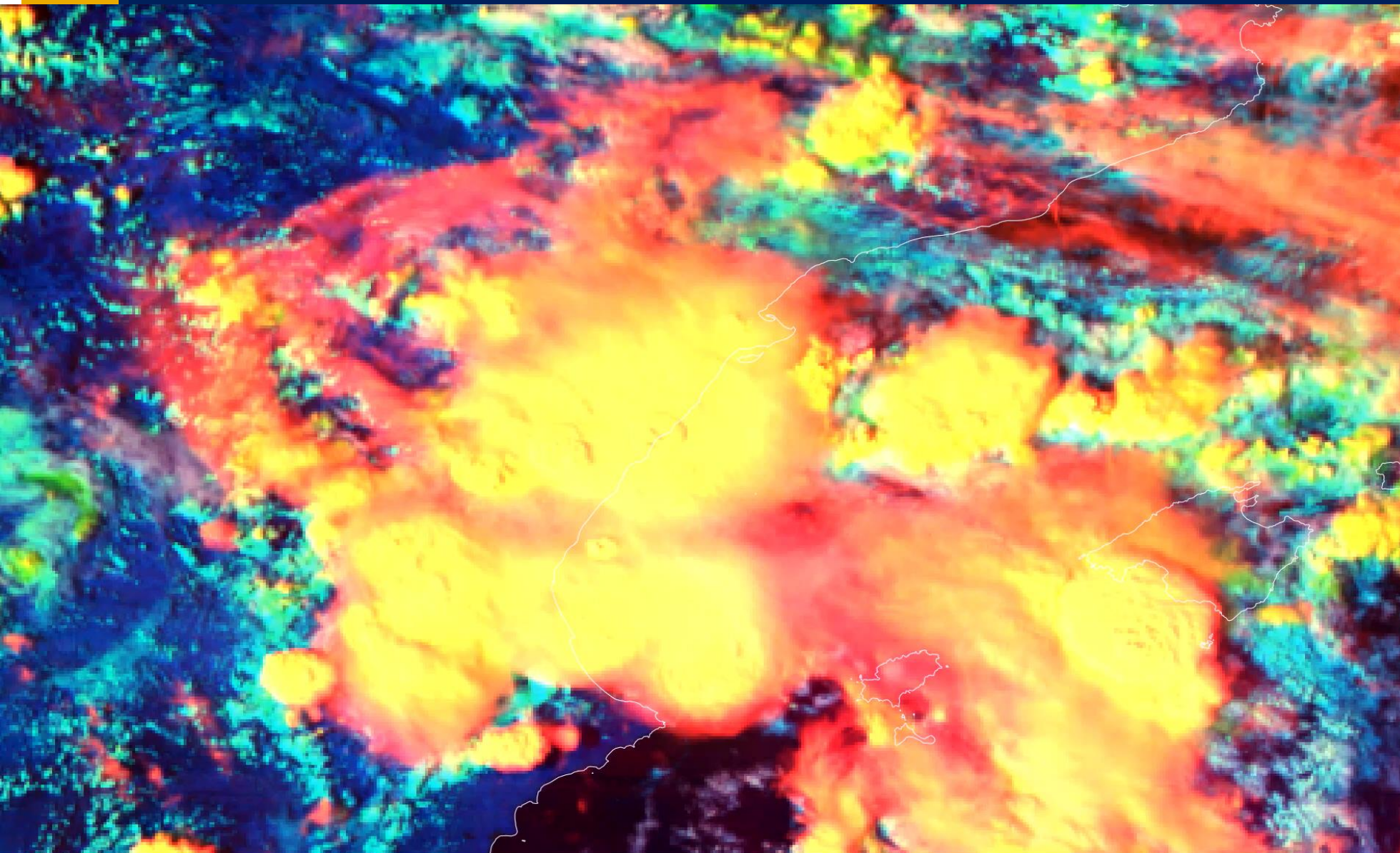


Combines information on

- cloud optical thickness
- cloud height
- cloud phase

Best RGB to **see thin cirrus clouds** due to 1.3 micron -in bright red

Clear distinction of low level water clouds -in cyan colour



Cloud Type RGB

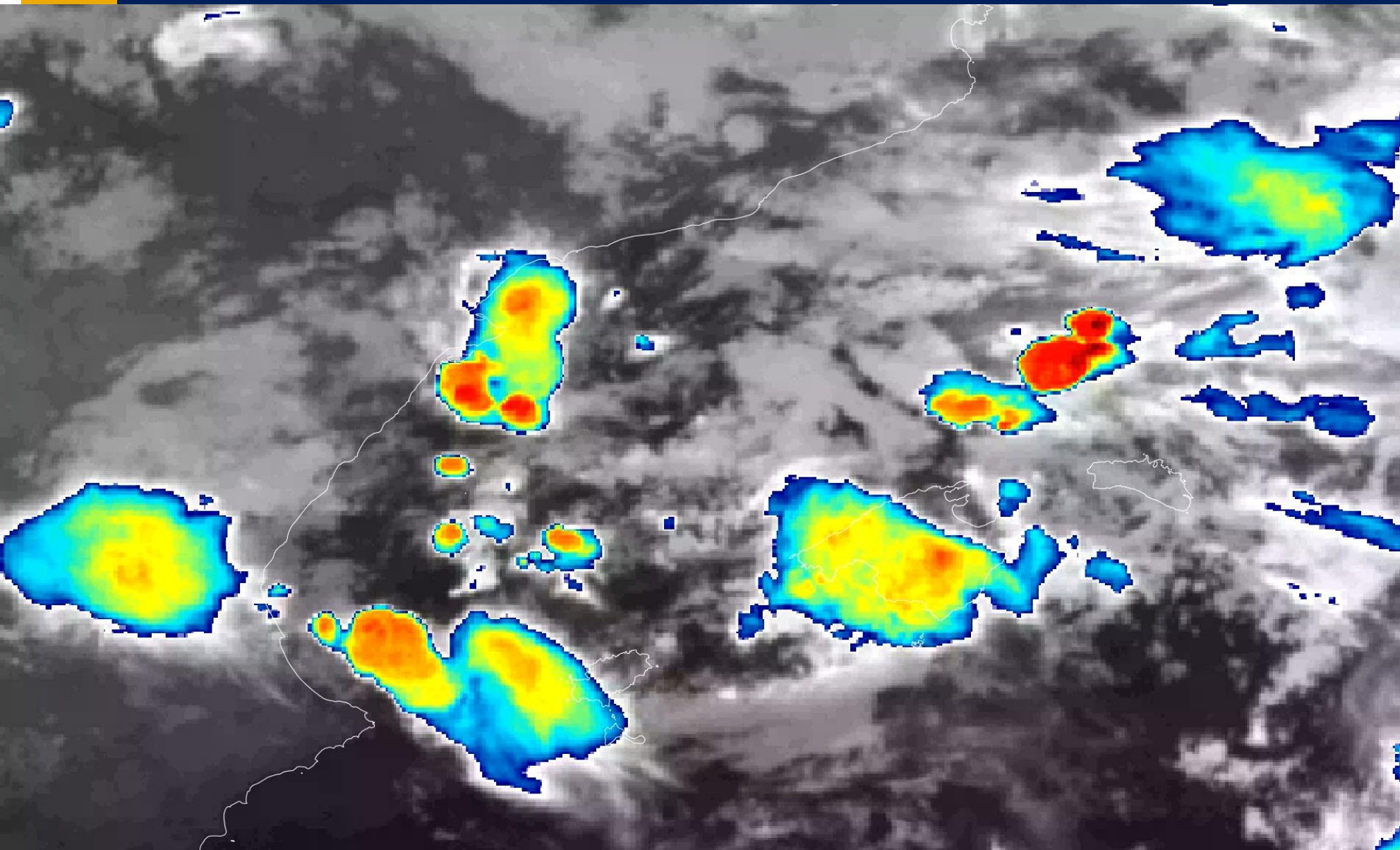
Emphasizing high-level features

- High, thin cirrus clouds (jet related – turbulence)
- Thick ice clouds (convection)
- Supercooled water clouds (icing danger)

>> important for aviation weather nowcasting



Cloud top temperature – IR10.5 coloured



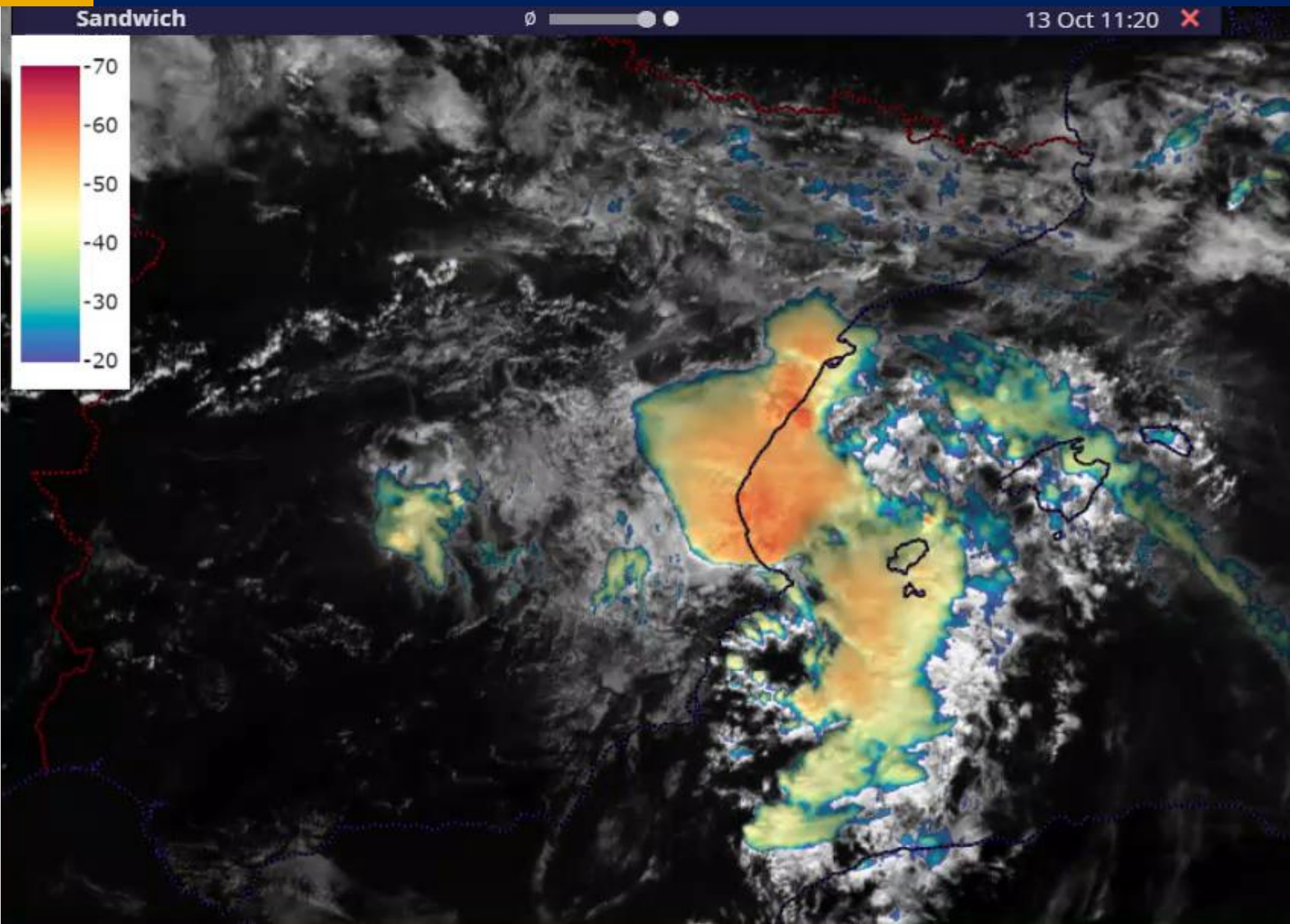
Thermal features

- Overshooting tops
- Cirrus plumes
- Cold ring
- Cold U/V

Cloud top features also showed during night-time in IR



“Sandwich” product – IR10.5 + VIS0.6



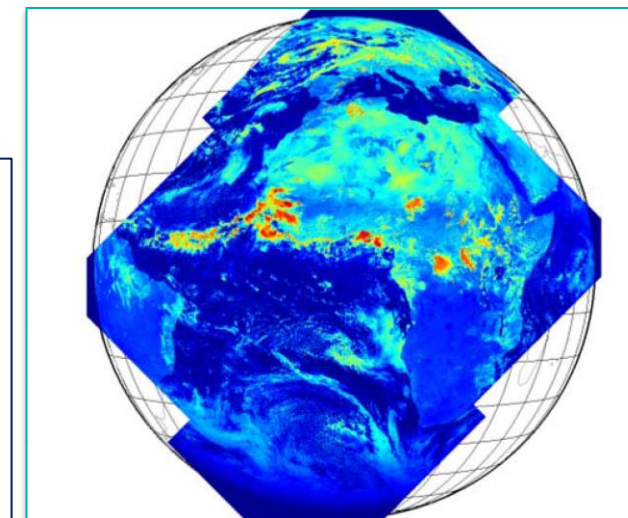
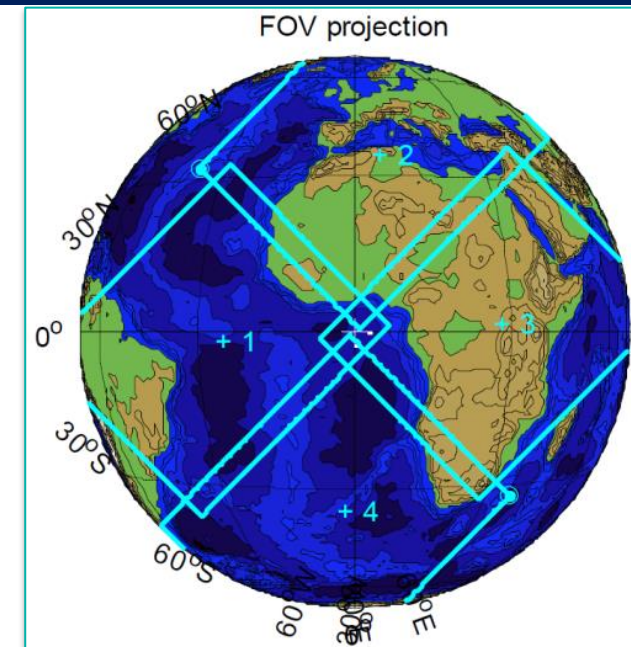
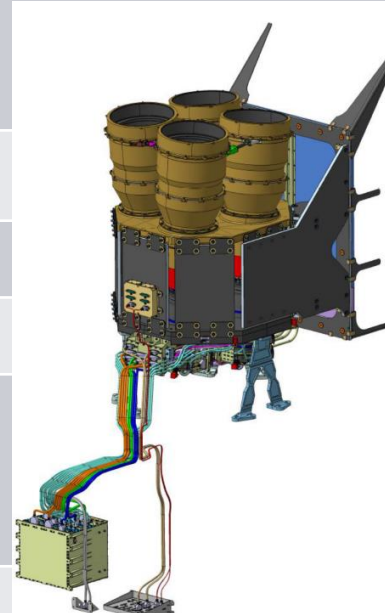
Combination with
VIS0.6 in 500m
resolution allows for
“3D view” of the cloud
top structures together
with thermal
characteristics



MTG Lightning Imager

LI in a nutshell

Spatial Resolution at Nadir	4.5 km (variable throughout the Field of View, FOV)
Spectral band	777.4 nm and 1.9 nm narrow band
Detector(s)	1000 x 1170 pixel (x 4) CMOS
Frame rate	1 ms (1 kHz acquisition frequency)
On-board processing	- Background evaluation and subtraction - Lightning detection - On-board filtering
Bandwidth	30 Mbps



MTG Lightning Imager field of view

A flash from space



The radiation produced by an electric discharge within or below a cloud reaches the cloud top after multiple scattering through the cloud and is detected by lightning imagers in space

MTG LI sees the optical signal from all types of flashes (intra-cloud, cloud-to-ground)!



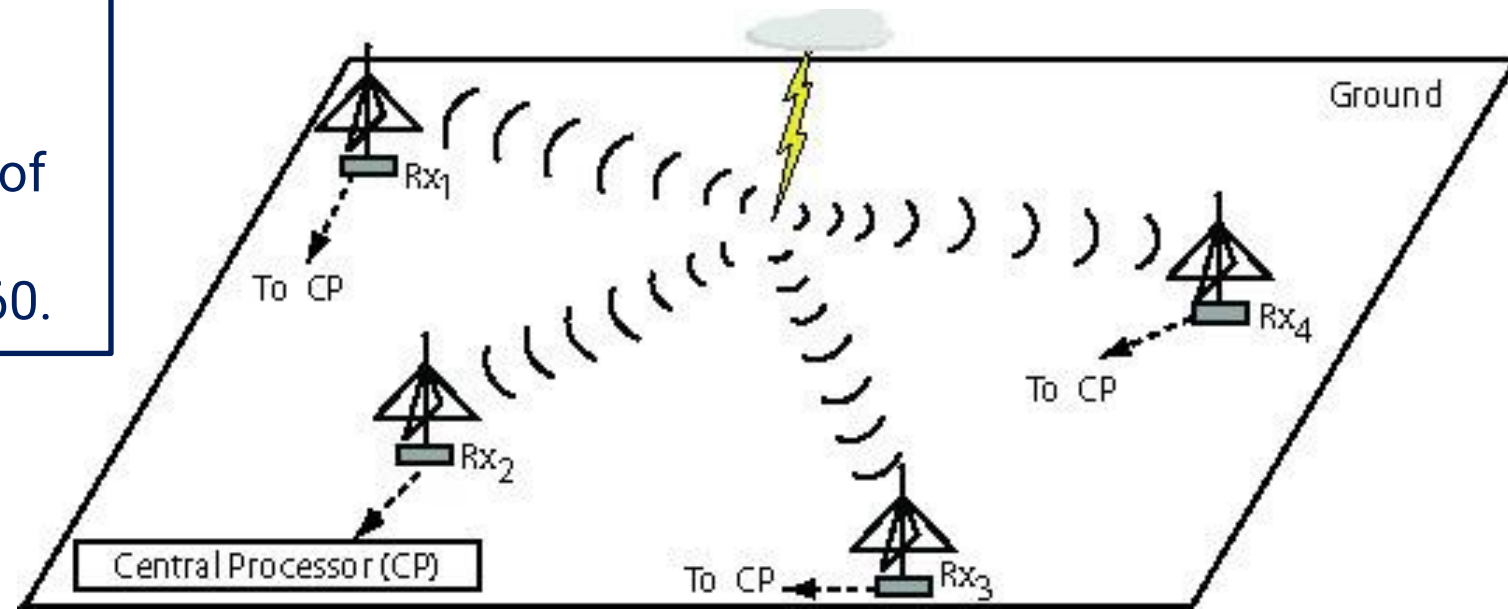
LI vs ground-based Lightning Location Systems (LLSs)

GROUND-BASED

A network of radio sensors plus central station that compares the observations of the sensors and computes lightning locations, e.g., NORDLIS, EUCLID, GLD360.

SPACE-BORNE

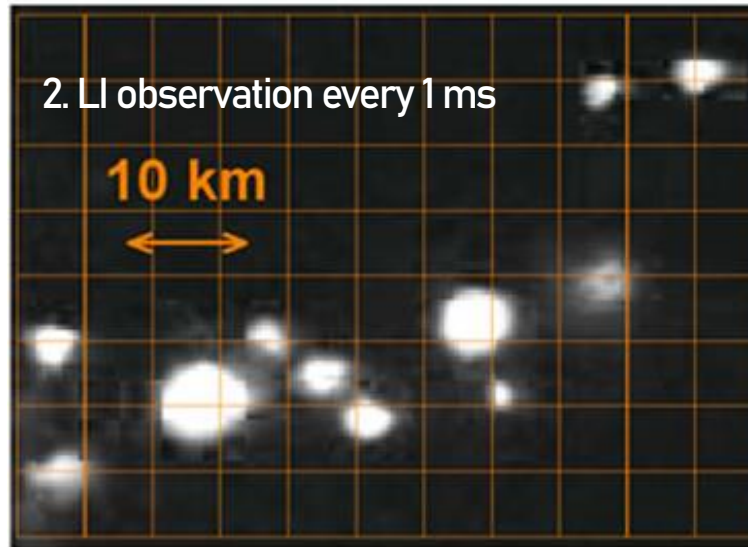
An **optical detector** that registers lightning optical emissions at the cloud tops, e.g., LI, GLM.



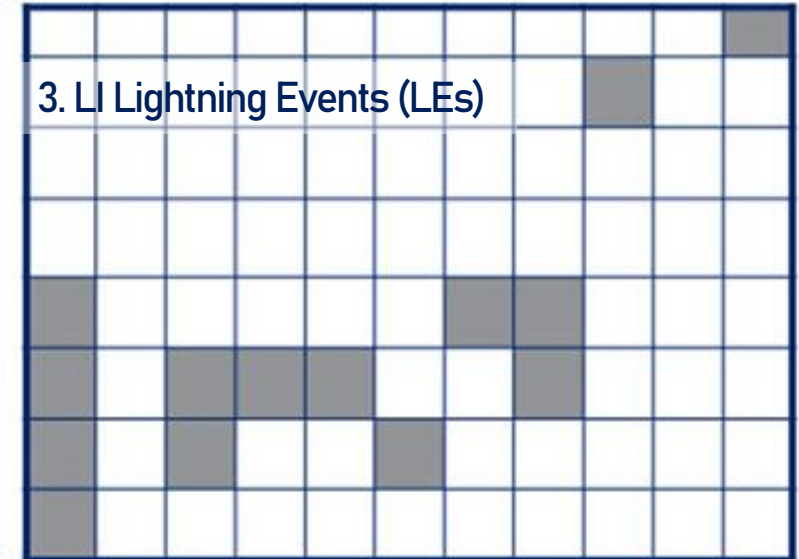
1. Cloud-top emission



2. LI observation every 1 ms



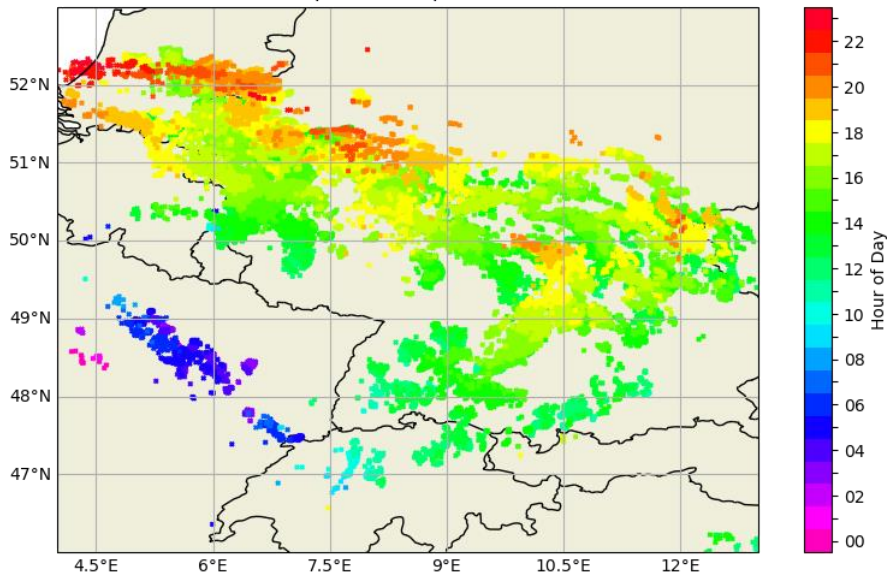
3. LI Lightning Events (LEs)



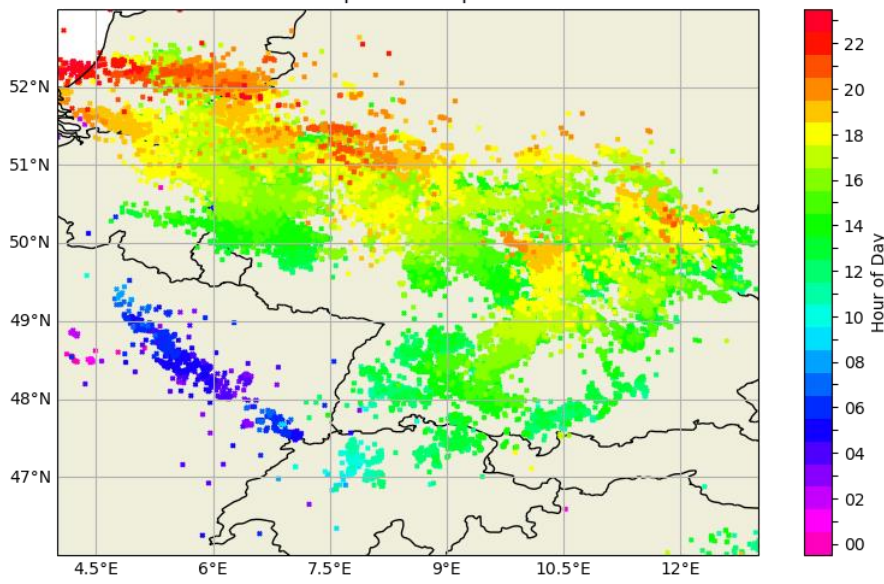


LI L2 data demo – Comparison with surface-based lightning detection data

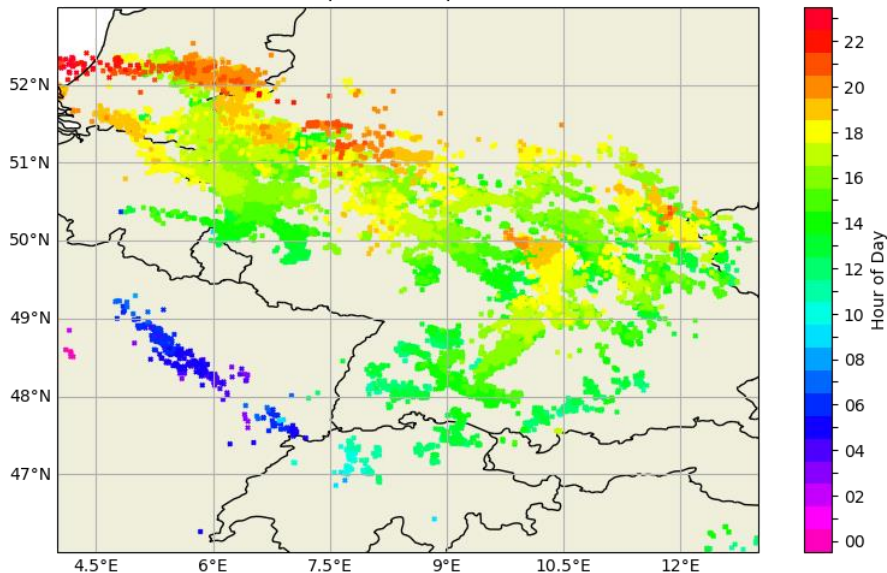
LI Europe flash map 2024-05-02



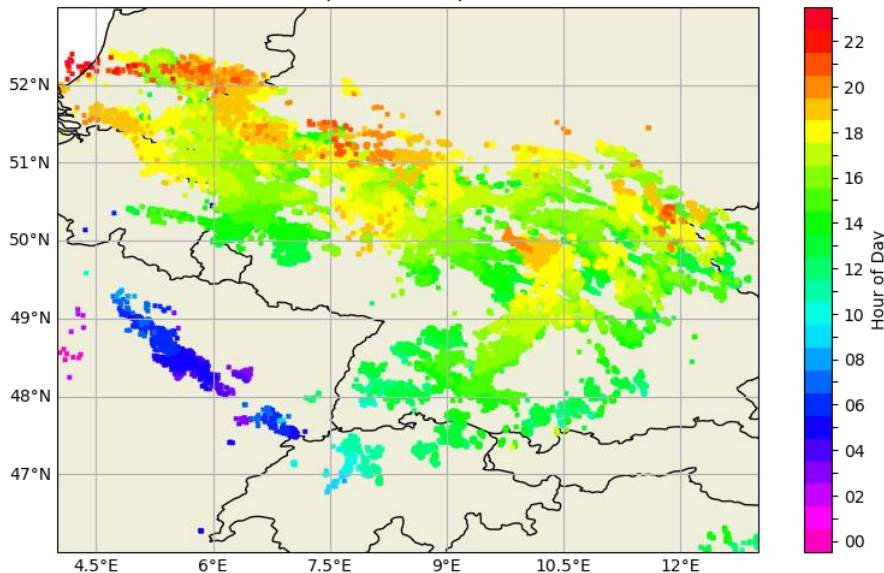
EUCLID Europe flash map 2024-05-02



GLD Europe flash map 2024-05-02



Leela Europe stroke map 2024-05-02

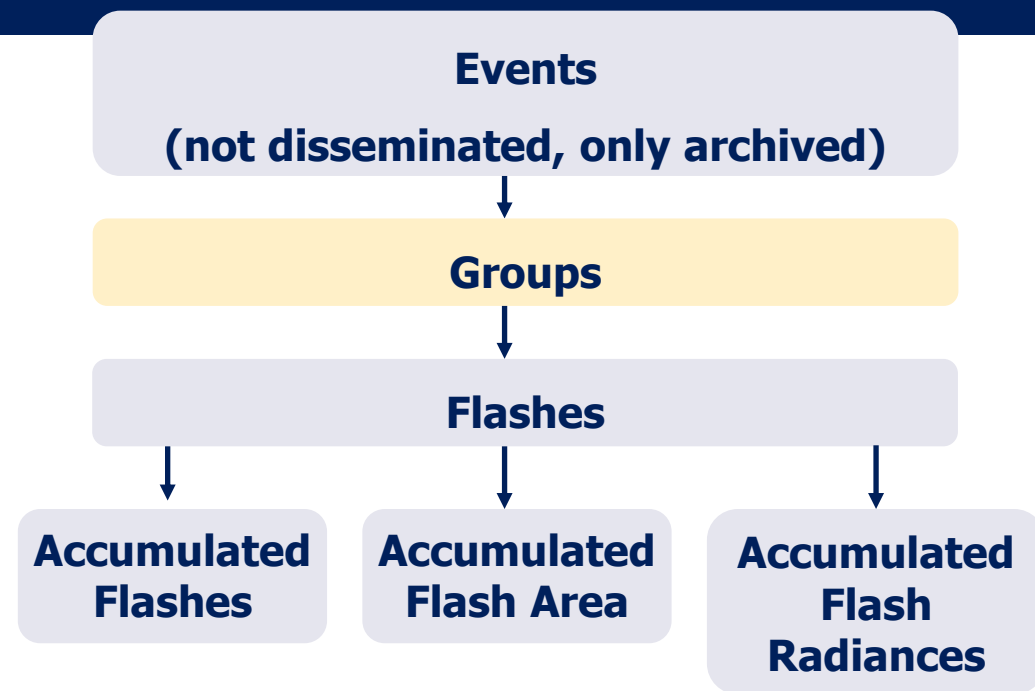
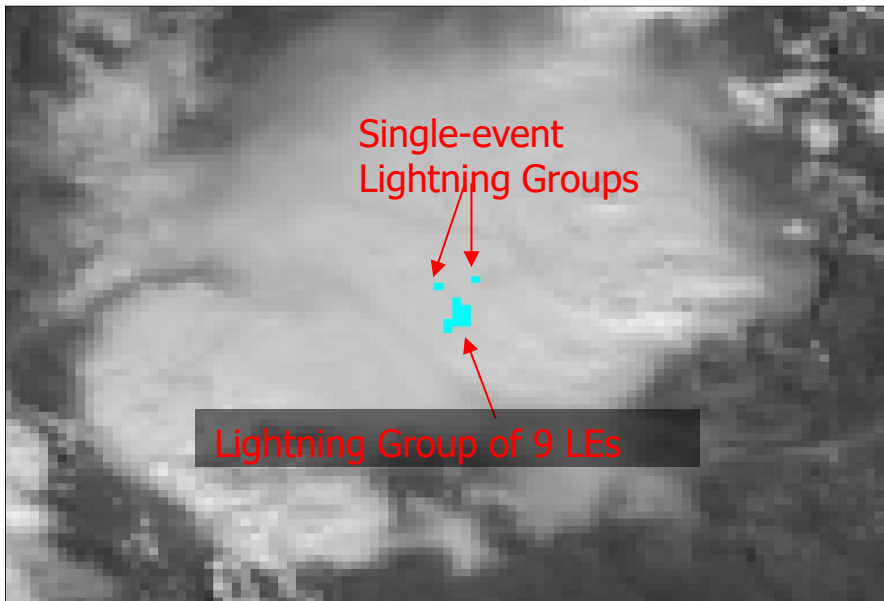
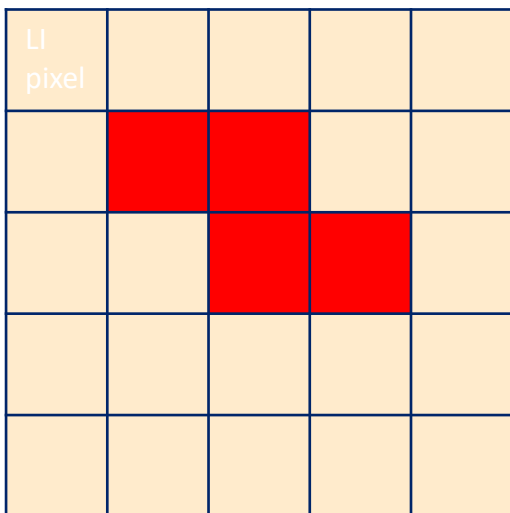


LI and the three ground-based LLSs all observed very similar space-time patterns of lighting, storm development and movement.

storms in southern Germany 02 May 2024



Level 2 Group Product – LI-L2-LGR

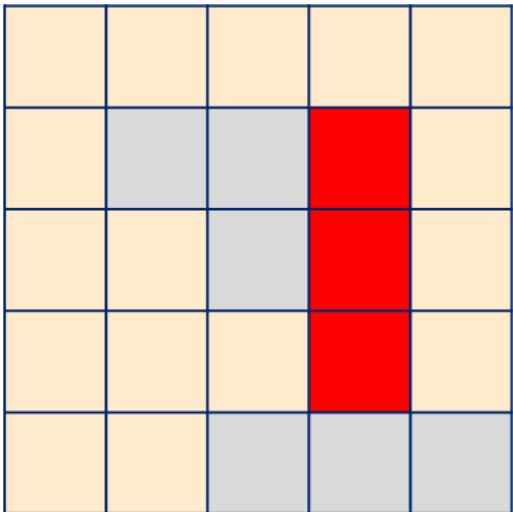


LI Group

- Collection of connected (pixel side touching) DTs on a single acquisition frame.
- Group location is the **radiance weighted centroid of its LE (lightning events) locations**.
- LGR can be made of 1 or more Events (the example on the left is a 4 Events group).
- LI groups represent ground lightning strokes and cloud lightning pulses in ground-based LLS data.
 - However, a pulse/stroke often triggers a sequence of many LI groups as the optical emission often lasts longer than 1 ms LI integration frame.

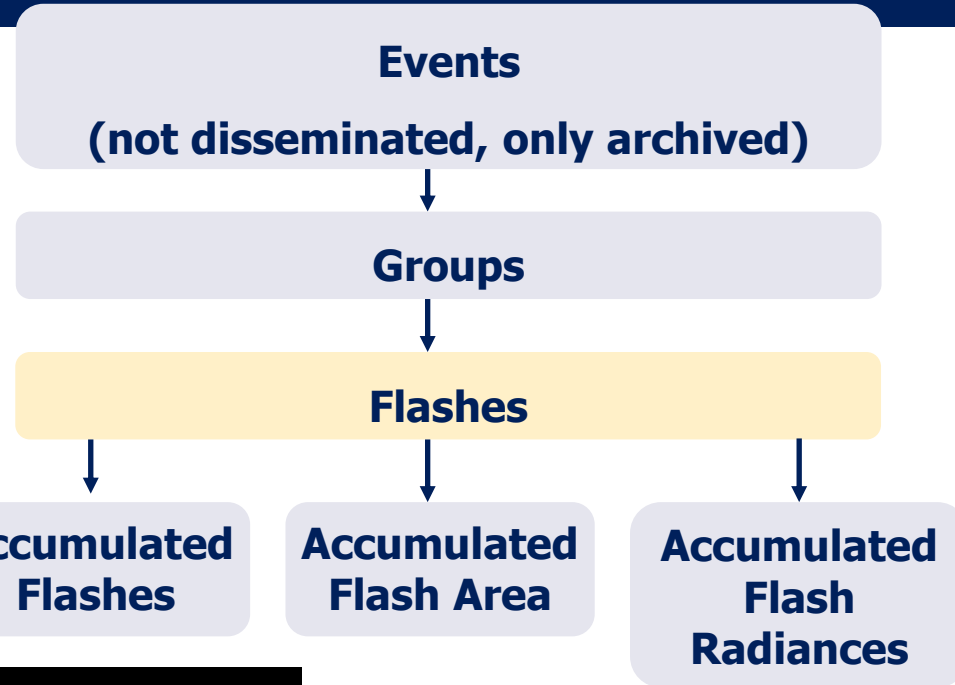


Level 2 Flash Product – LI-L2-LFL



LI Flash

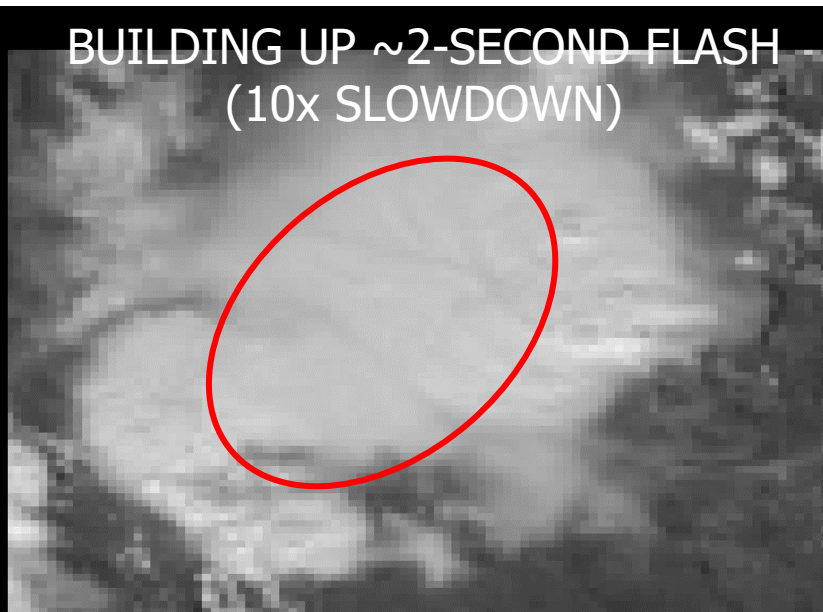
- Collection of Groups that are correlated in space (16.5 km) and time (330 ms).
- Flash location is the radiance-weighted centroid of its group locations.
- LI Flash can be made of 1 or more LI Groups.
- LI flashes roughly correspond to flashes in ground-based LLS data.



INDIVIDUAL GROUPS (10x SLOWDOWN)



BUILDING UP ~2-SECOND FLASH (10x SLOWDOWN)

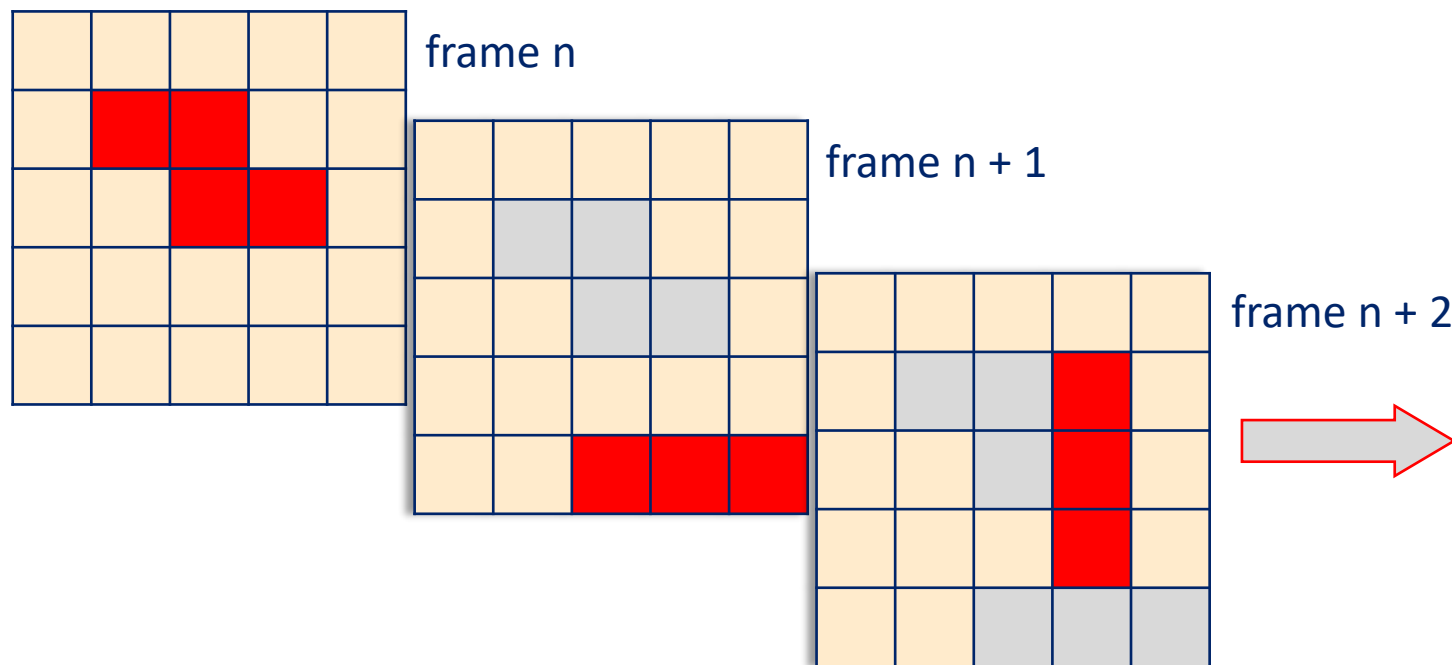


An example of a L2-LFL (right) being built up from individual L2-LGRs, made of individual LEs in a continuous sequence of 1 ms LI integration frames (left). Note that this example is a very large and long-lasting 'megafash' in Africa.



Level 2 gridded products – LI-L2-AFA, AF and AFR

Accumulation over 3 frames



LI Pixel				
	1	1	1	
		1	1	
			1	
		1	1	1

LI Level 2 Accumulated Flash Area (AFA)

keeps track of the areas touched by multiple flashes (does not provide the event density)

LI Pixel				
	1/10	1/10	1/10	
		1/10	2/10	
			1/10	
		1/10	1/10	1/10

LI Level 2 Accumulated Flash (AF)

keeps track of the density of events within the flash and within sequences of accumulated flashes

LI Pixel				
	R1	R2	R3	
		R4	R5+ R5'	
			R6	
		R7	R8	R9

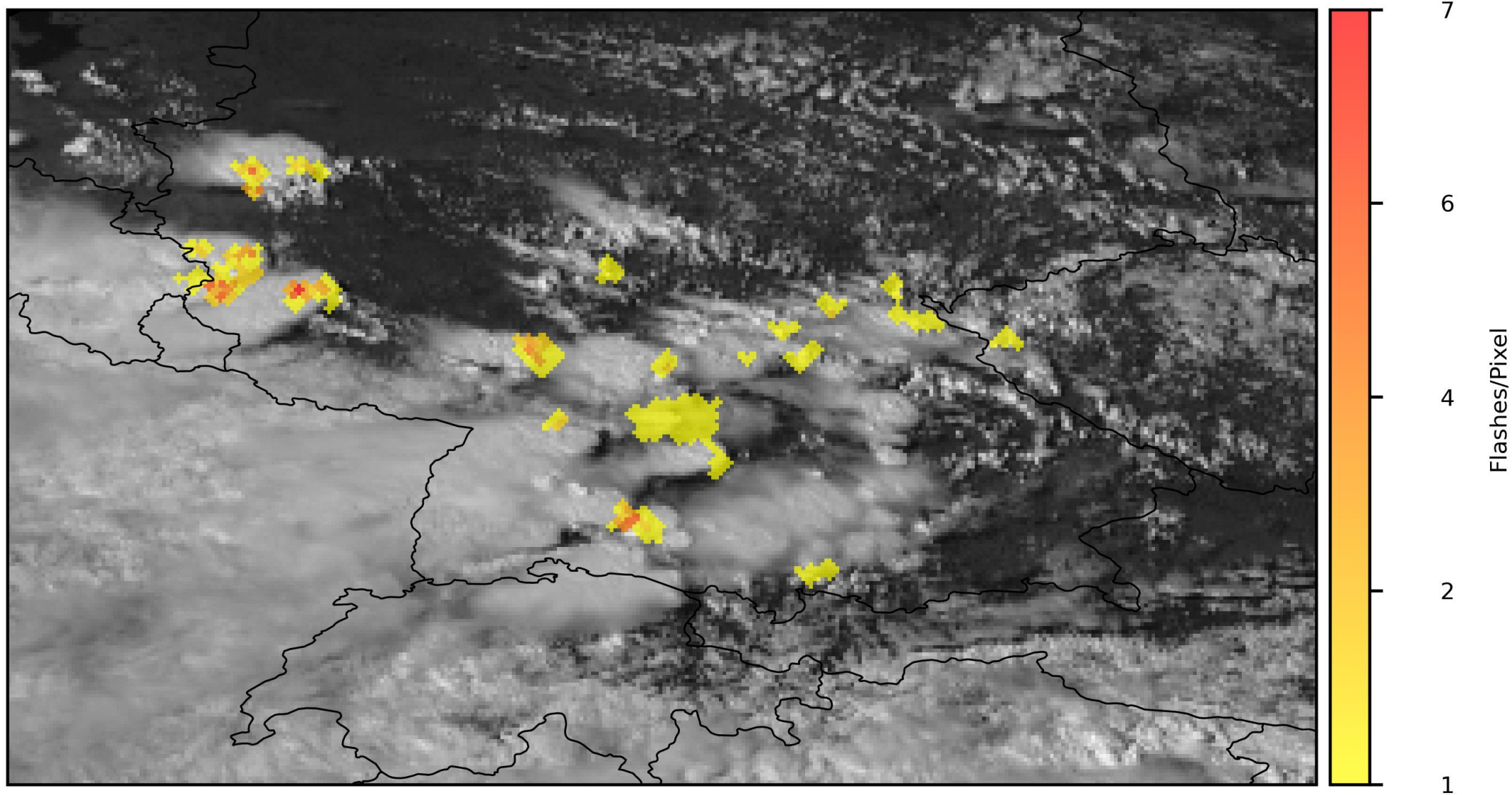
LI Level 2 Accumulated Flash Radiance (AFR)

represents the total radiance within a certain pixel from multiple flashes



Level 2 gridded products – LI-L2-AFA (Accumulated Flash Area)

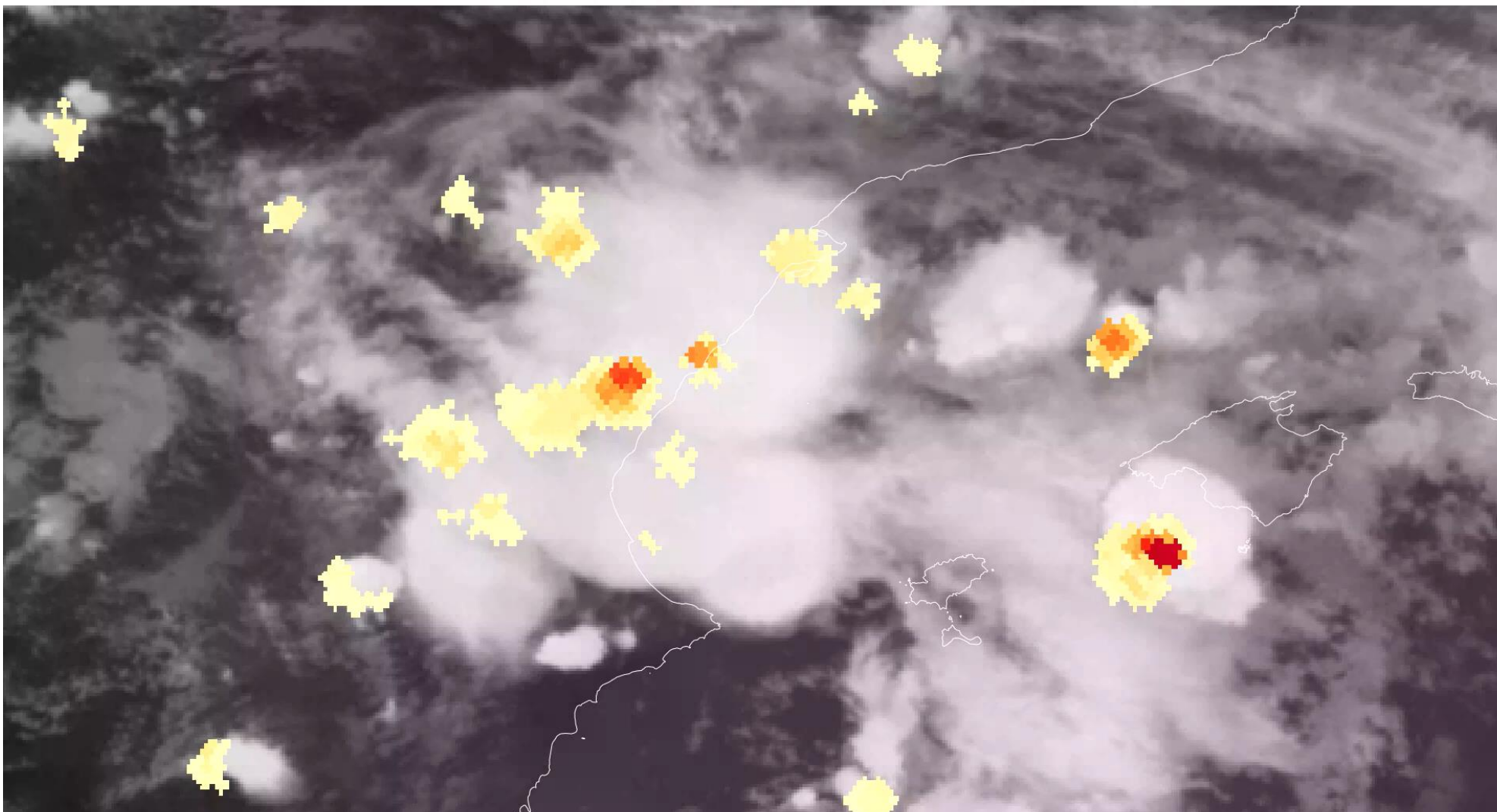
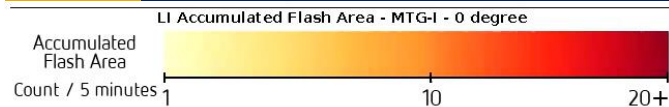
Accumulated Flash Area (AFA) 2024-05-02T14:00:00-14:00:30



An accumulation of AFA products over 10 minutes on the background of SEVIRI 10.5 μm image.



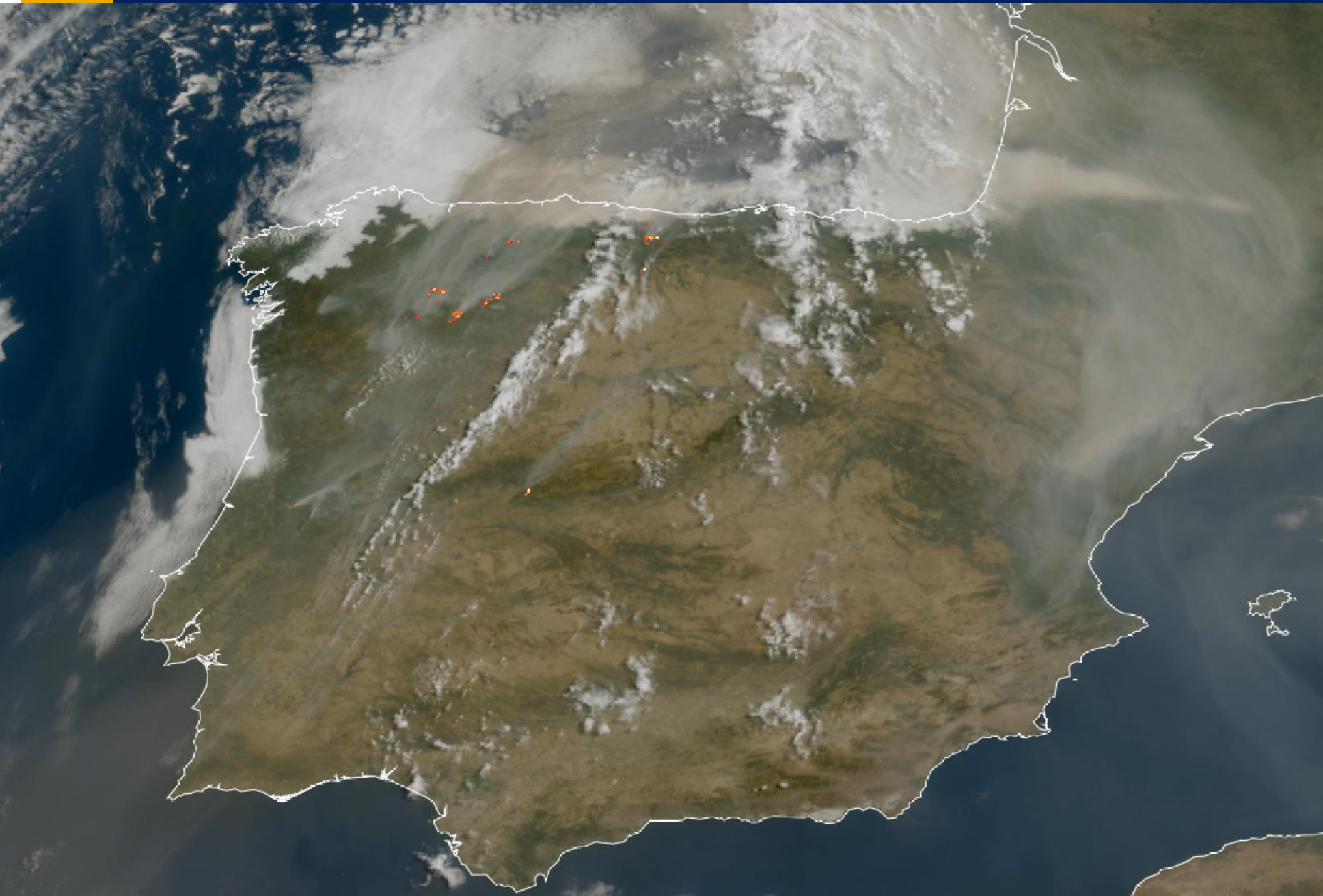
Level 2 gridded products – LI-L2-AFA (Accumulated Flash Area)



Recent storms
over eastern
Spain and
Balearic islands



Fires and severe weather over Iberian peninsula –



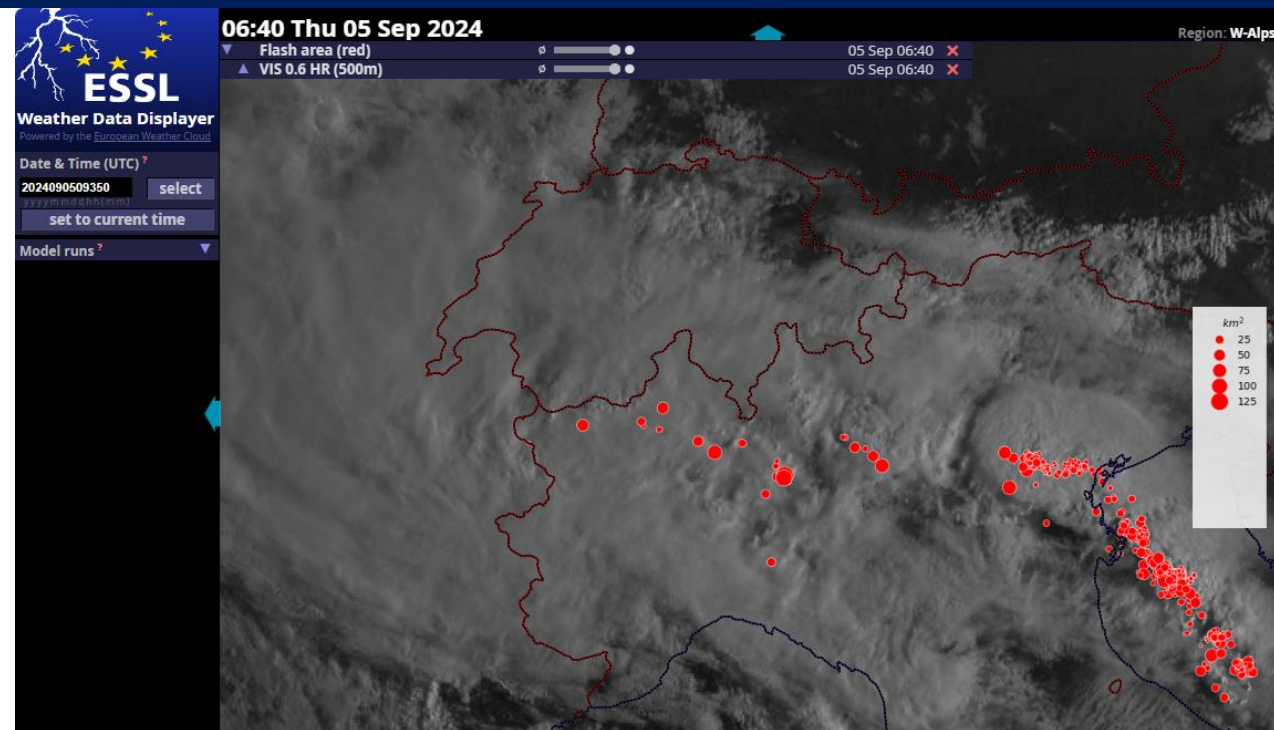
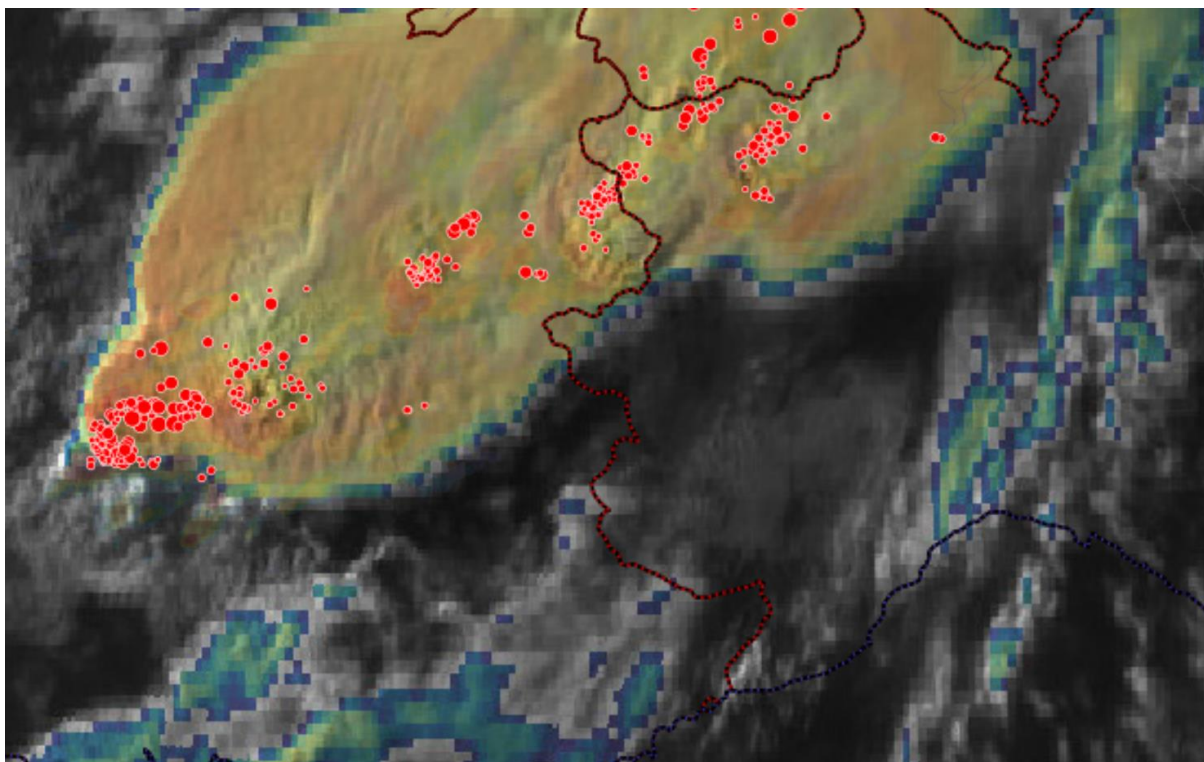
17 Aug 2025

Fires and severe weather over Iberian peninsula

- FCI True colour RGB
- Fire pixels – combination of FCI channels IR3.8, NIR2.25, NIR1.6
- LI Accumulated flash area

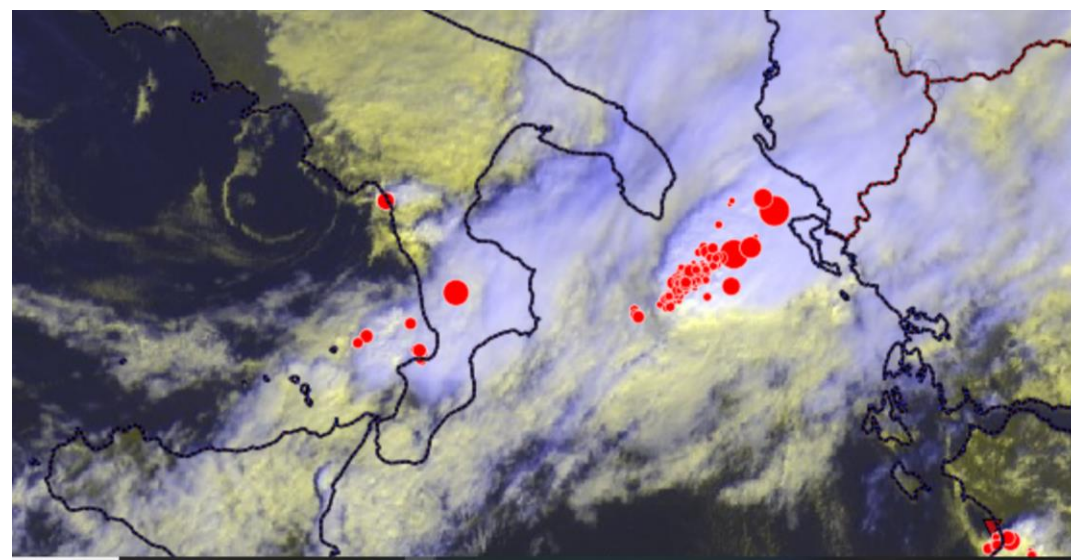


Potential of LI data for nowcasting



Significant potential of LI data for nowcasting of severe convective storms.

Sizes of red dots relative to **LI flash size**.





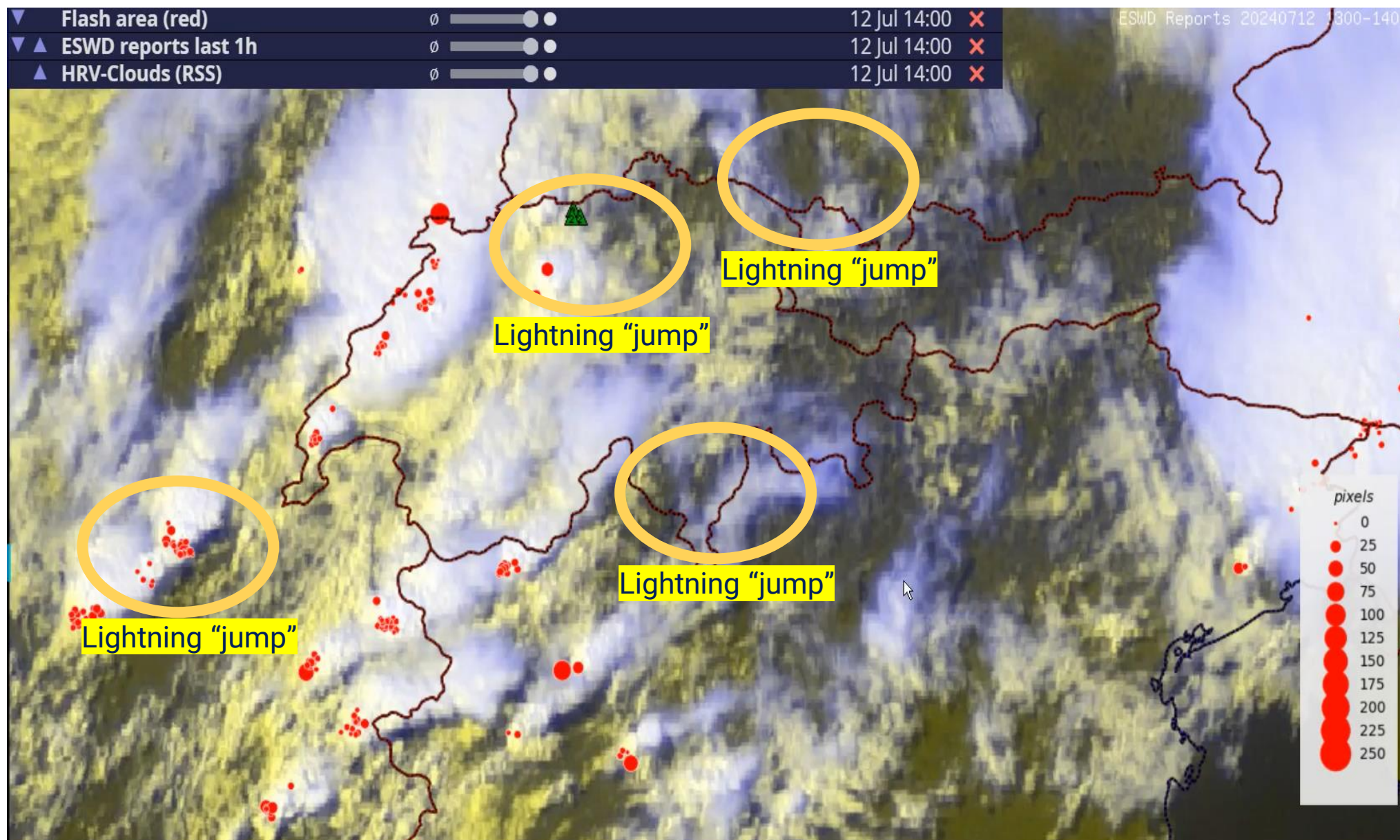
Potential of LI data for nowcasting

monitoring
frequency of
flashes allows
nowcasting
severe weather

increase in flash
frequency >>
increased
probability of
hail/strong
winds/severe rain

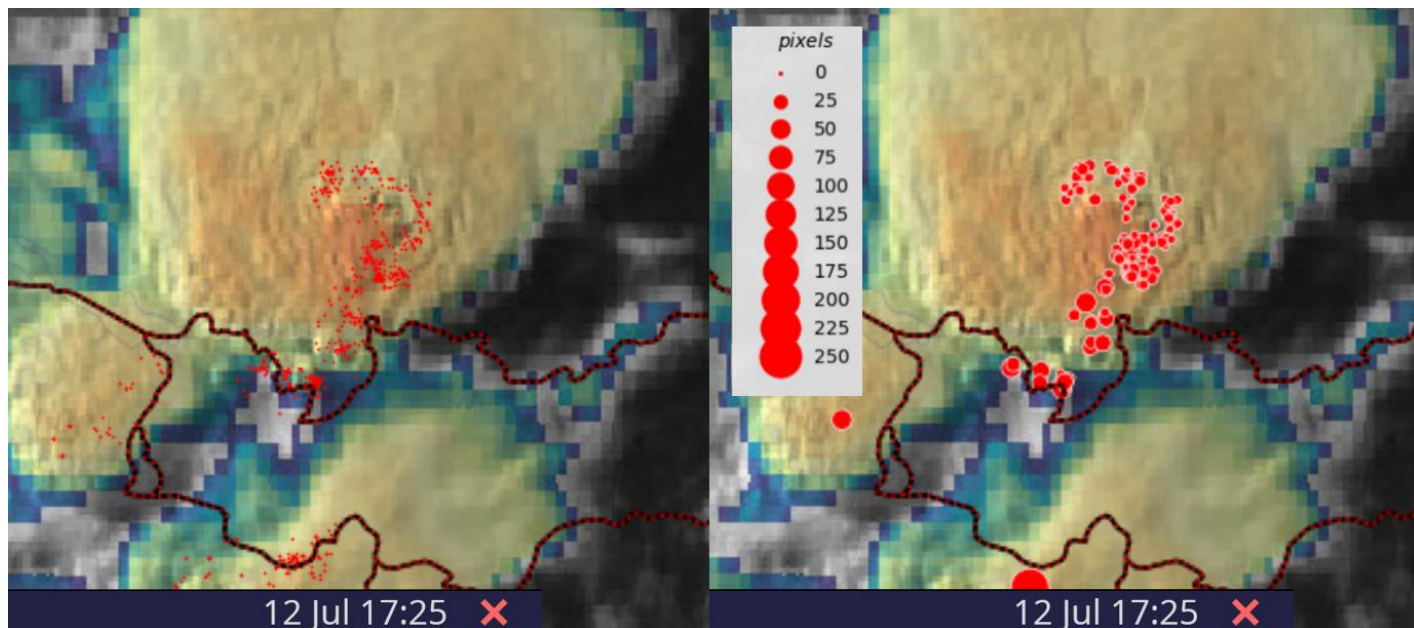
12 July 2024,
14-19 UTC

Courtesy:
Tomas Pucik



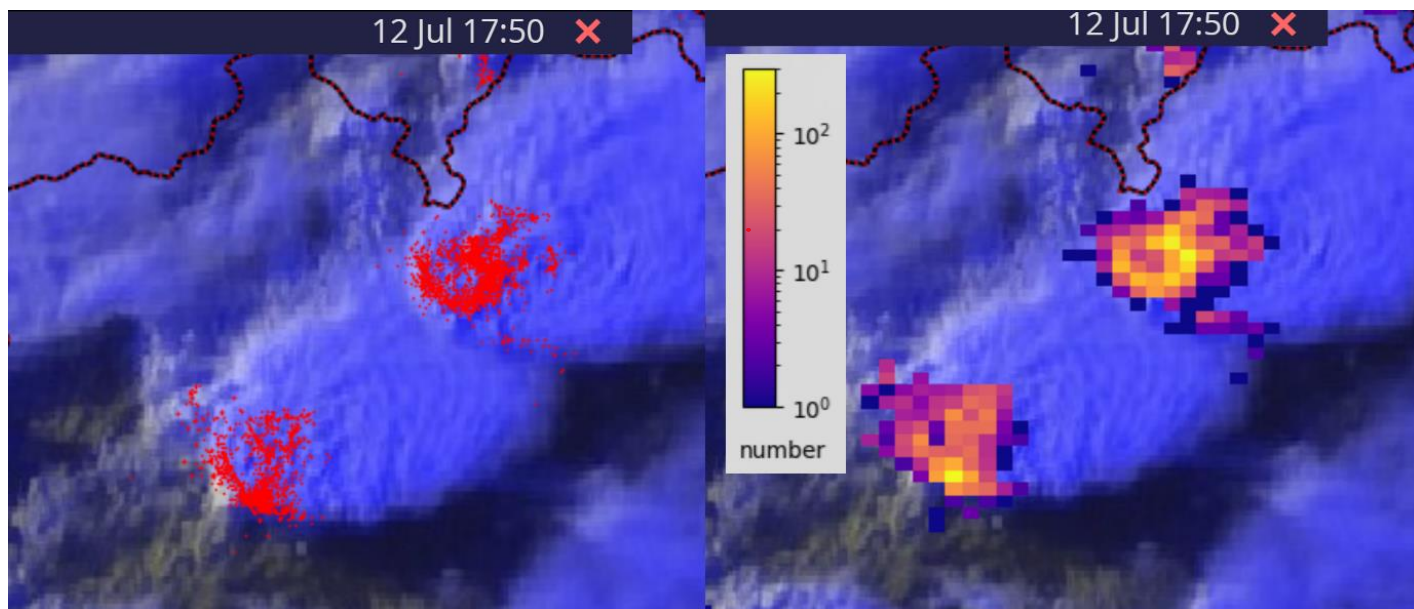


Features in the LI data



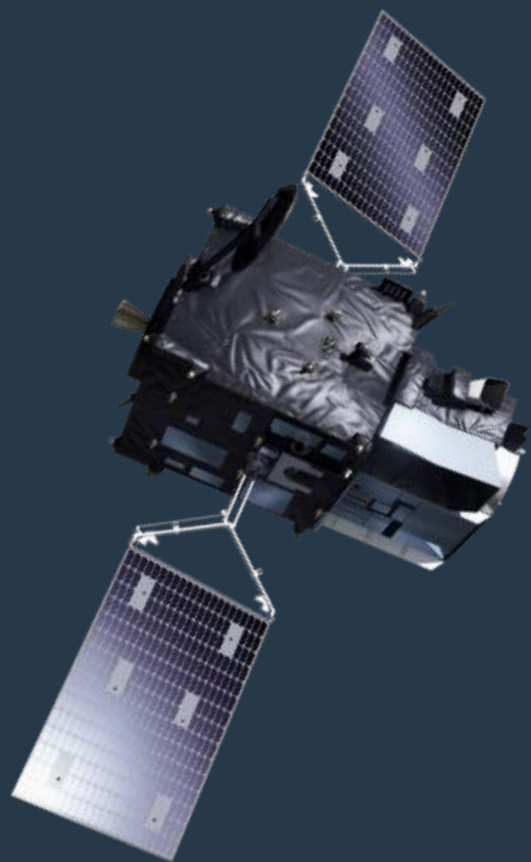
“Lightning hole”:

- Core of storm too optically dense for lightning signal to penetrate
- Lack of lightning activity due to updraft being too strong for generation of charged particles



FCI and LI combined provide users with unprecedented data for monitoring convection initiation and development

12 July 2024



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



MTG-S infrared sounding mission (IRS)

www.eumetsat.int

MTG-S1
with Sentinel-4/UVN

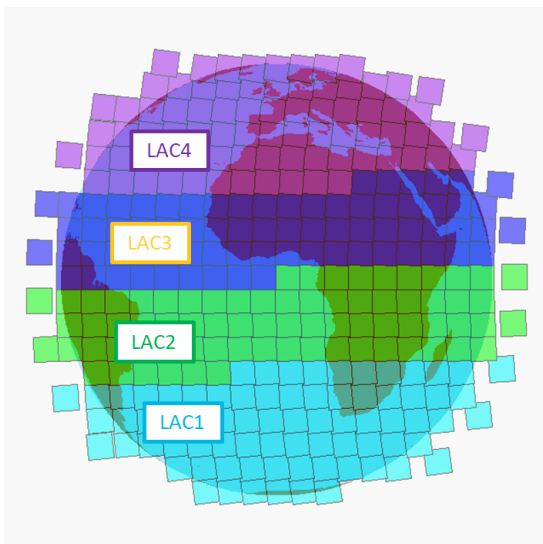
launched on 1 July 2025
currently in commissioning



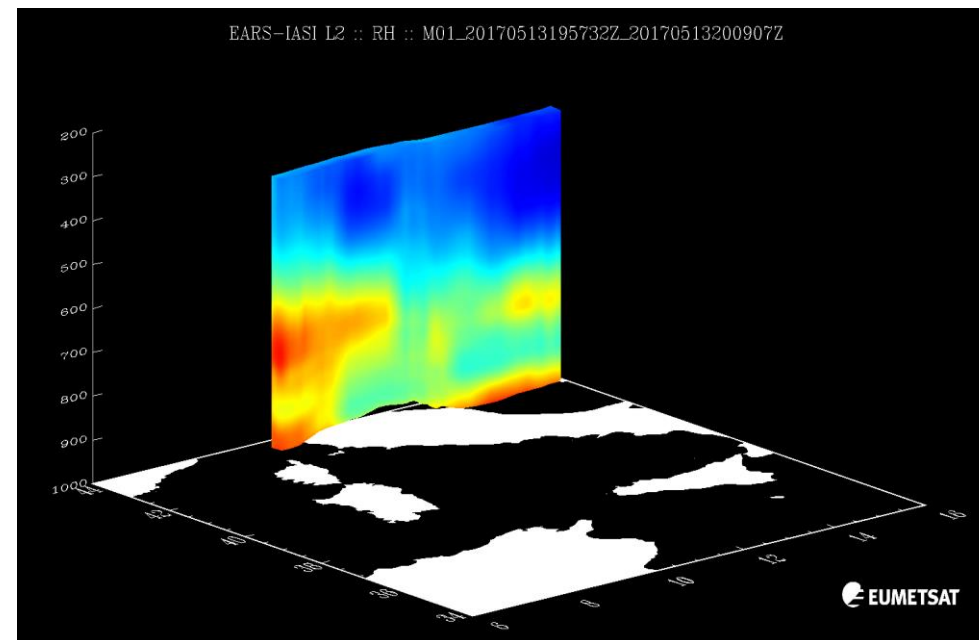
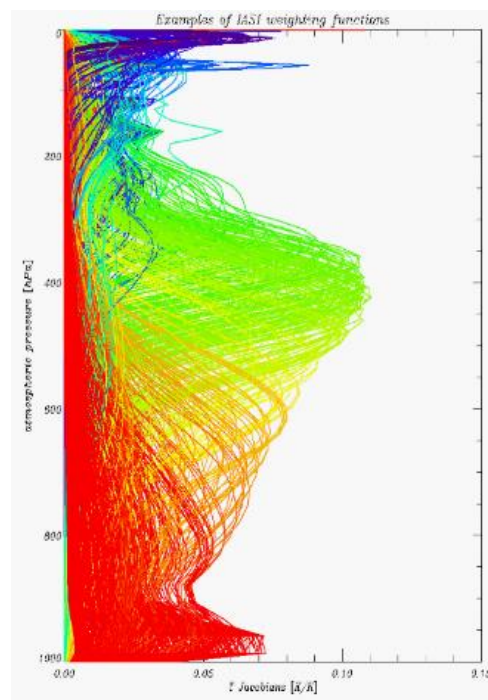
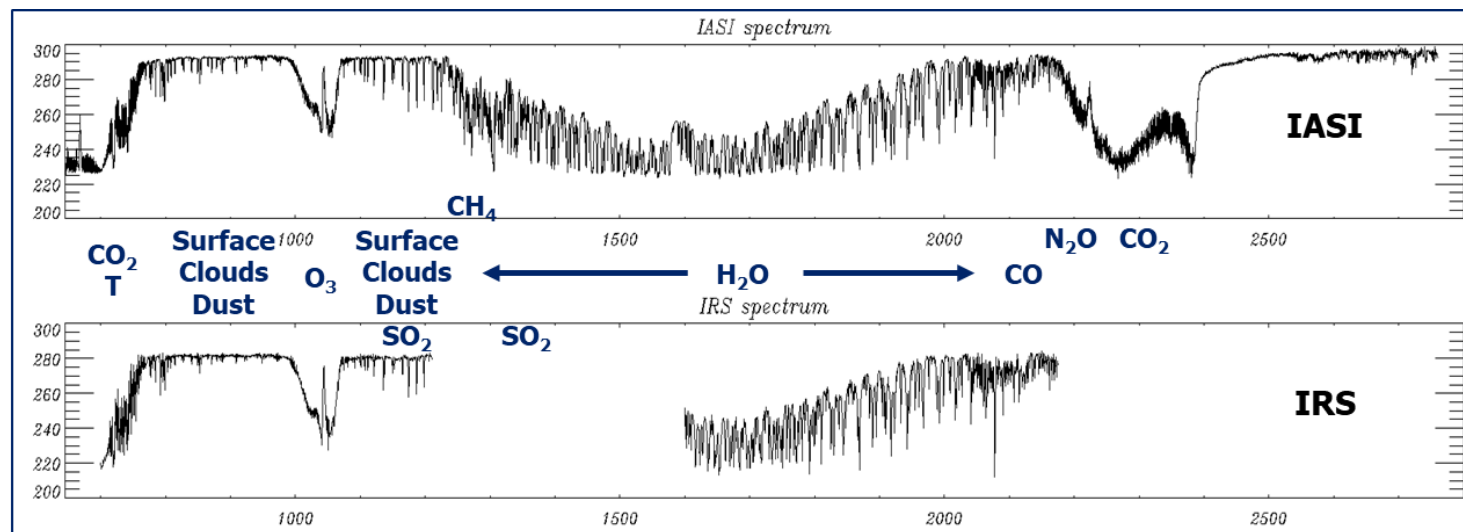
Photo courtesy of SpaceX

MTG-S Infrared Sounding mission (IRS)

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



- ✓ The Earth disk is split in 4 Local Area Coverage (LAC) zones, each covered in 15 min by a succession of “steps and stares” called dwells
- ✓ LAC4 (northern mid-latitudes) covered every 30 minutes
- ✓ LAC1, 2, 3 alternatively viewed in-between



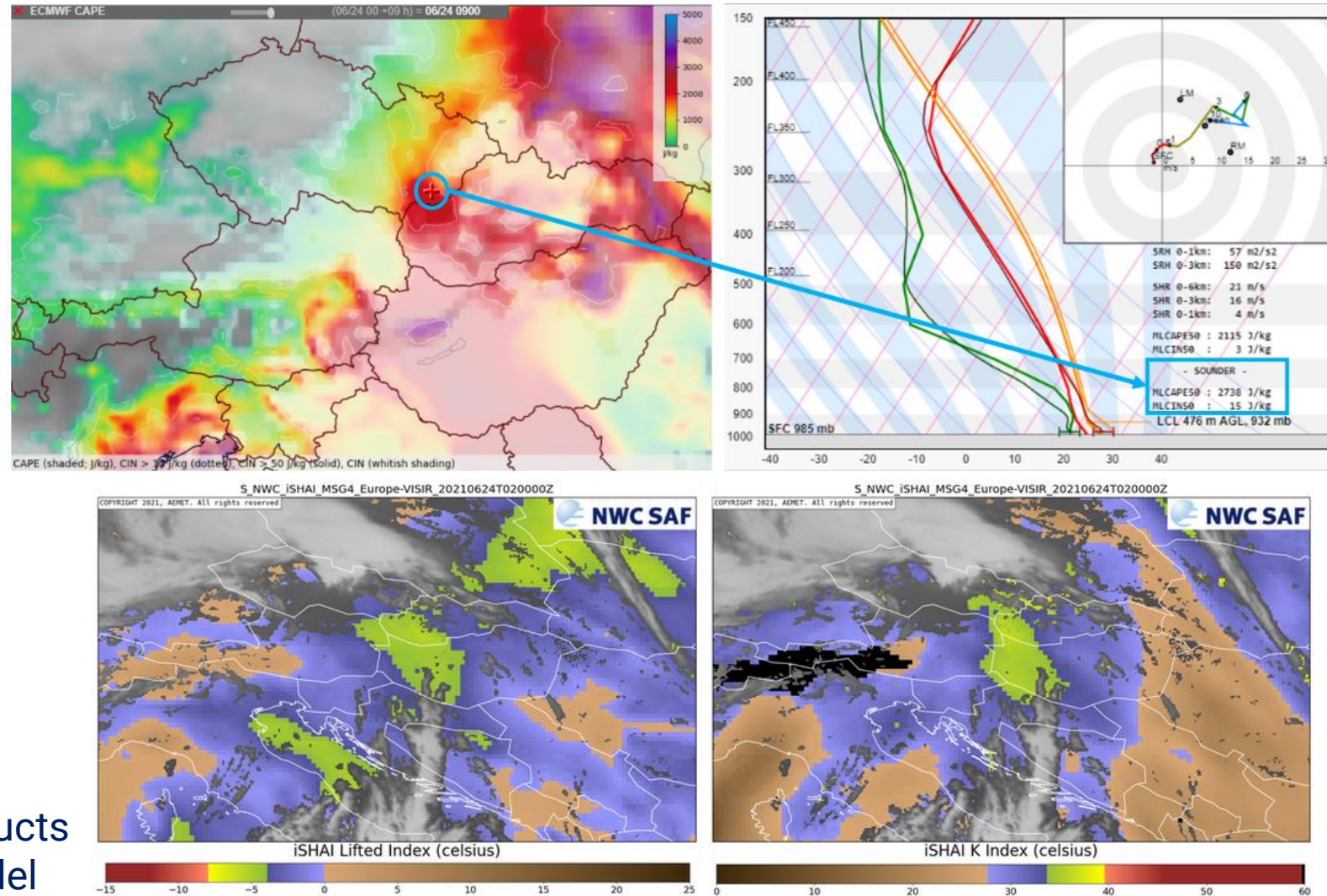
SIMULATED MTG InfraRed Sounder Dataset for Nowcasting

IRS L2 State Vector Products:

- Profiles (temperature, humidity, ozone)
- Surface parameters
- Instability indices and total vertical column
- Cloud products

simulated MTG-IRS geophysical (L2) products at 30-min Based on ECMWF IFS 9-km model analyses and grid, and CAMS 54-km model reanalyses

Convective Storm case 24 June 2021, F4 tornado in Czechia





MTG – a new era for satellite meteorology and Earth system prediction

www.eumetsat.int

MTG-I

Full Disc image service

- 16 spectral channels over Europe and Africa every 10 minutes
- Lightning Imager

MTG-S

Full Disc sounding service

- Hyperspectral Infrared Sounder
- Copernicus Sentinel-4 UVN

MTG-I

Rapid Scanning Service

- 16 spectral channels over Europe every 2.5 minutes

- Improved spectral imagery, higher resolution, new channels - enhanced and new applications (incl. forecasting, media)
- Continuity of climate record, starting new records
- Novel lightning imagery - better tracking and understanding thunderstorms
- Atmospheric soundings every 30 minutes over Europe - major impact on NWP, nowcasting

