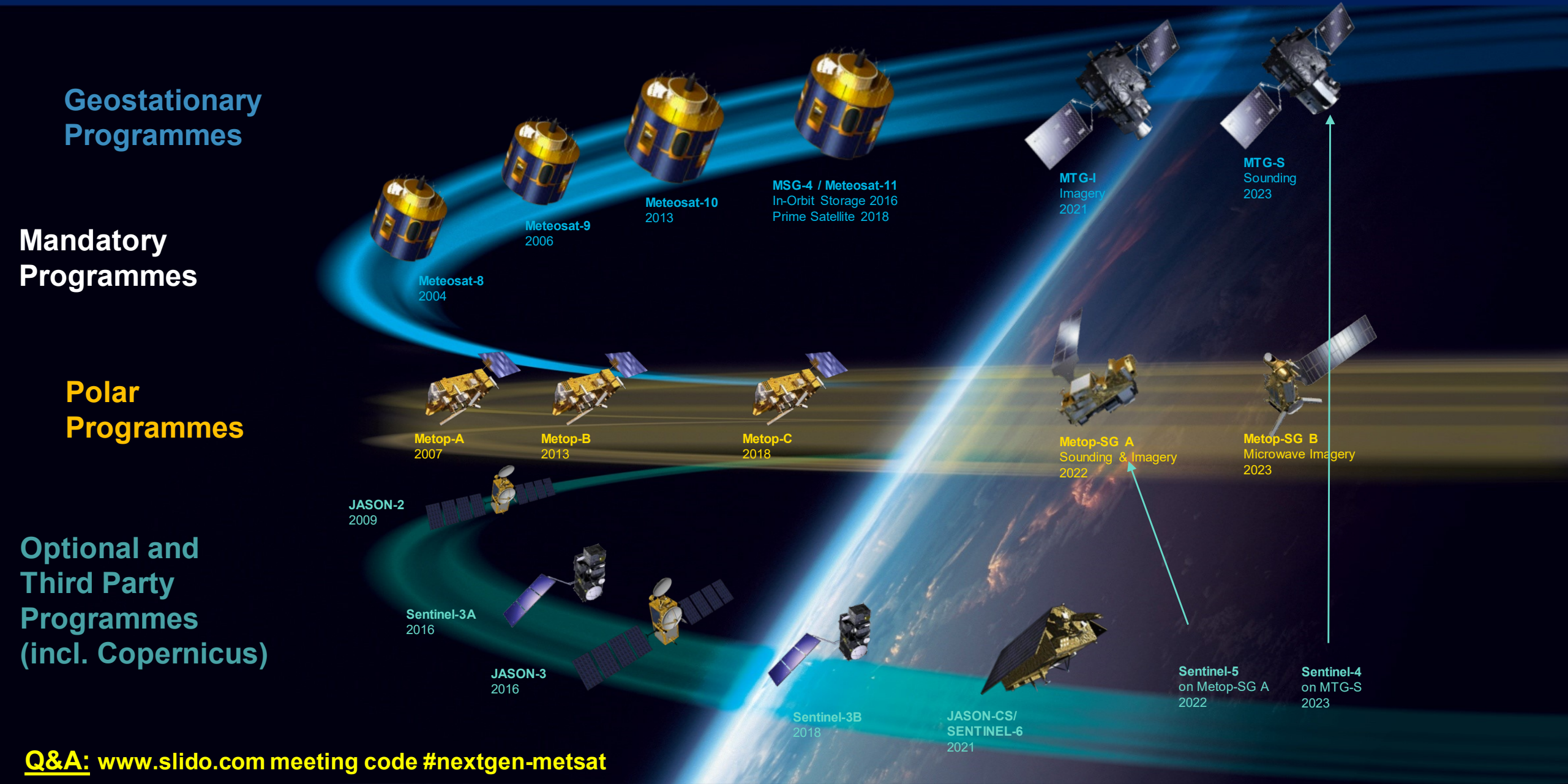
European research opportunities and priorities for the next generation of meteorological satellites

Presenter: Bojan R. Bojkov
Convener: Stephan Bojinski

EGU2020 Sharing Geoscience Online
Townhall Meeting (TM7)
29 April / 5 May 2020

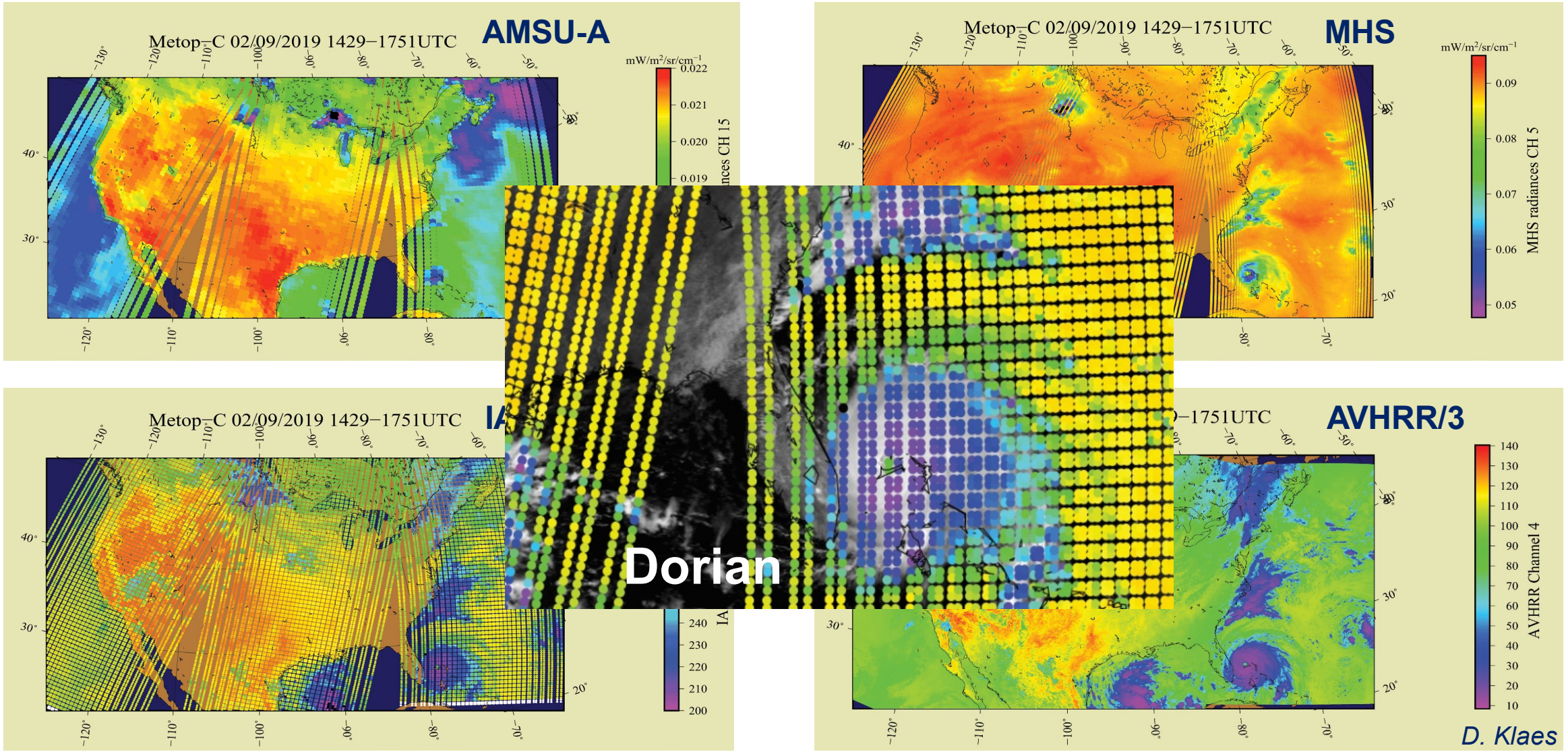
Ask your questions here:
www.slido.com meeting code #nextgen-metsat

EUMETSAT Missions – *current and future*

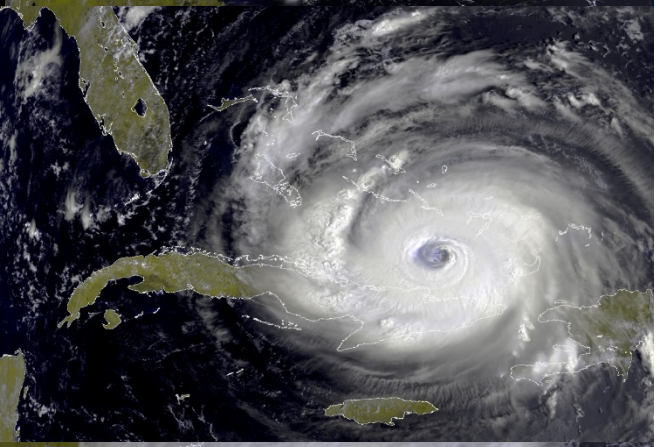


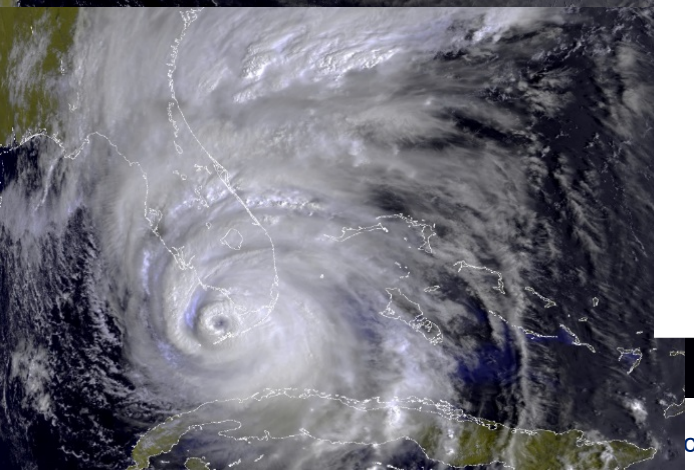
Q&A: www.slido.com meeting code #nextgen-metsat

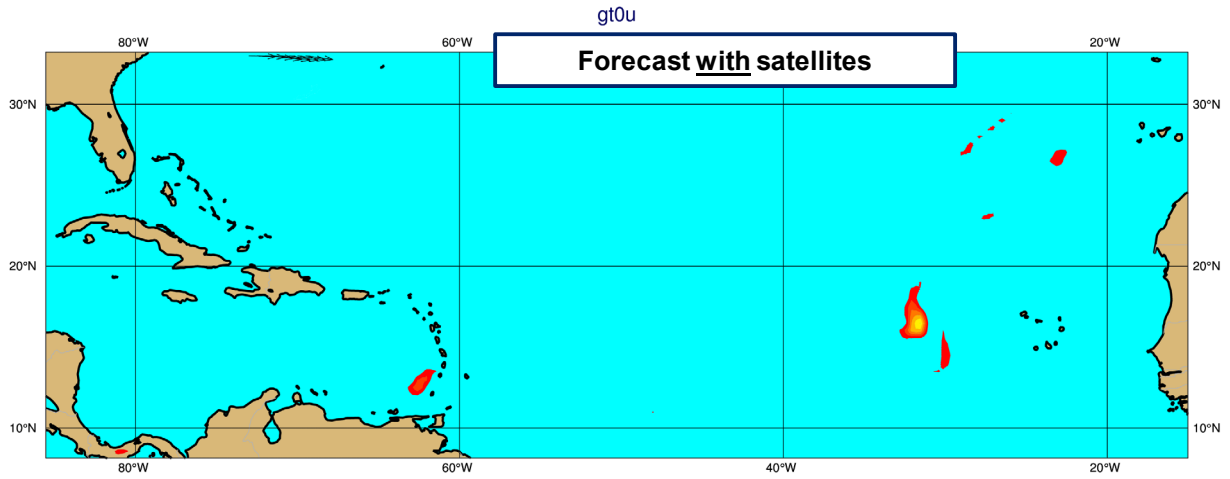
EUMETSAT Metop-series provides data to Numerical Weather Prediction (NWP)



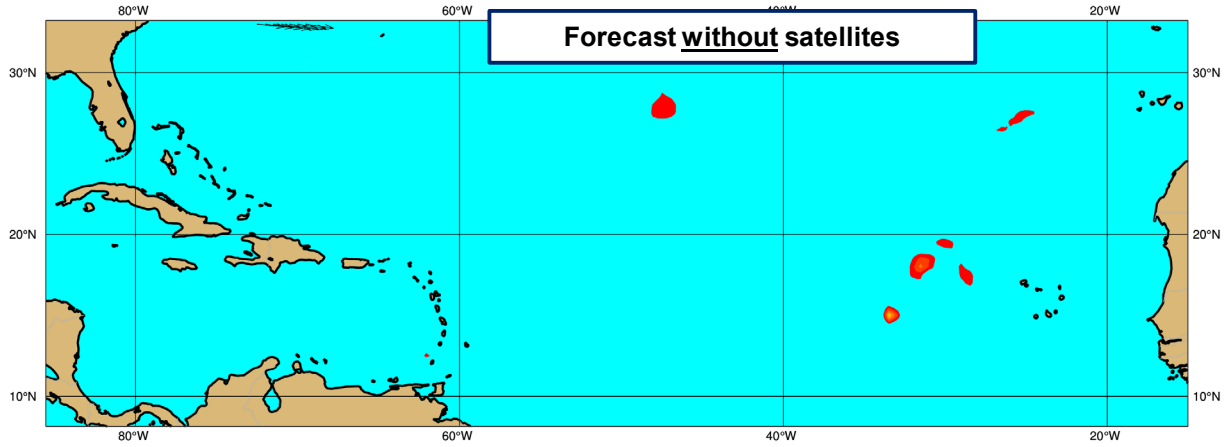
NOAA-EUMETSAT (IJPS) contribution to the forecasting of IRMA (Aug. 2017)

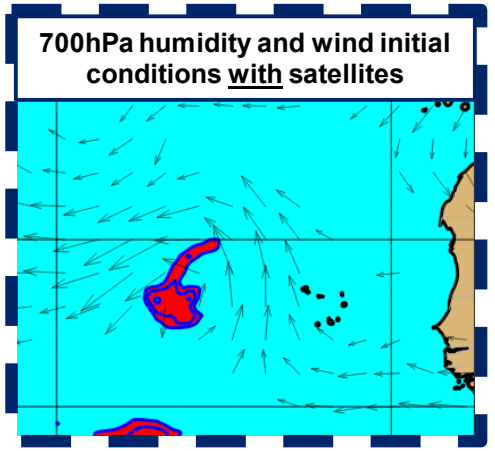




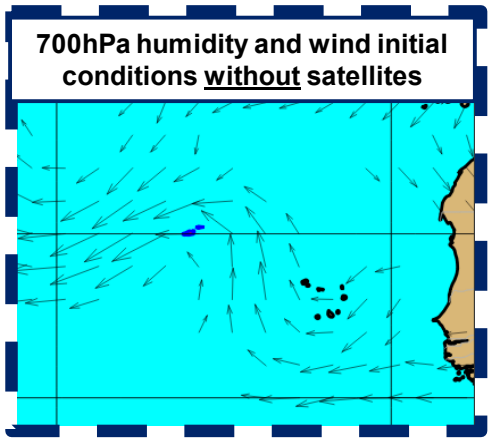


Thursday 31 August 2017 00 UTC ecmf 500 hPa Vorticity (relative)
Thursday 31 August 2017 00 UTC ecmf 500 hPa U component of wind/V component of wind



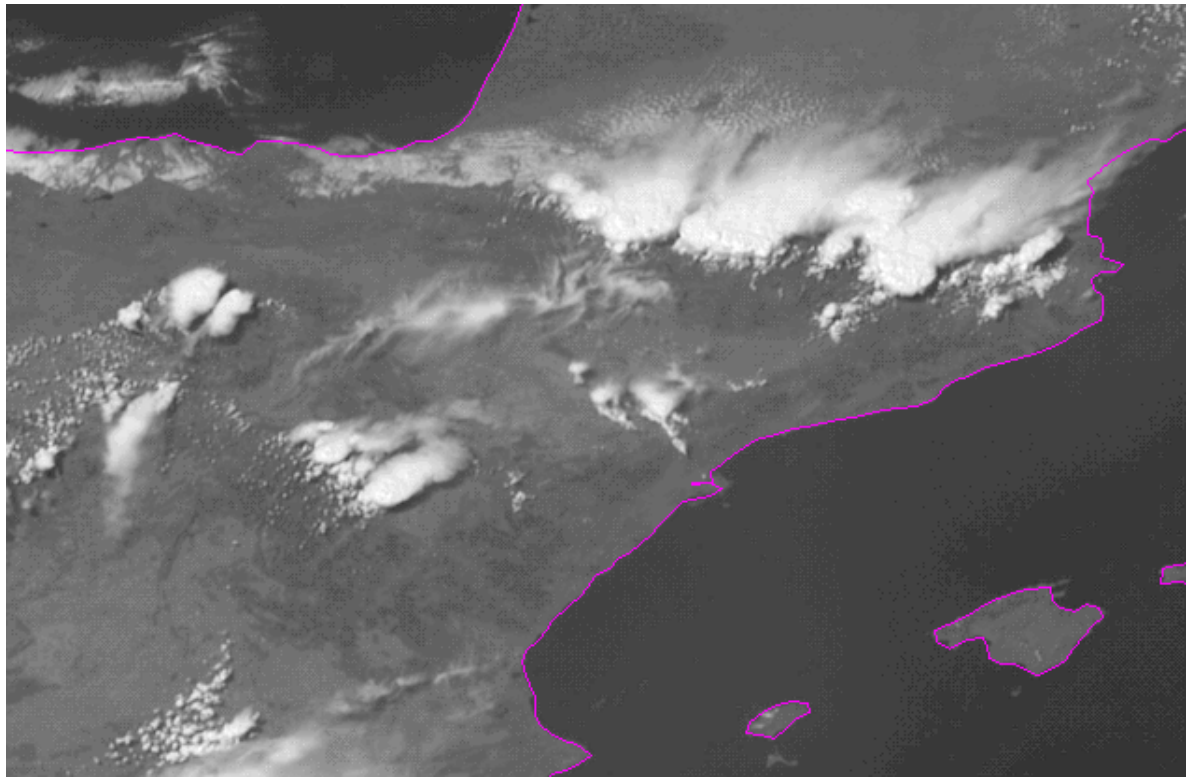


Red shading humidity > 95%

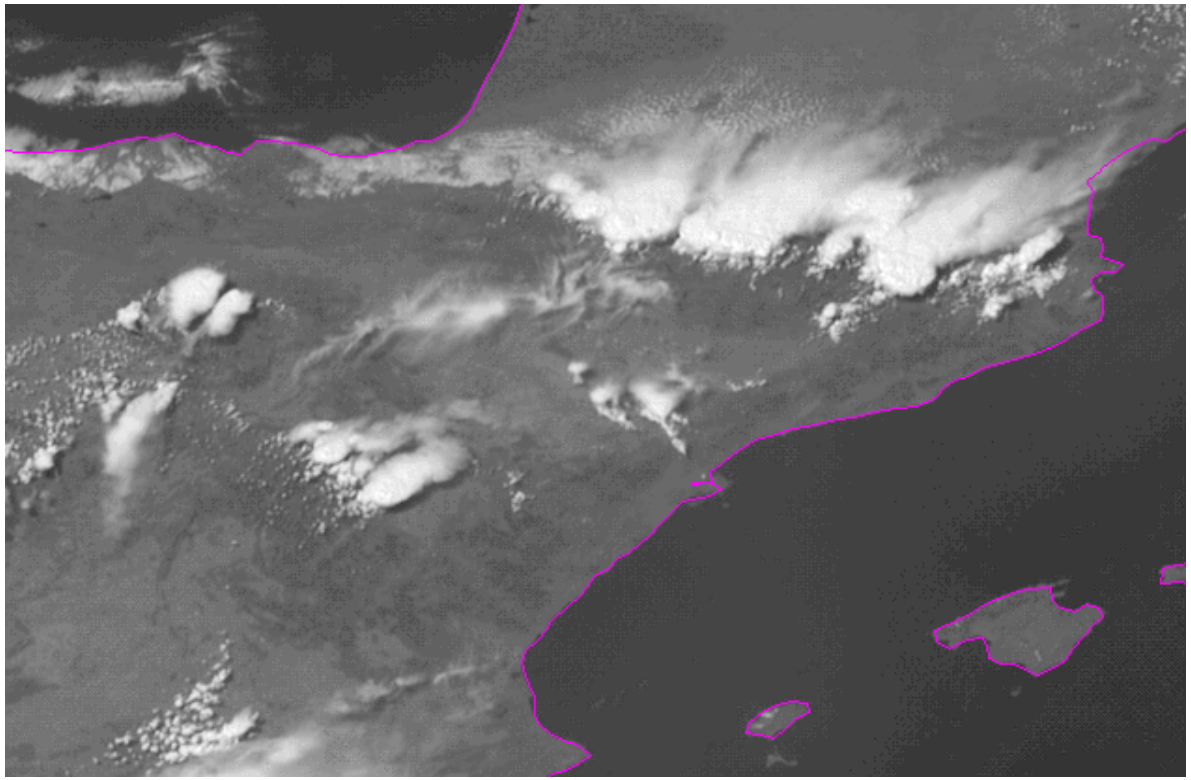


Source: ECMWF (2018)

The operational capability of a two Meteosat satellite system: monitoring thunderstorms over Spain



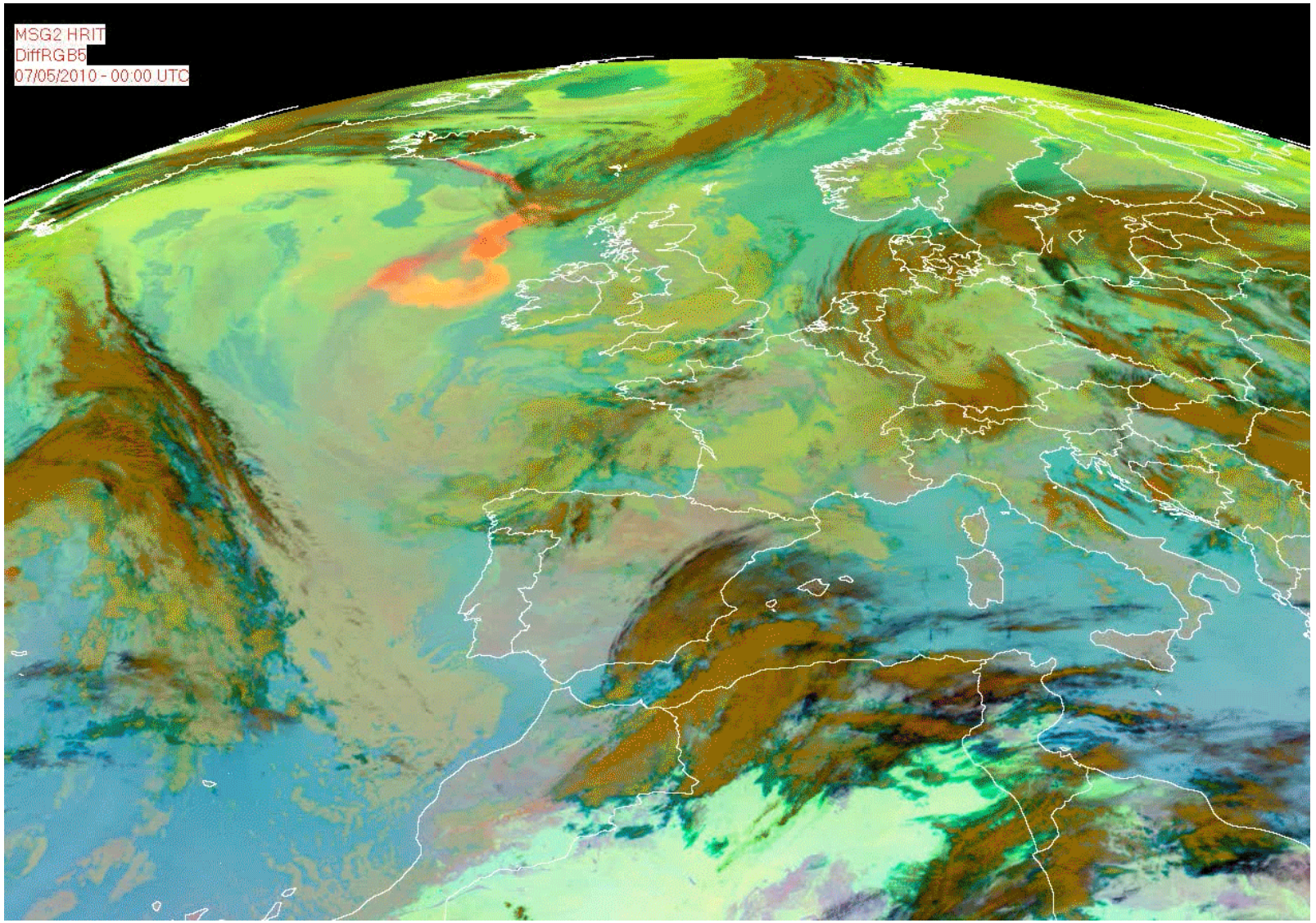
15-minute scan



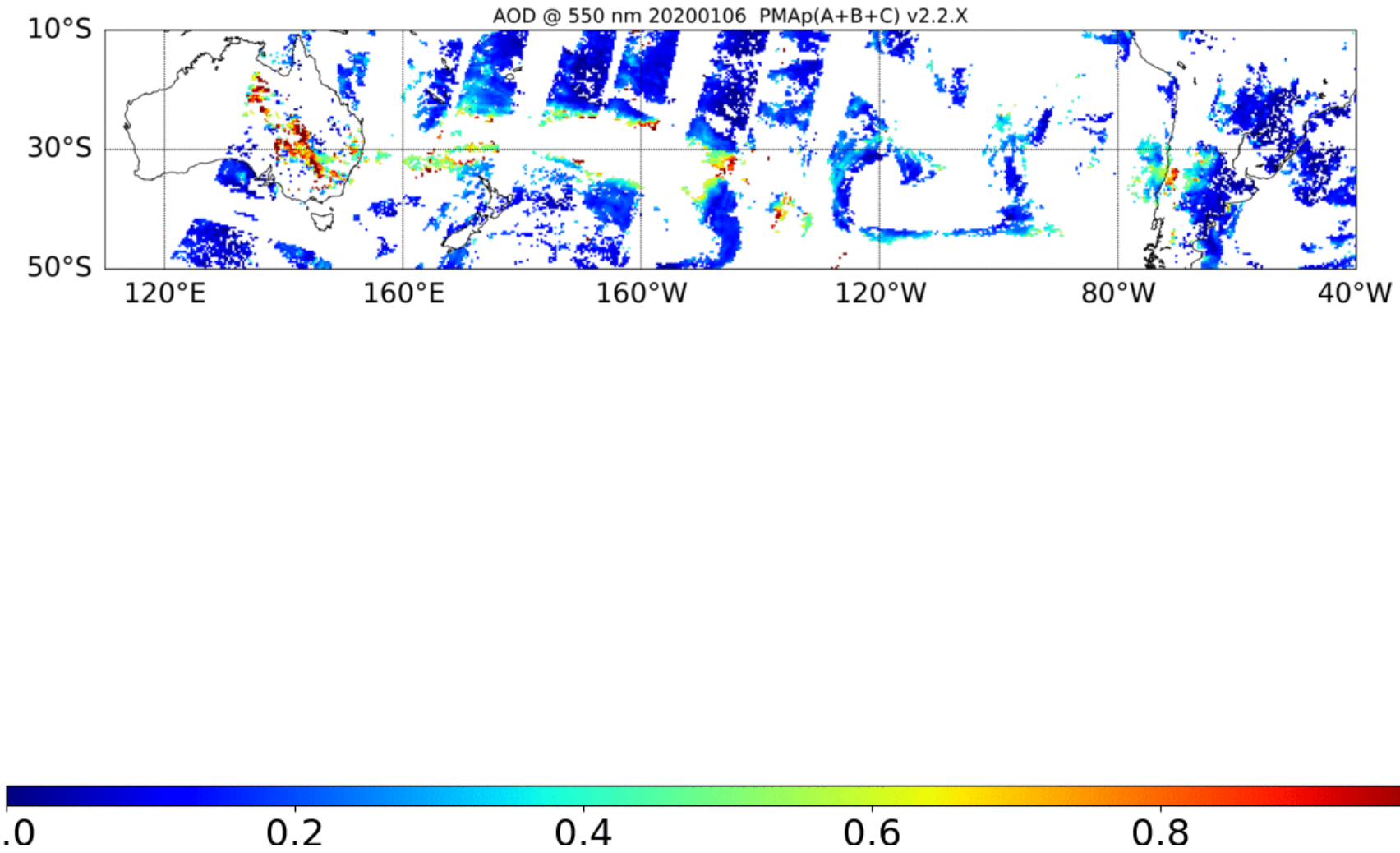
5-minute scan

Meteosat in support for aviation

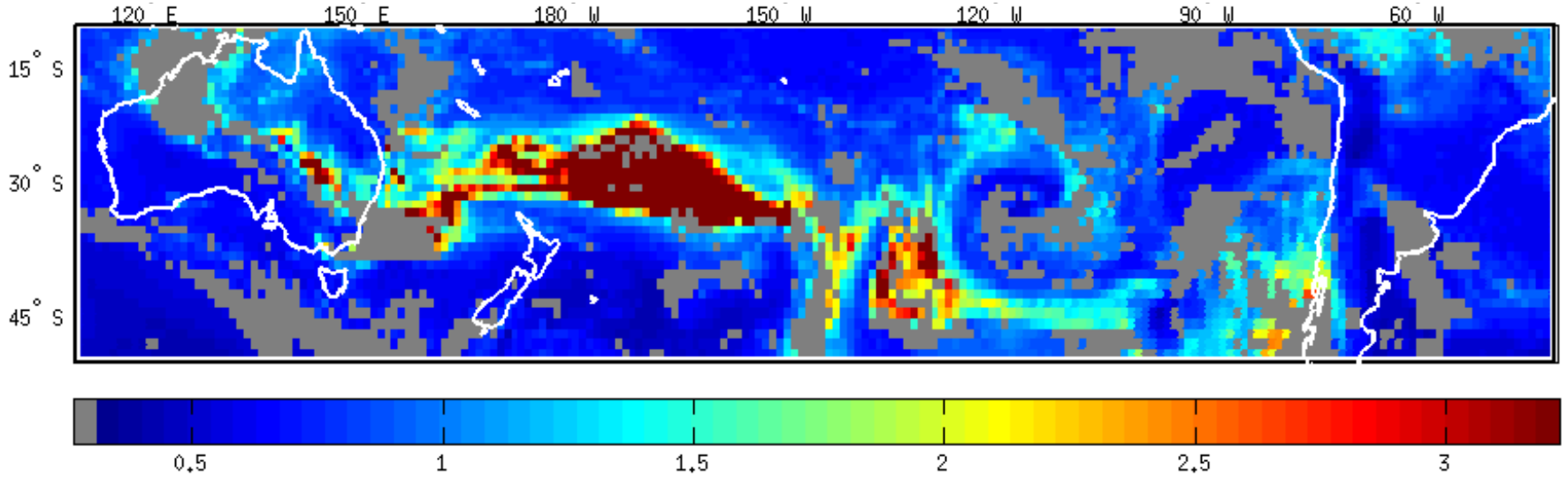
Eyjafjallajökull ash cloud from 7 to 11 May 2010 (second eruption)



Complementarity Capabilities: Aerosol Optical Depth (AOD) from Australian Fires as seen by Metop (and Sentinel-3)



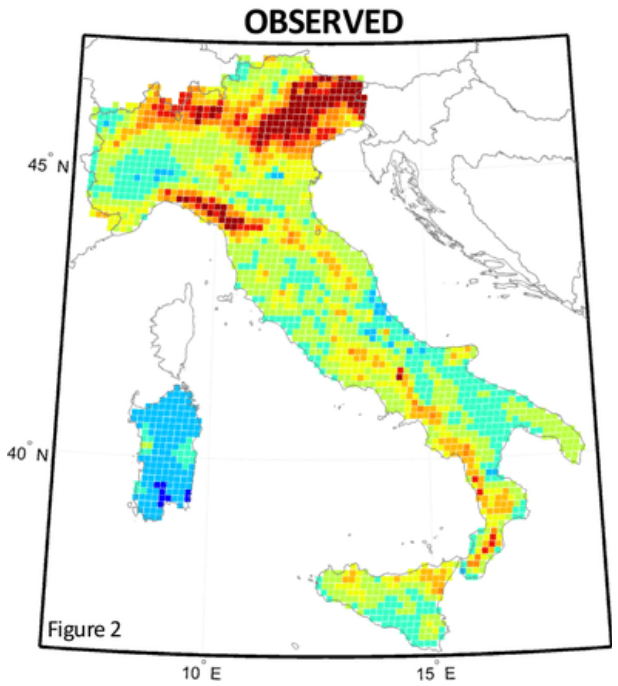
Carbon Monoxide from IASI on Metop-A/B/C: Australian Fires (6-13 January 2020)



Integrated CO [10^3 kg/m^2]

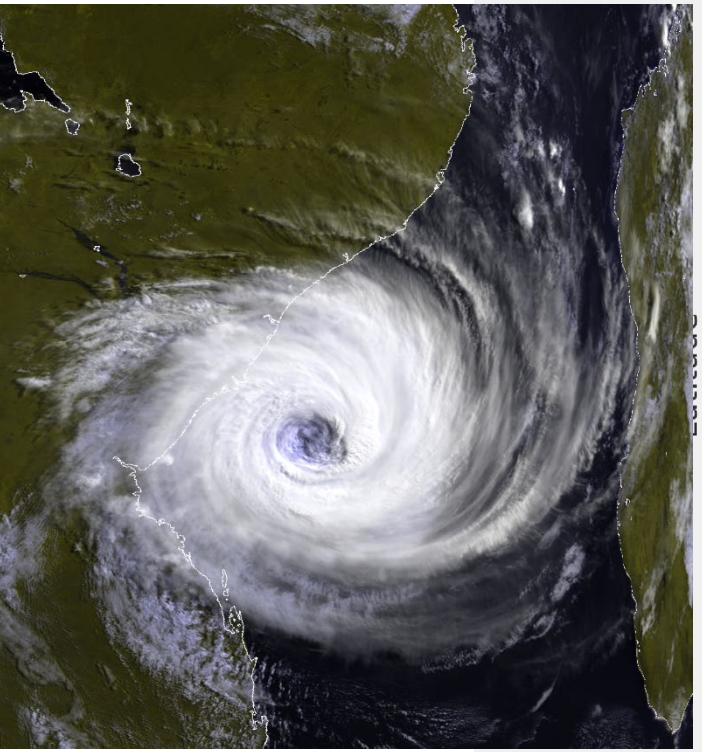
SM2RAIN: precipitation from SCAT soil moisture data

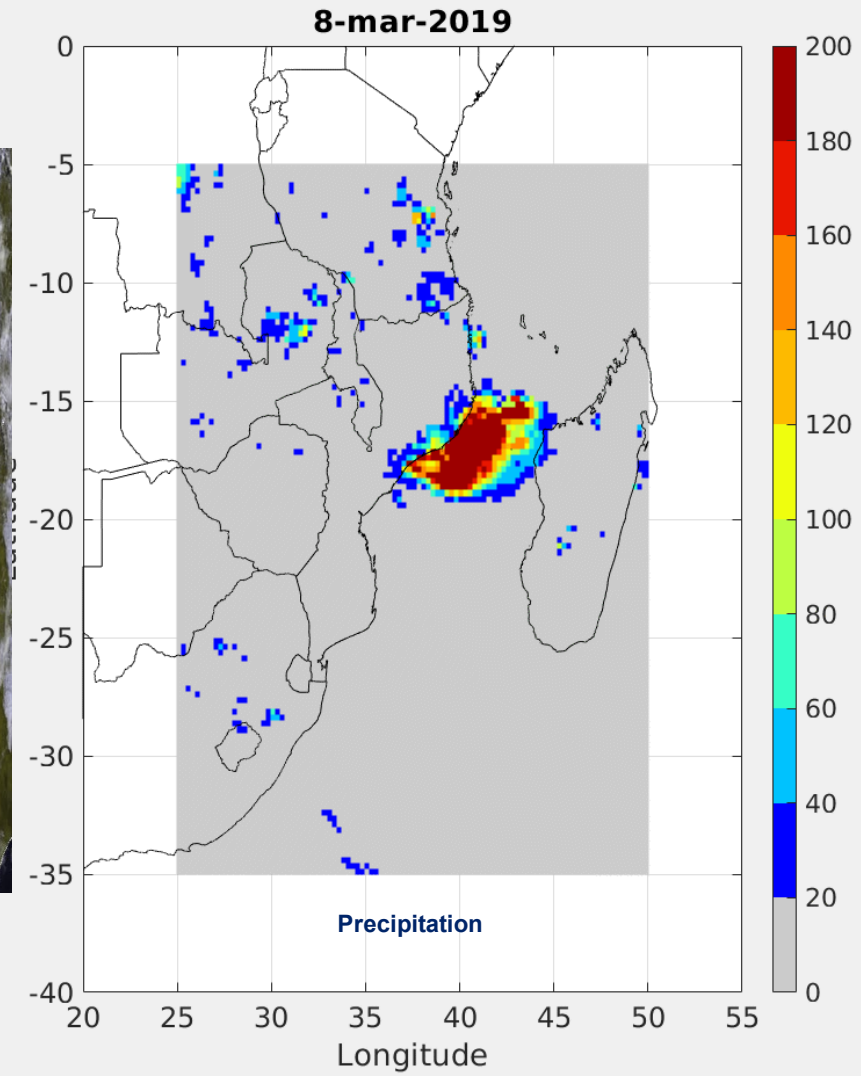
- **Application:** SM2RAIN algorithm (Brocca, *et al.*, 2013, 2014) using ASCAT soil moisture data from H-SAF
- Based on the inversion of the soil water balance equation, i.e. it estimates the rainfall by using the change in time of the amount of water stored in to the soil, thus considering it “as a natural rain gauge”

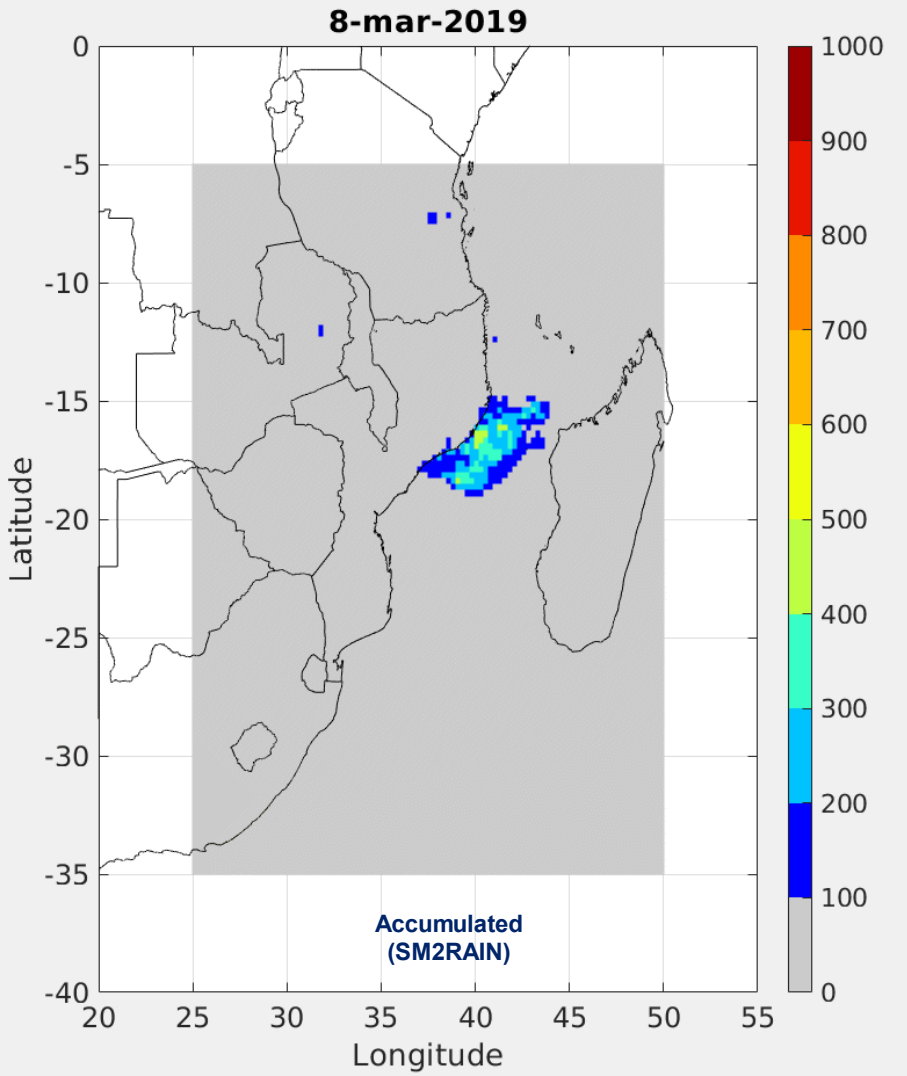


Courtesy: Luca Brocca, CNR

IDAI over Mozambique (8-18 March 2019) as seen by SM2RAIN



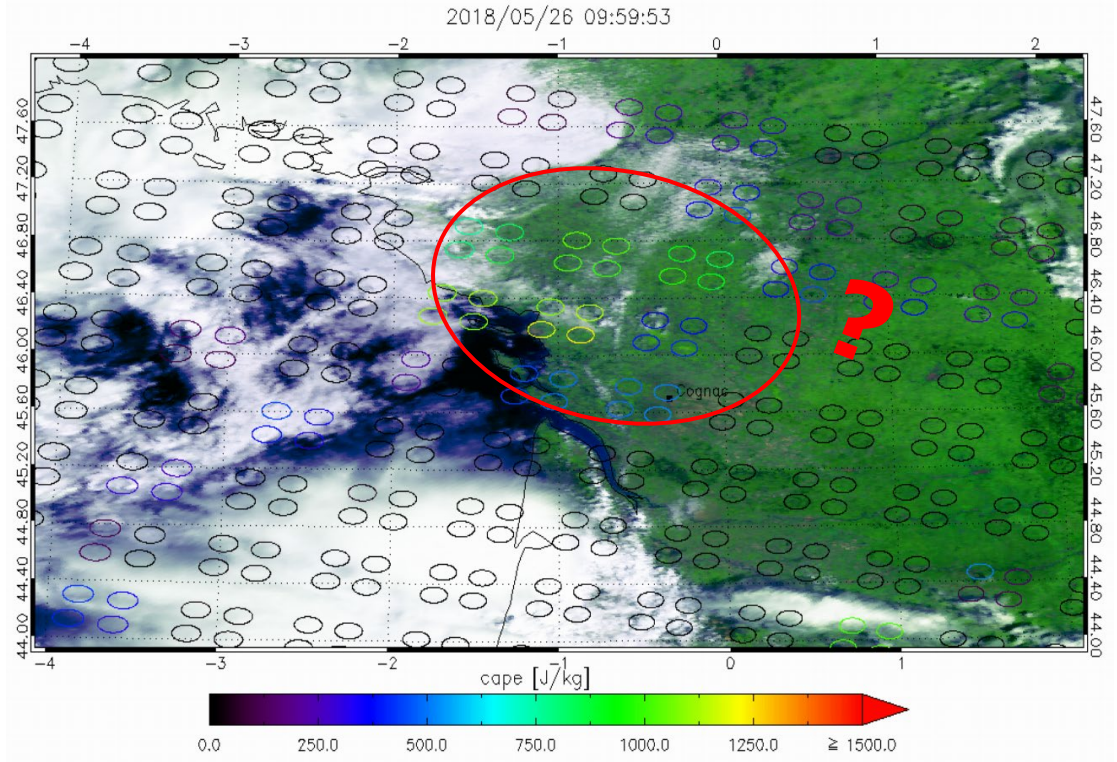


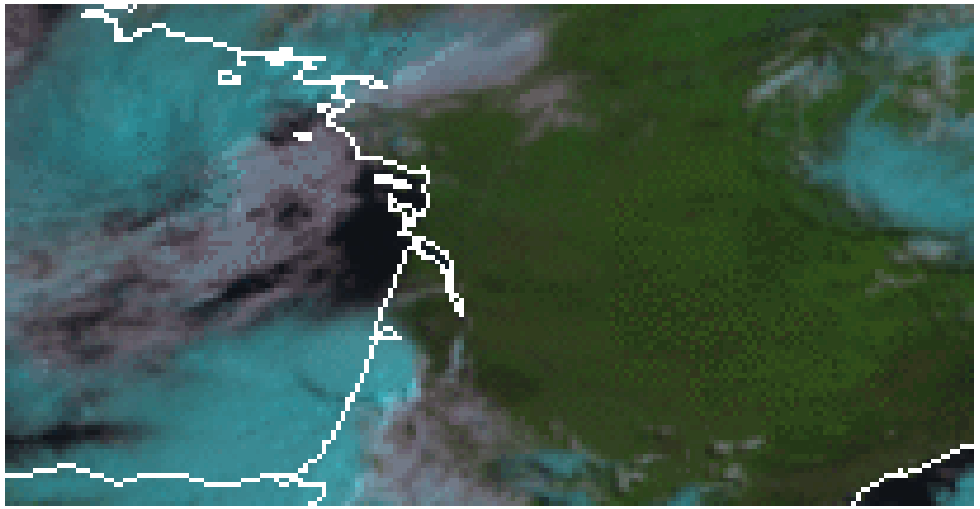


The MTG and EPS-SG – *the European context*

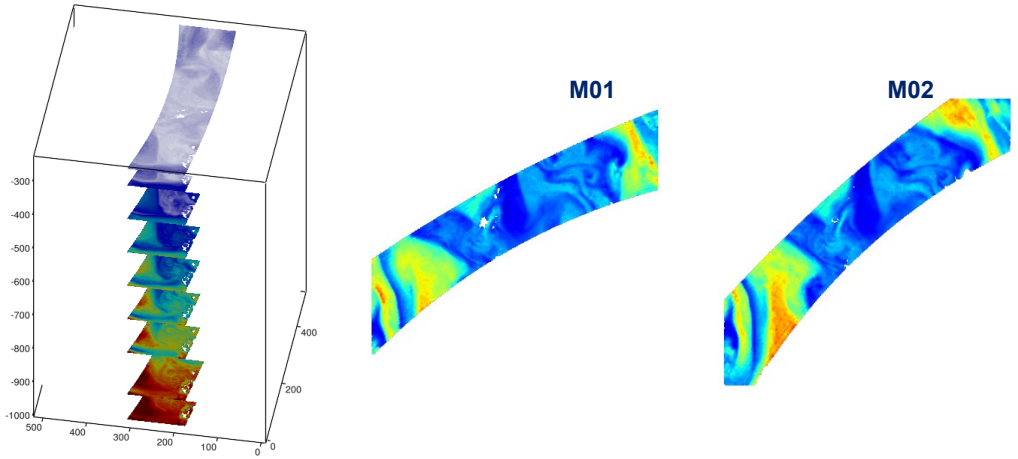
- The Meteosat programme (incl. the future MTG) is recognised as a European success story and a European Asset by the EU Space Strategy adopted in October 2016
- The MTG and EPS-SG programmes have been funded by the 30 EUMETSAT Member States (most of them EU Member States) at a level of 7 Billion Euros through the 2040s. ESA also contributes to the funding of these programmes for the development of the prototype satellites
- The first satellites of the MTG and EPS-SG programmes will be launched in the 2021 / 2022 timeframe (nb in the time frame of Horizon Europe)

Severe hail storms prediction with IASI: Bordeaux Cognac 26/05/2018 (Nowcasting preparation for Meteosat Third Generation)





3D wind product demonstration for MTG/IRS

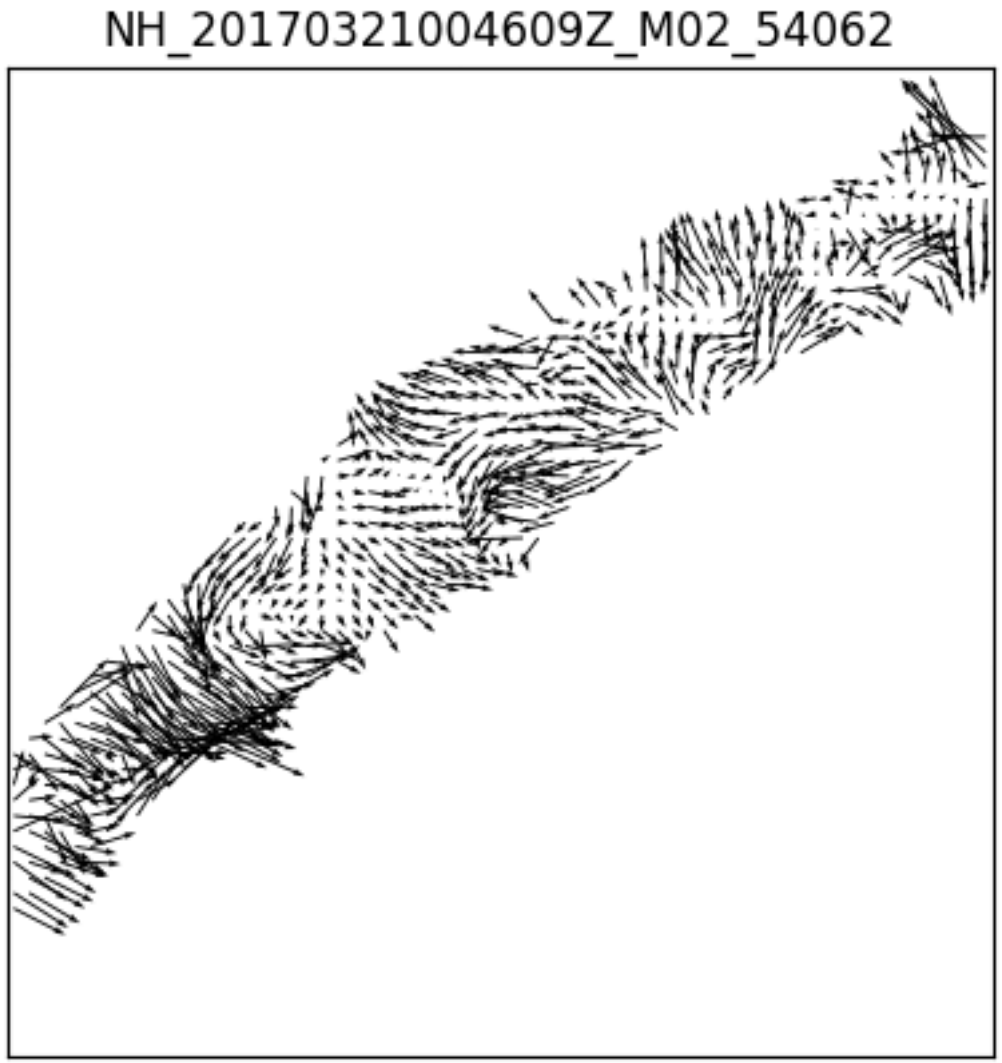


Based on Metop IASI Level-2 products:

- Water vapour, ozone, and temperature concentrations patterns are tracked between two successive images
- Troposphere and low stratosphere
- High-latitude regions (~45 deg. polewards)
- Dual operation: *Metop-A + Metop-B*

Global product:

- Tracking based only on data
- No circulation model embedded
- Levels consistency ensured by the full global inversion
  → wind profiles retrieved at each point location

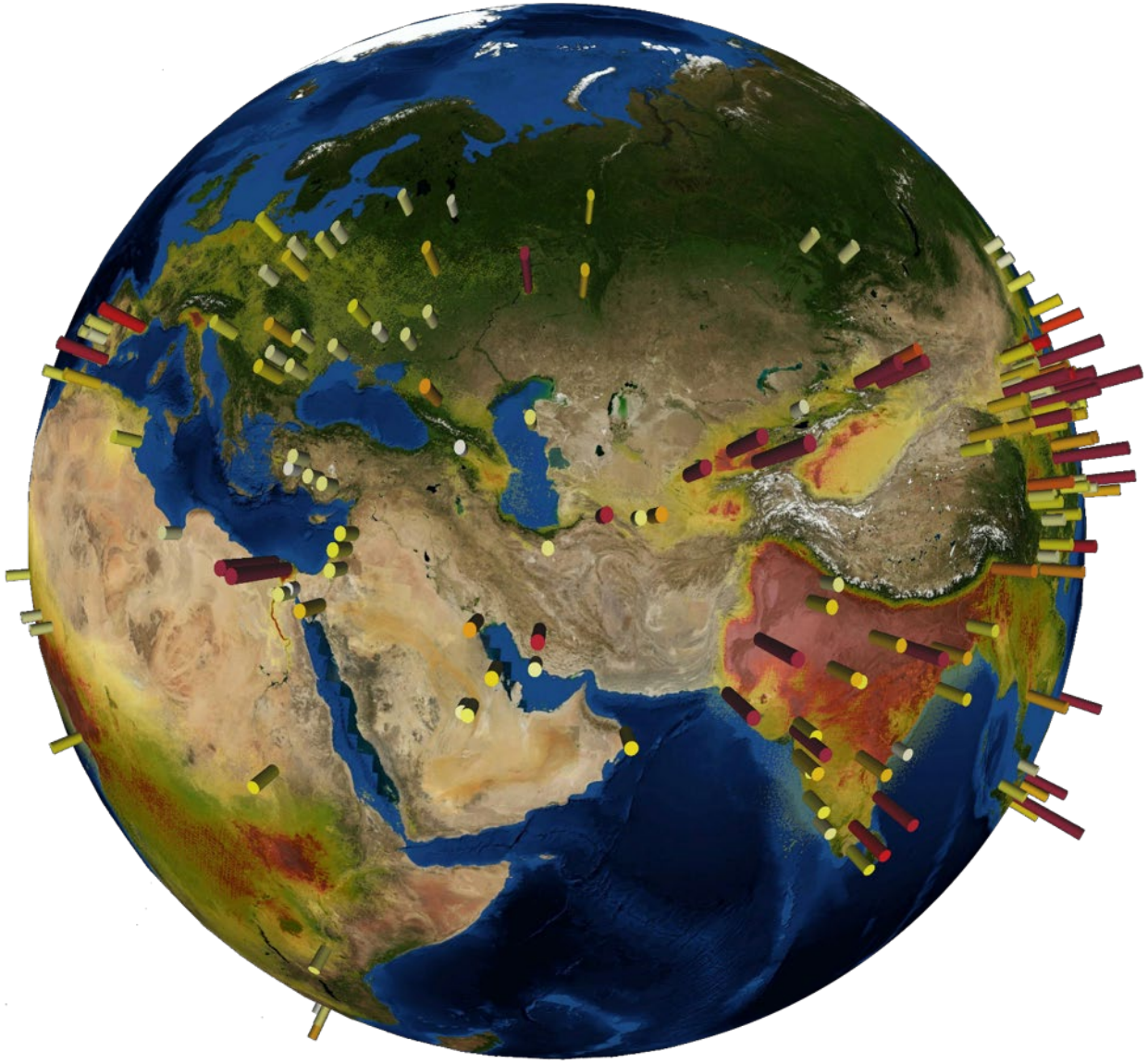


Ammonia emissions from IASI → *future monitoring from MTG and EPS-SG*

Ammonia emission fluxes calculated based on almost a decade of IASI measurements (Martin Van Damme and Lieven Clarisse / ULB → *see Nature paper, December 2018*)

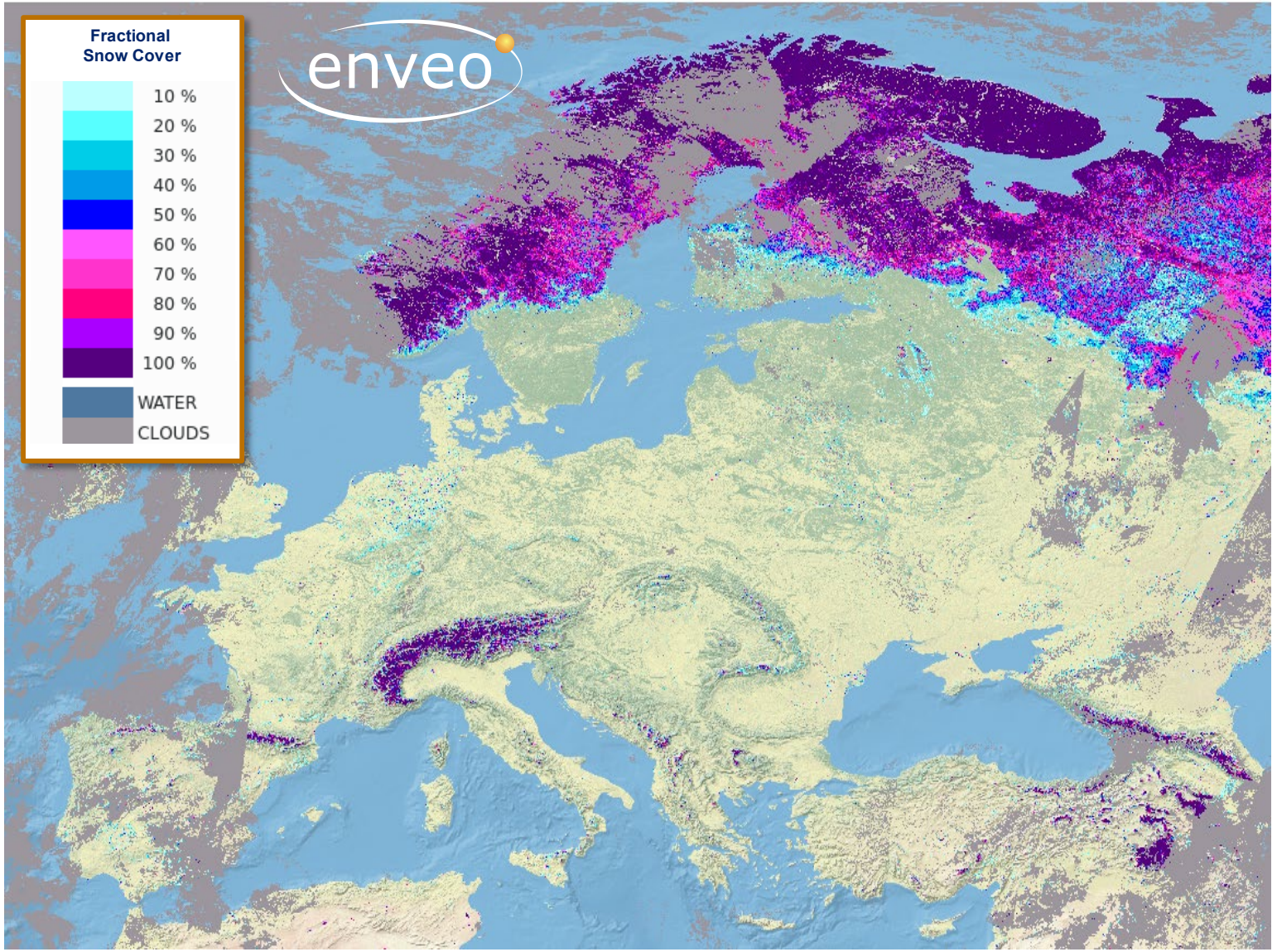
- Ammonia affects air quality and has implications for human health and life expectancy.
- Excess ammonia in the environment also contributes to the acidification and eutrophication of ecosystems and to climate change

MTG/IRS will measure Europe every half hour with a ~4-8km resolution.

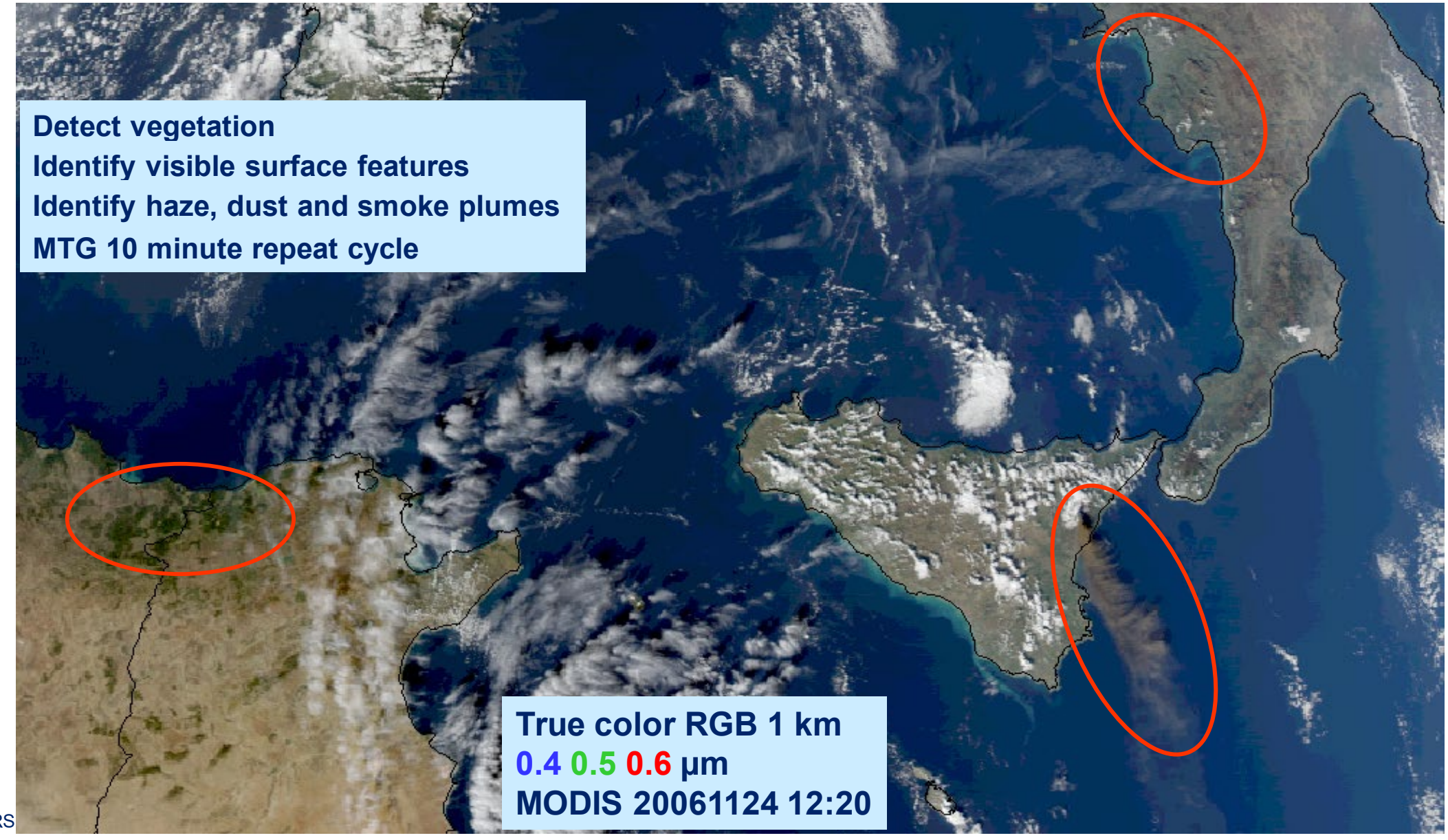


Snow Cover/Extent Demonstrator for EPS-SG METimage

- SEDOS study lead by ENVEO GmbH (A)
- Demonstrator for EPS-SG METimage using Sentinel-3 SLSTR/OLCI
- Close cooperation on Cal/Val foreseen with the EUMETSAT H-SAF
- Right: Sentinel-3A Fractional Snow Extent, 500 m (21-23 April 2018)



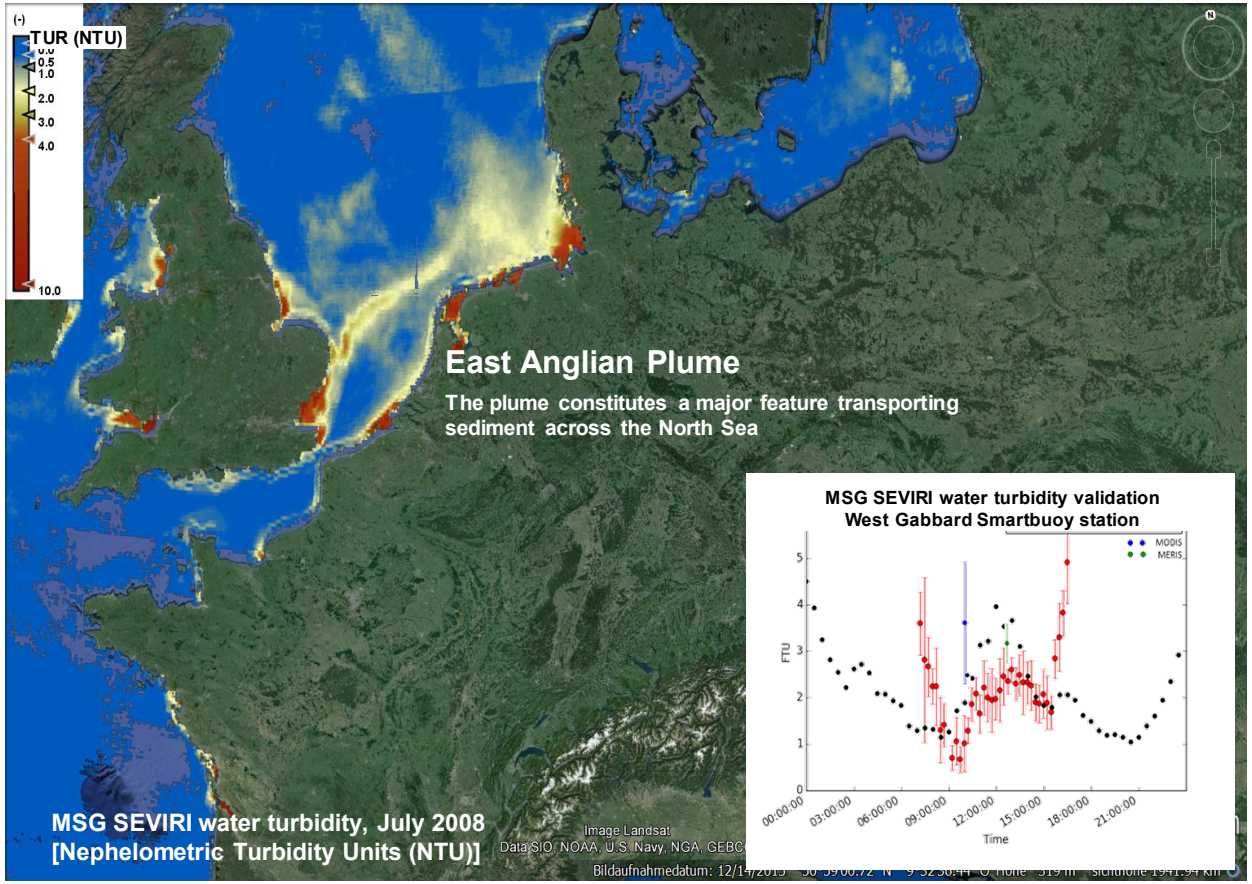
From MSG SEVIRI to MTG FCI (simulated data)



Water turbidity parameters demo using MSG SEVIRI

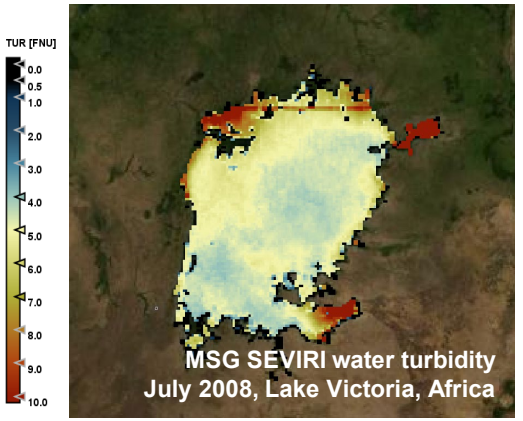
EUMETSAT study, Feb. 2015 – Mar. 2016

1. **User Requirements analysis**
2. **Prototype Processor development and validation**



Development endorsed by CMEMS

User Applications	Parameter	Best Spatial Resolution	Resolution	Accuracy
Coastal water quality (EU MSFD)	TUR, SPM, SD	300m-1km	1h – 10y+	threshold
Water quality of European lakes (EU WFD)	TUR, SD, XCYA	300m-1km	1h – 10y+	threshold
Coastal water quality - Africa	TUR, SD, XHAB	~1km	1h – 10y+, NRT	scientifically sound
Water quality of African lakes	TUR, SD, XCYA	300m-1km	1h – 10y+	scientifically sound
Sediment transport	TUR, SPM	10m-1km	1h – 10y+	absolute
Ecosystem modelling (eutrophication)	KdPAR/ZE, SPM	1-10km	1h – 10y+, some NRT	uncertainty per pixel
Offshore diving operations	TUR (HVIS)	1-100m?	10m – 6h, NRT	scientifically sound
Carbon burial by coccolithophores	COCCO	~10km?	1h – 10y+	unknown
Support for OC validation	Rrs	300m-1km	5m – 10y+	absolute

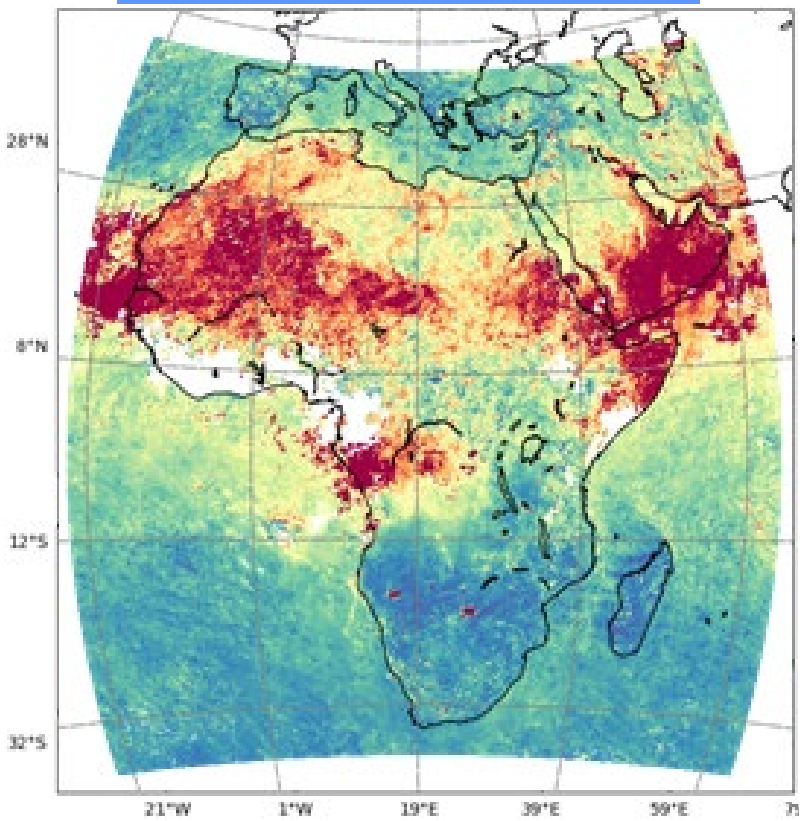


EUMETSAT

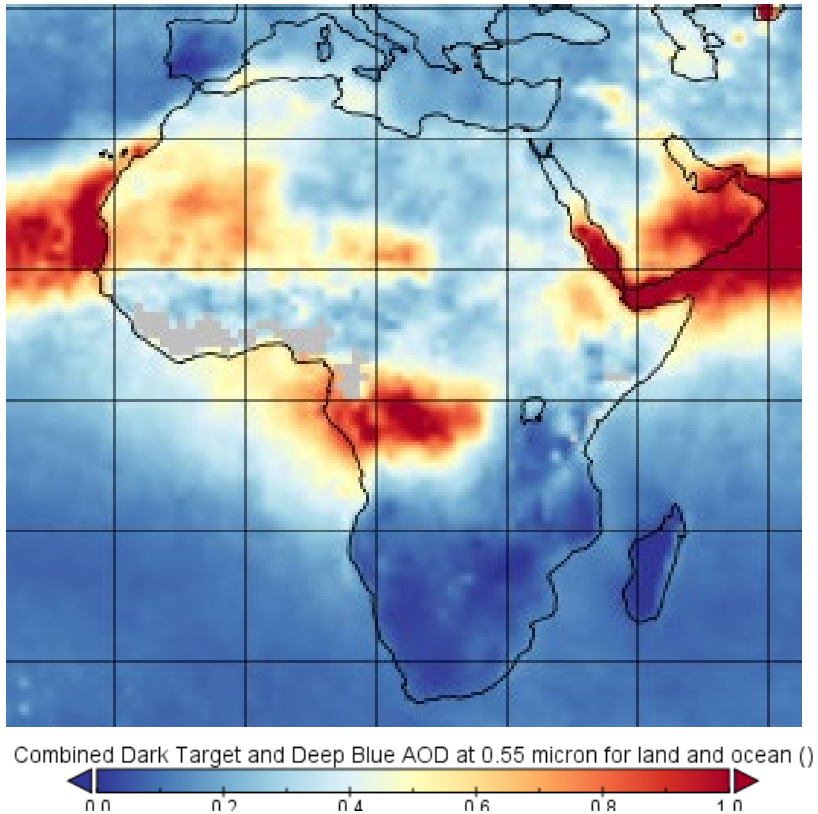
MTG/FCI AOD preparations: understanding GRASP using S3/OLCI

Monthly Average July 2018

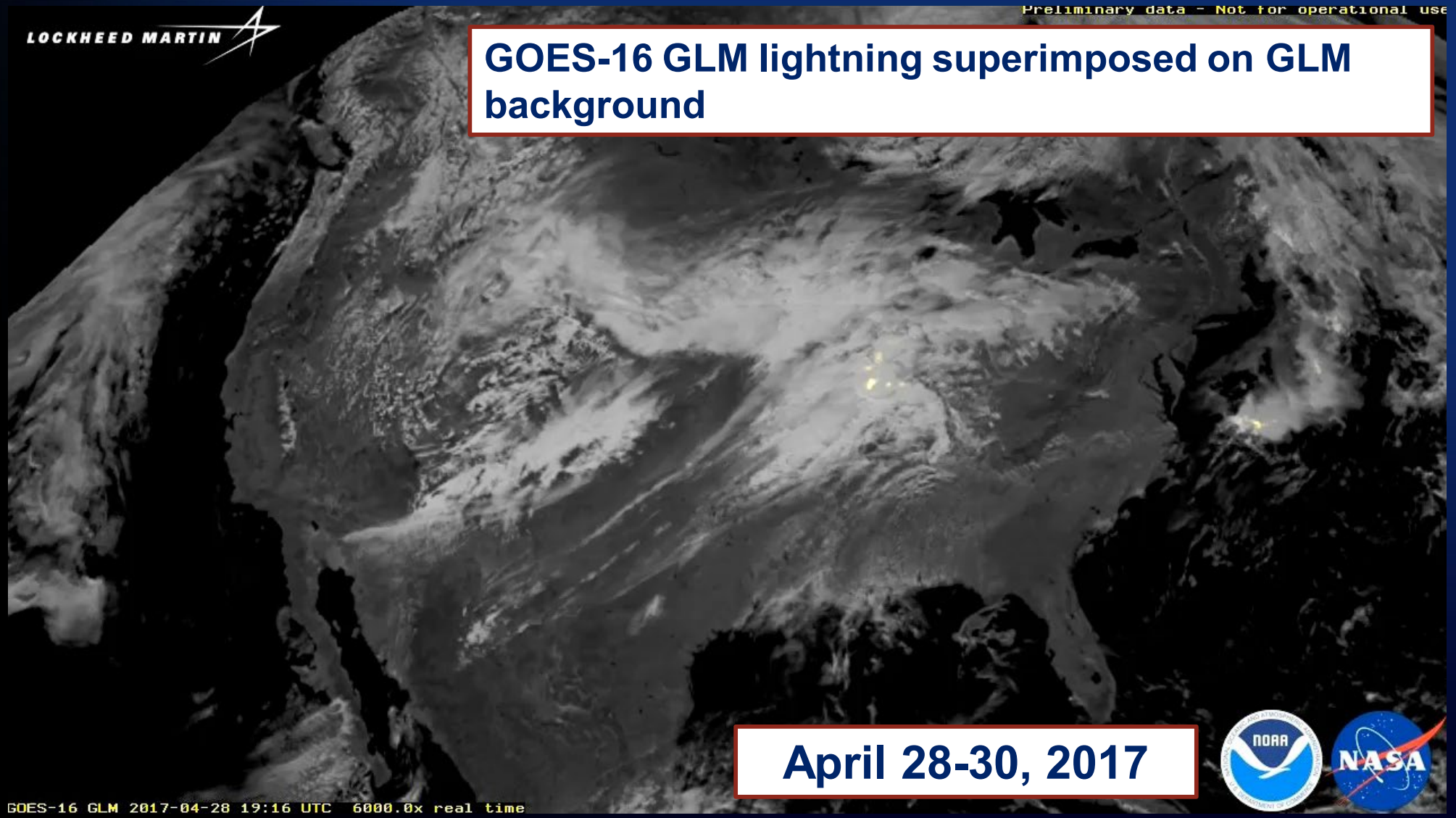
S3A OLCI AOD(560 nm)



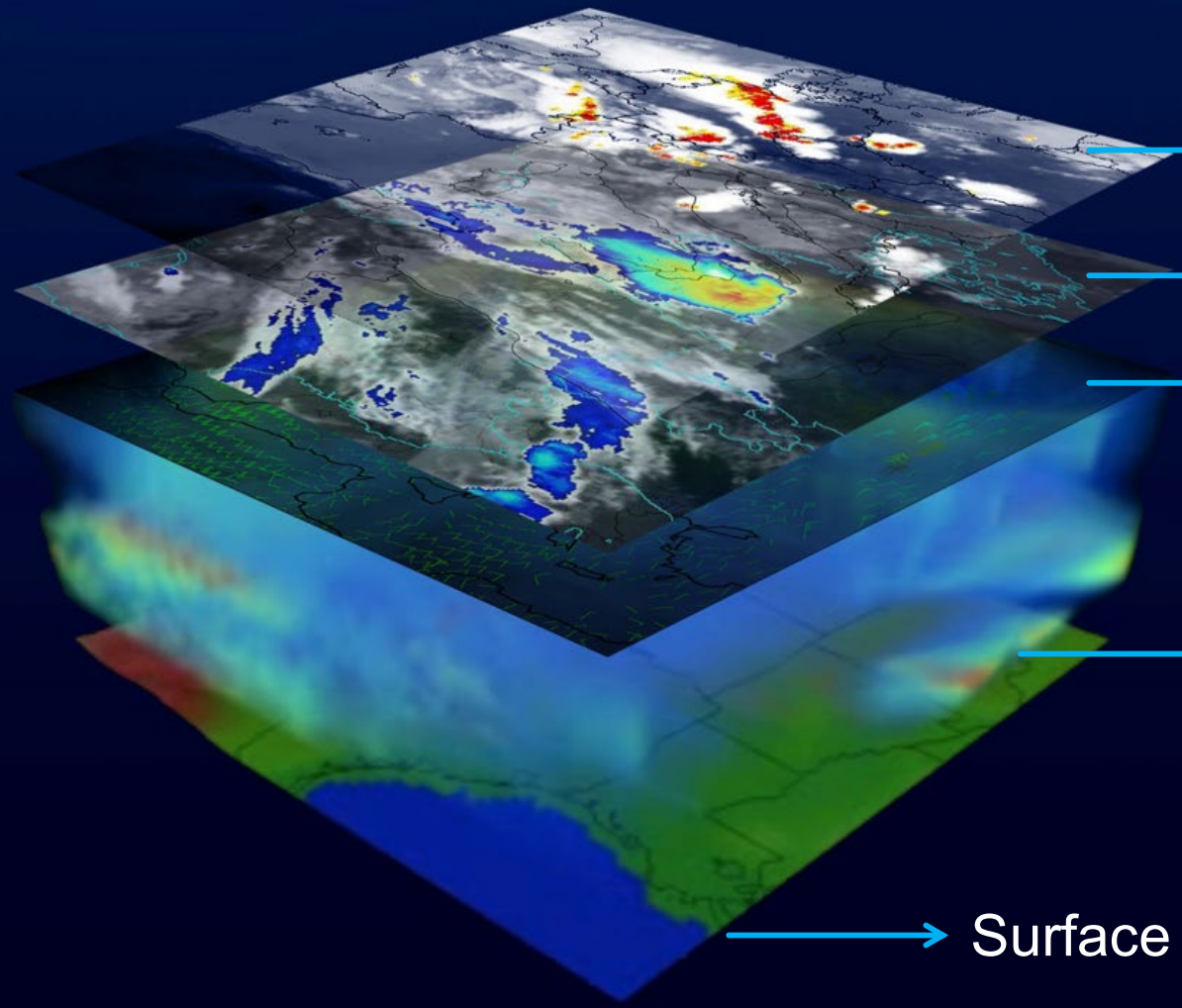
MODIS Terra AOD(550 nm)



Lightning monitoring: an example NOAA/GOES-16 (R)



Implementing the 4D weather cube with MTG…



Lightning

Convection

Winds

Atmosphere

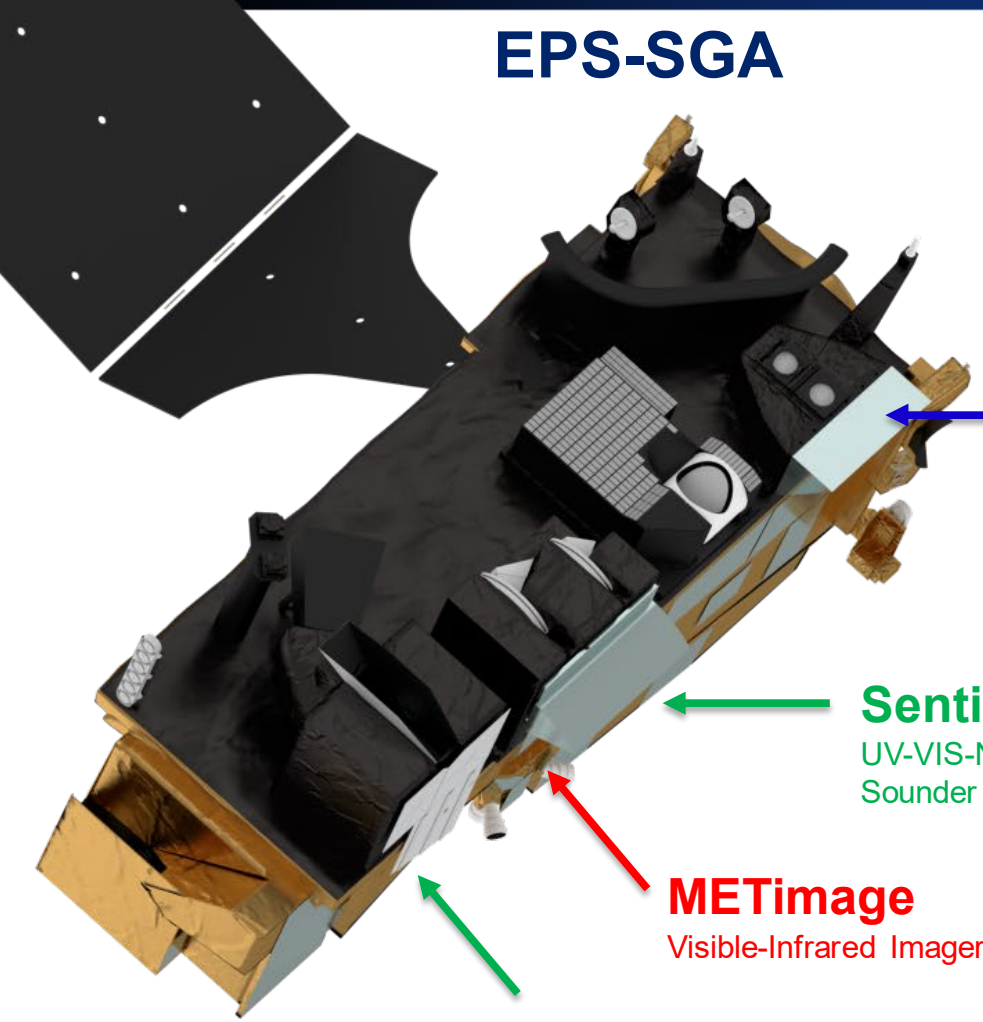
Surface Properties

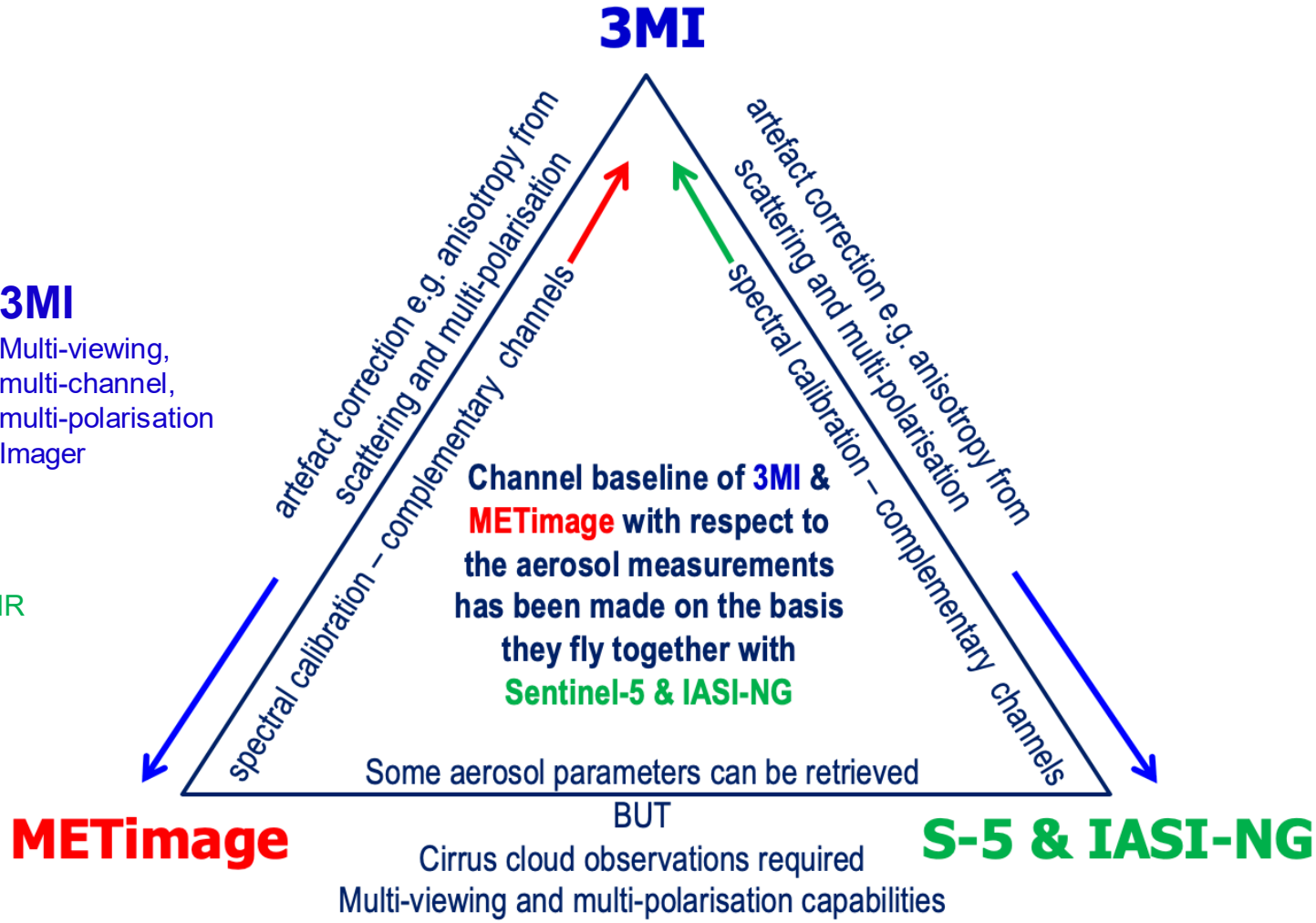
EUMETSAT is living the

Research to Operations

Operations to Research

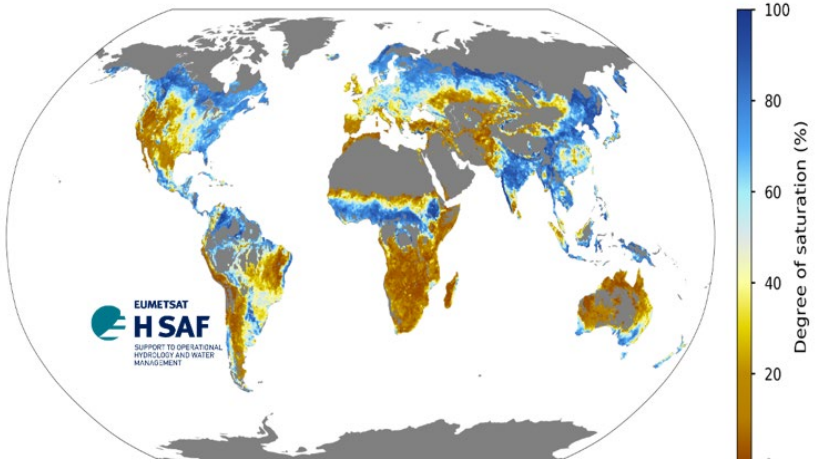
R&D needed: synergy of EPS-SGA instruments…





Cal/Val, Reprocessing, and Climate Records

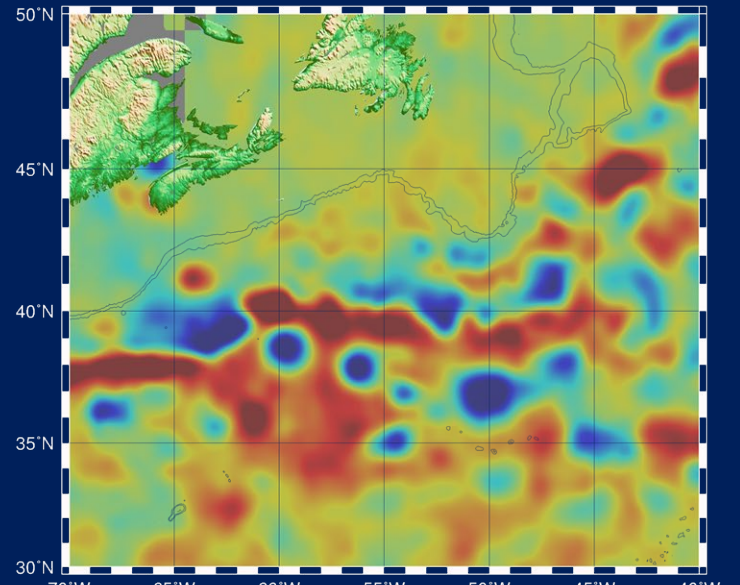
10-year ASCAT soil moisture record at 12.5 km resolution (2007-2017)



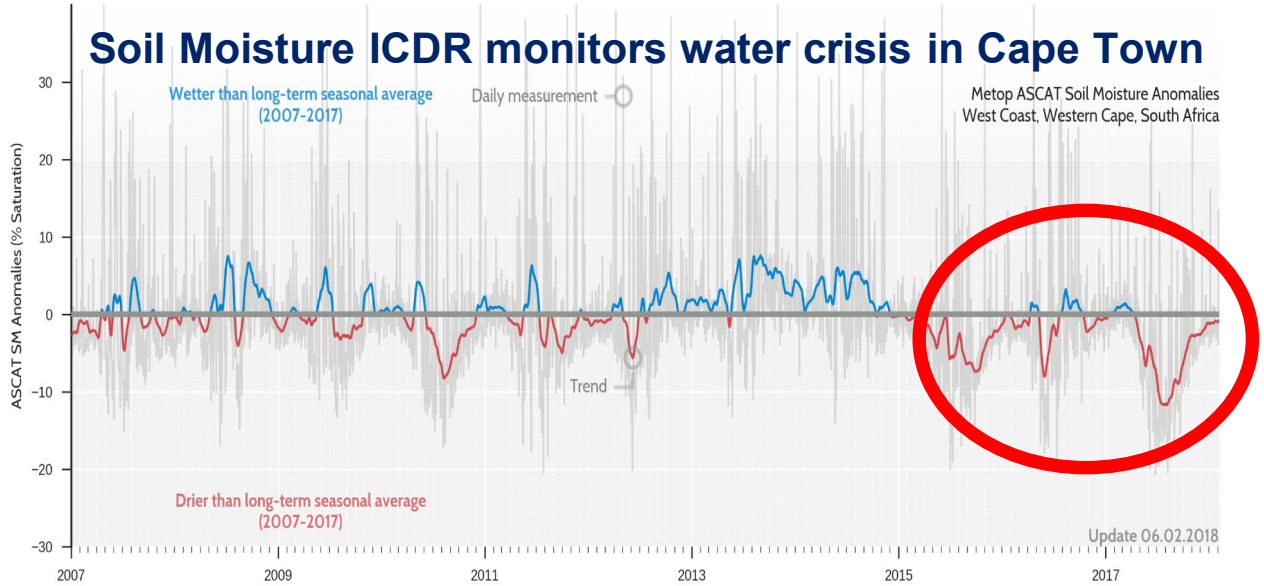
ASCAT Transponder (calibration)

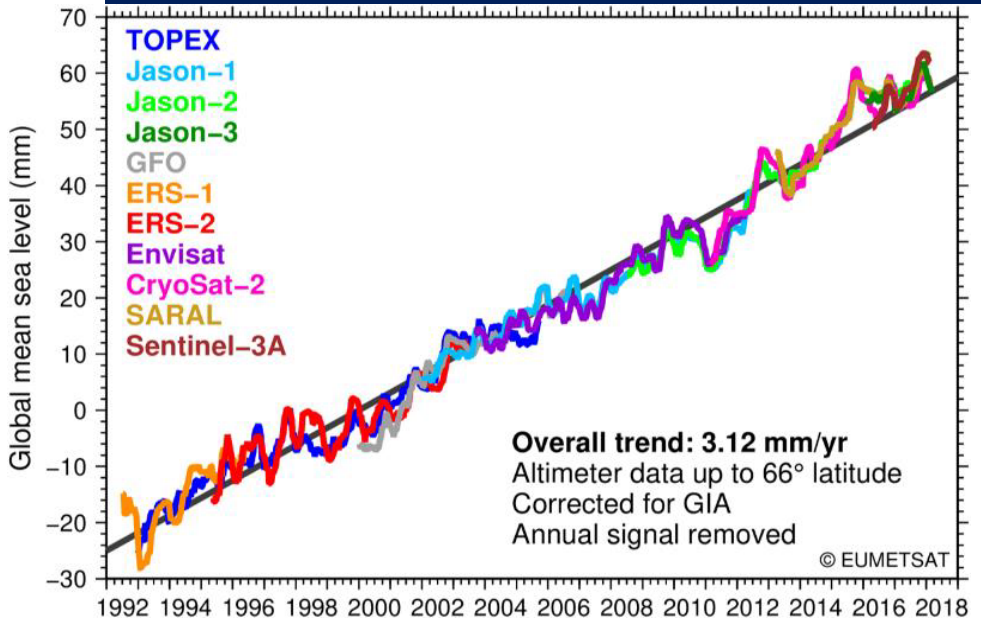
Example: Altimeter Interoperability

sea level anomaly (cm)



Soil Moisture ICDR monitors water crisis in Cape Town





EUMETSAT

MTG and EPS-SG & Research and Development

- MTG and EPS-SG are operational programmes each guaranteeing more than 20 years of observations to the European providers of weather and environment information services but also to the European Science and Climate research Communities

- The MTG and EPS-SG satellites will fly highly innovative instruments developed by European industry, several being even “world première”: there will therefore be a need for investing in R&D activities to get the most out of these new data, and to create innovation through their use, alone or in combination with other data

- The Copernicus Sentinel-4 and Sentinel-5 air quality missions will be implemented as part of the MTG and EPS-SG satellite systems, by additional instruments on board the MTG and Metop-SG satellites, to be used in synergy with EUMETSAT instruments: this offers unique opportunities for developing innovative multi-sensor products for the monitoring of the atmosphere, the oceans and climate change

MTG and EPS-SG & Research and Development (ii)

- Data from EUMETSAT instruments to be used in combination with data from Sentinel-4/-5 instruments will be available free of charge to Copernicus, as per agreements signed with the EC, and all MTG and EPS-SG data are expected to be available free of charge for research purposes, in line with the current EUMETSAT Meteosat and EPS Data Policies

- The applications of MTG and EPS-SG, which are science-driven, have high societal and economic impact (EPS-SG alone has an impact of 5 BEUR per year to the EU economy), *i.e. weather forecasts to protect lives, properties and infrastructures, support to transport, monitoring of pollutions, trace gases and GHG, contribution to climate monitoring, …*

- MTG and EPS-SG data, as well as from precursor missions such as for example Sentinel-3, are of high relevance to research and development

How EUMETSAT can help?

Contact User Support:

The EUMETSAT User Service Helpdesk can answer your questions regarding MTG and EPS-SG → Contact our team at ops@eumetsat.int

or visit:

https://www.eumetsat.int

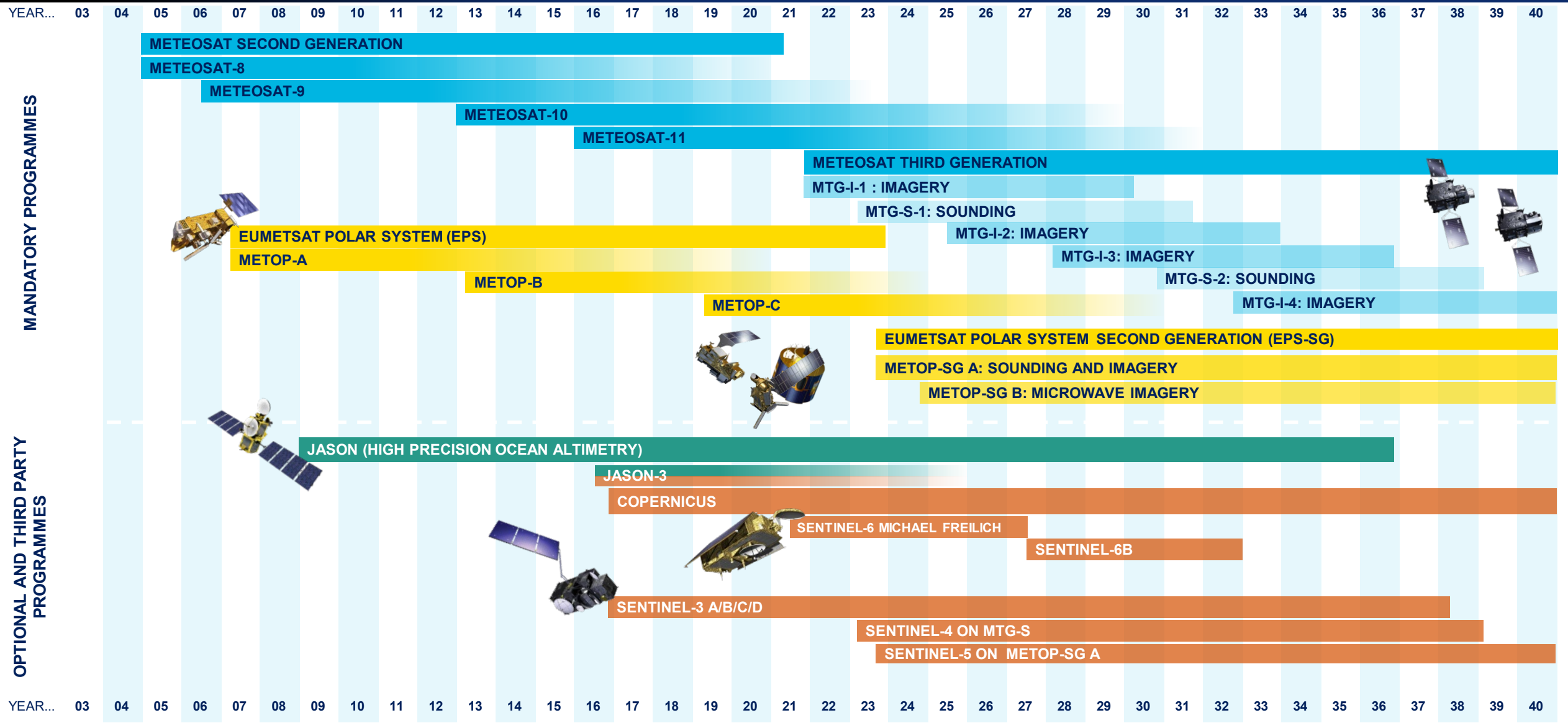
Save the date: 2021 MTG and EPS-SG User Days

22-24 June 2021
Darmstadt, Germany

Key audiences:

- **National meteorological and environmental services**
- **Research and academia**

Thank you for your attention!



EUMETSAT

BACKUP / Miscellaneous

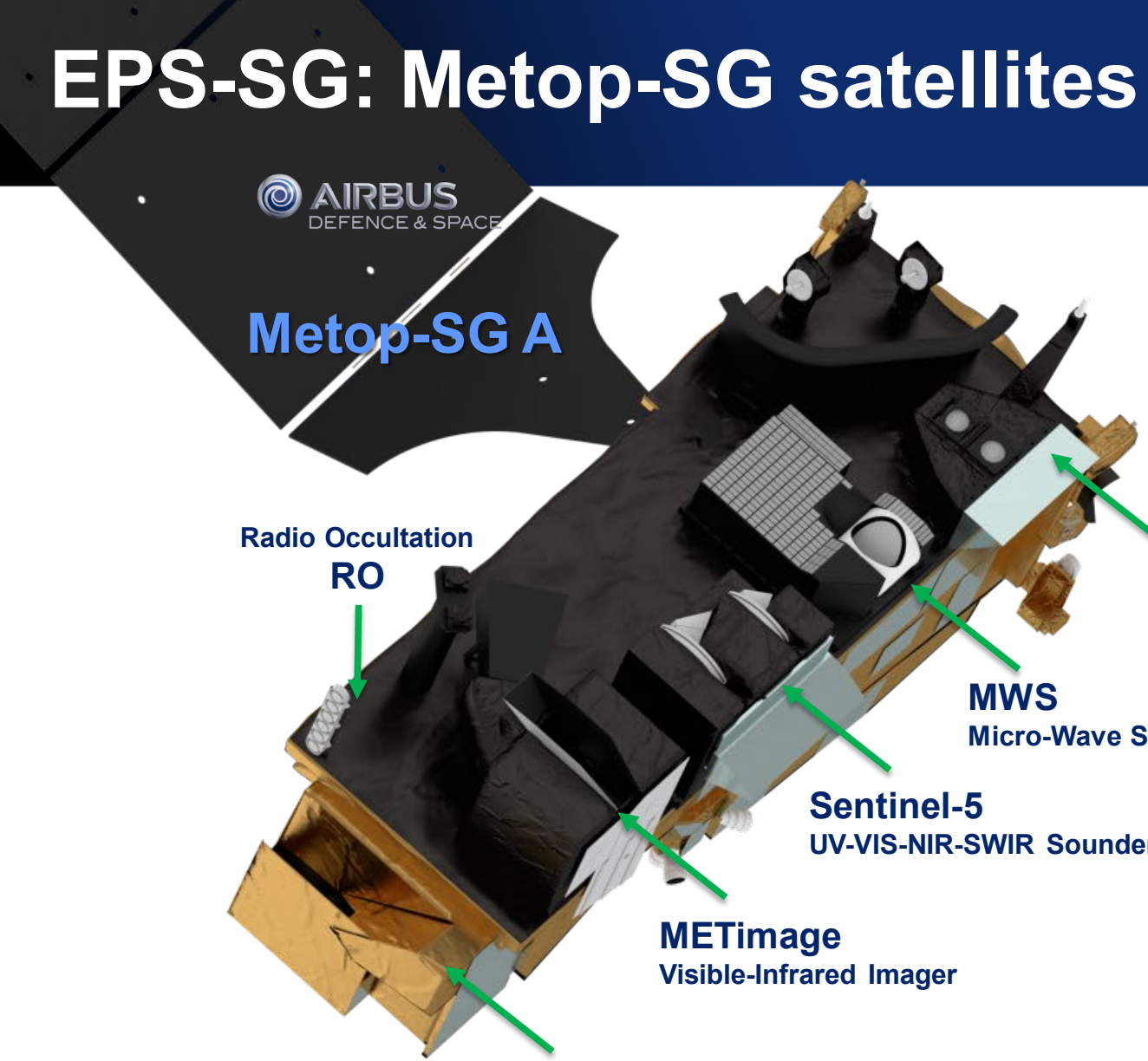
Meteosat Third Generation: Imaging mission (MTG-I)

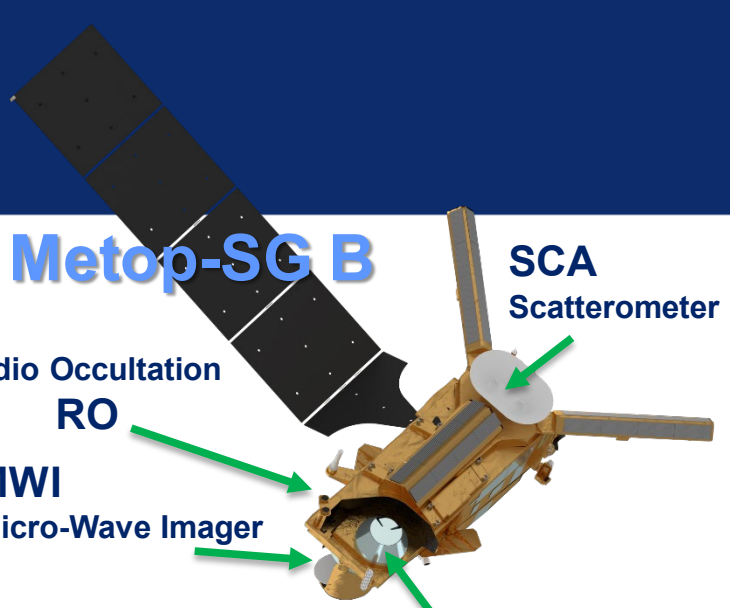
- Imagery mission implemented by two MTG-I satellites
- Full disc imagery every 10 minutes in 16 bands & fast imagery of Europe every 2.5 minutes (Flexible Combined Imager, FCI)
- New Lightning Imager (LI)
- **Operational exploitation: 2022-2042**

Meteosat Third Generation: Sounding mission (MTG-S)

- Hyperspectral infrared sounding mission (IRS)
- 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
- **Operational exploitation: 2024-2043**

EPS-SG: Metop-SG satellites





Two-satellite configuration Metop-SG-A and –B on the same orbit, separated by 90°

Metop-like orbit:
- → Sun synchronous
- → low earth orbit at 835 km mean altitude
- → 09:30 local time of the descending node

First launches:
11/2022 Metop-SG A1 11/2023 Metop-SG B1

EPS-SG benefits to activities of users

Main Payload	Enhanced Capabilities	Innovative Capabilities	Applications Benefiting
High-Resolution Infrared Sounding **(IASI-NG)**	+75% information in temperature profiles +30% in humidity-profiles	More trace gases and their vertical profiles	NWP, NWC, AC, CM, Oceanography
Microwave Sounding **(MWS)**	Enhanced spatial over-sampling	Ice-cloud info in support of water-vapour profiling	NWP, NWC, CM, Hydrology
Radio Occultation Sounding **(RO)**	Large increase of number of radio-occultations	Tracking of Galileo, Beidou and QZSS signals	NWP, CM
Nadir viewing UV/VIS/NIR/SWIR Sounding **(UVNS/Sentinel-5)**	Drastic increase of spatial resolution	Additional trace gas measurements; CO_2 being studied	Air Quality, CM, AC
VIS/IR Imaging **(METimage)**	Better radiometric and spatial resolution	Far more variables measured with higher accuracy	NWC, NWP, CM, Land-surface analysis, Oceanography, Hydrology
Scatterometry **(SCA)**	Higher spatial resolution and coverage	Cross polarisation for higher wind speeds	NWP, NWC, CM, Hydrology, Oceanography
Multi-viewing, -channel, -polarisation Imaging **(3MI)**	New mission	Aerosol parameters	Air quality, CM, NWC, Land surface analysis
Microwave Imaging **(MWI)**	New mission	Precipitation observations	NWP, NWC, Hydrology, CM, Oceanography
Ice Cloud Imaging **(ICI)**	New mission	Cloud microphysics parameters	NWP, NWC, Hydrology, CM

NWP: Numerical Weather Prediction; NWC: Nowcasting; CM: Climate Monitoring; AC: Atm. Composition

EPS-SG Sounding Missions

Main Payload	Heritage	Applications Benefiting
High-Resolution Infrared Sounding **(IASI-NG)**	IASI	NWP, NWC, AC, CM, Oceanography
Microwave Sounding **(MWS)**	AMSU-A and MHS	NWP, NWC, CM, Hydrology
Radio Occultation Sounding **(RO)**	GRAS	NWP, CM
Nadir viewing UV/VIS/NIR/SWIR Sounding **(UVNS/Sentinel-5)**	GOME-2	Air Quality, CM, AC

NWP: Numerical Weather Prediction; NWC: Nowcasting; CM: Climate Monitoring; AC: Atm. Composition

All missions on SAT-A, RO on both satellites

EPS-SG Imaging Missions

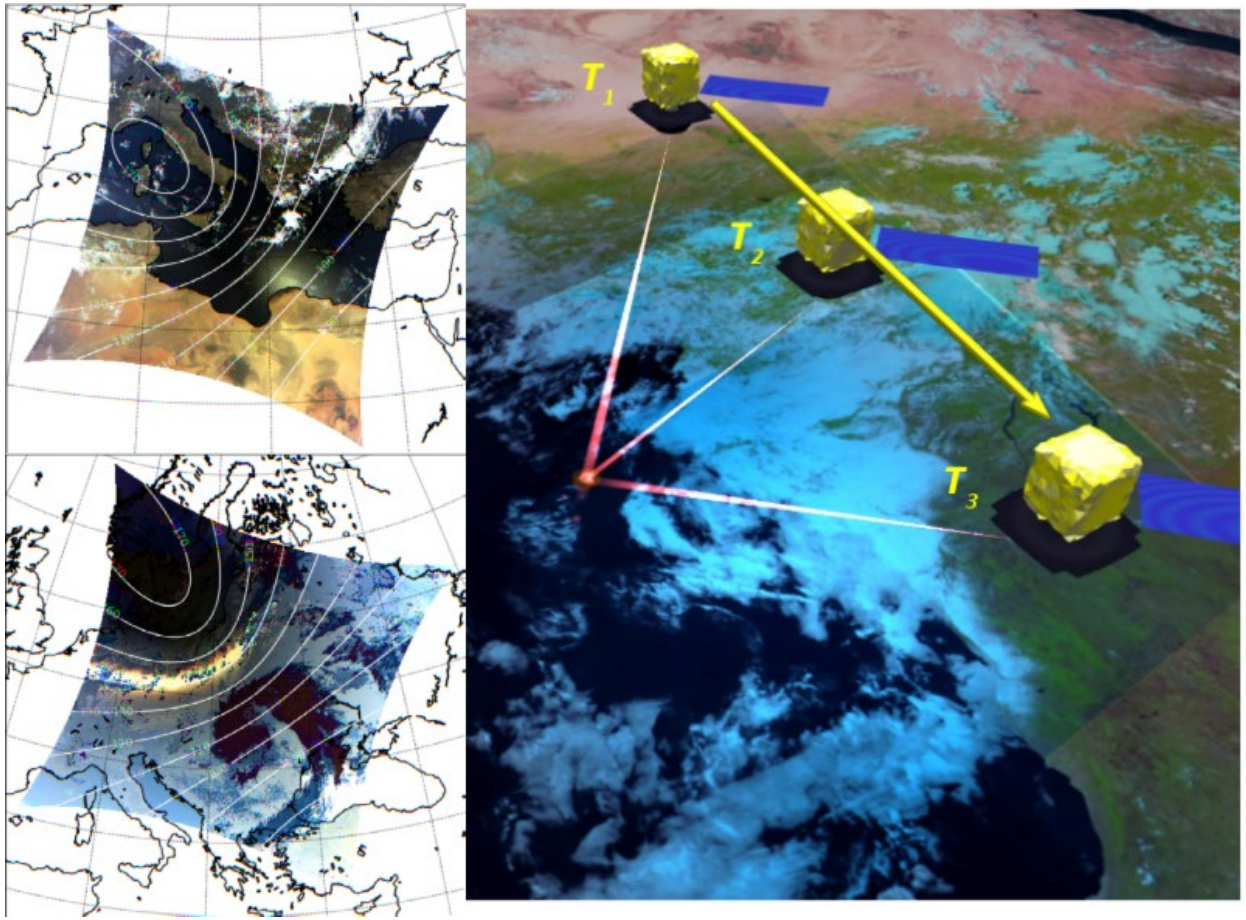
Main Payload	Heritage	Applications Benefiting
VIS/IR Imaging **(METimage)**	AVHRR	NWC, NWP, CM, Land-surface analysis, oceanography, hydrology
Scatterometry **(SCA)**	ASCAT	NWP, NWC, CM, hydrology, oceanography
Multi-viewing, -channel, -polarisation Imaging **(3MI)**	New mission	Air quality, CM, NWC, Land surface analysis
Microwave Imaging **(MWI)**	New mission	NWP, NWC, Hydrology, CM, Oceanography
Ice Cloud Imaging **(ICI)**	New mission	NWP, NWC, Hydrology, CM

NWP: Numerical Weather Prediction; NWC: Nowcasting; CM: Climate Monitoring; AC: Atm. Composition

MetImage and 3MI on board EPS-SGa
SCA, MWI, ICI on board EPS-SGb

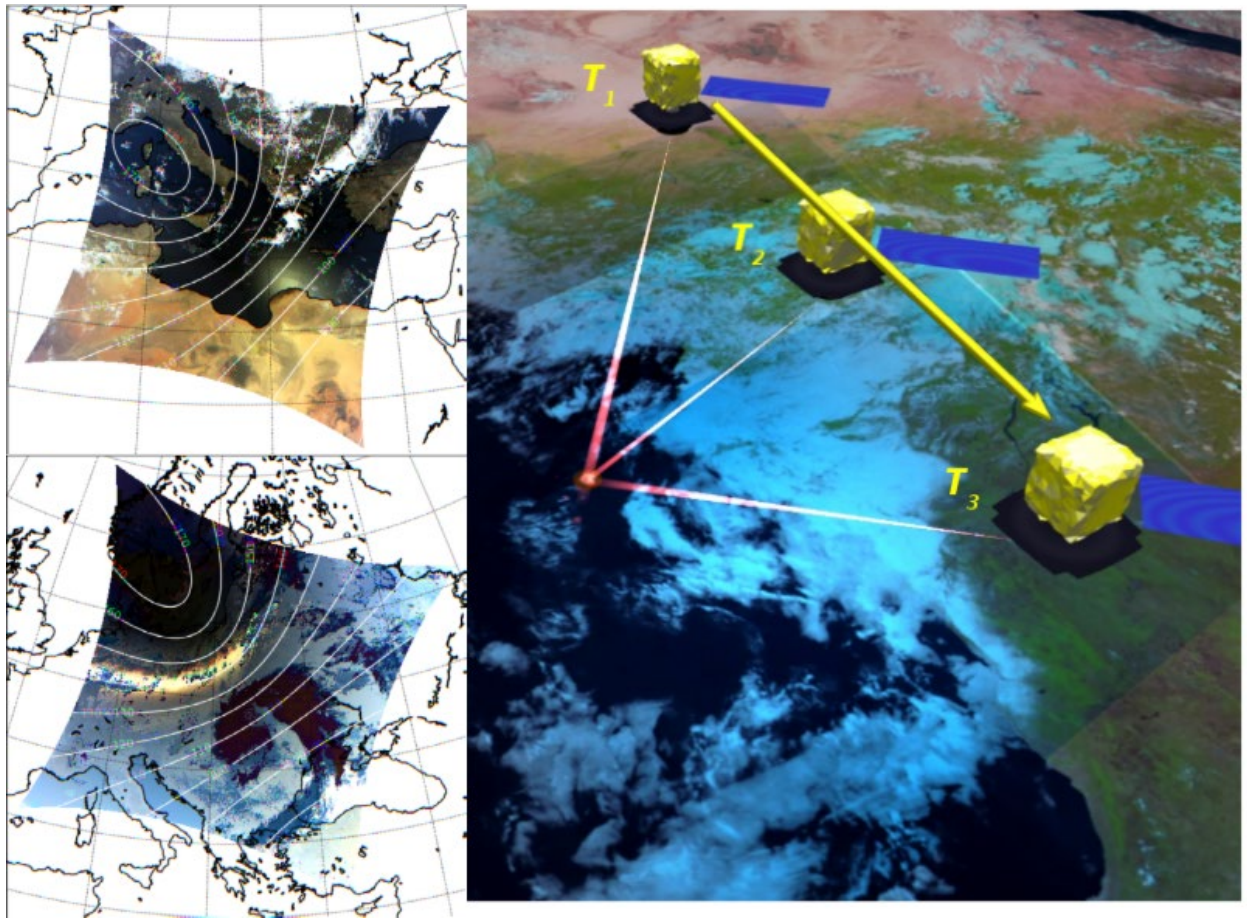
The EPS-SG 3MI mission

The 3MI mission
for operational monitoring
of aerosols from EPS-SG

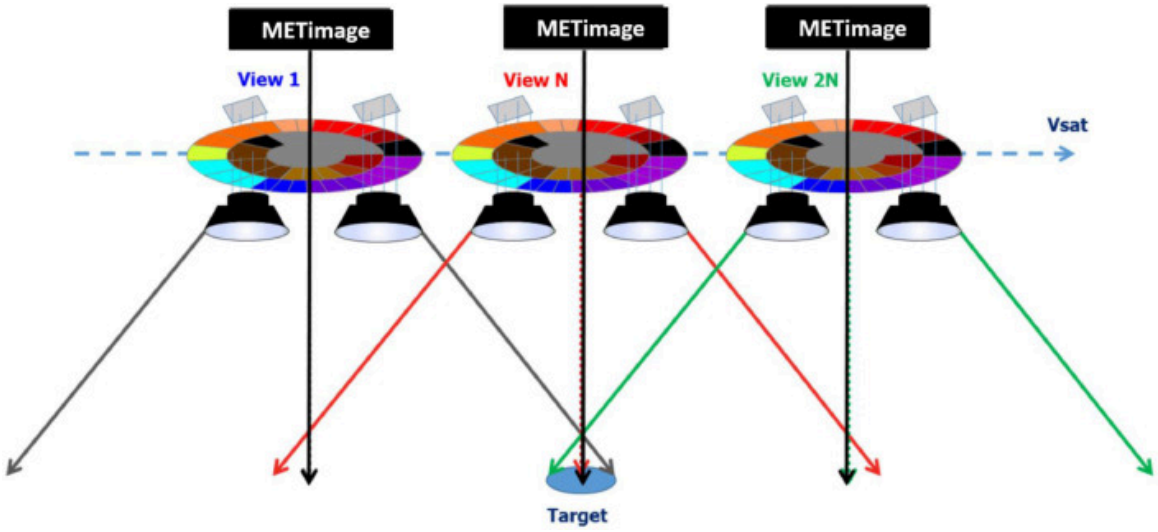


- 3MI currently under implementation phase by ESA/EUMETSAT - Launch on METOP-SG expected end of 2022
- An aerosol dedicated mission with advanced cloud observing capabilities
- 3MI builds on POLDER / MODIS heritage
- How and why 3MI brings innovation ?

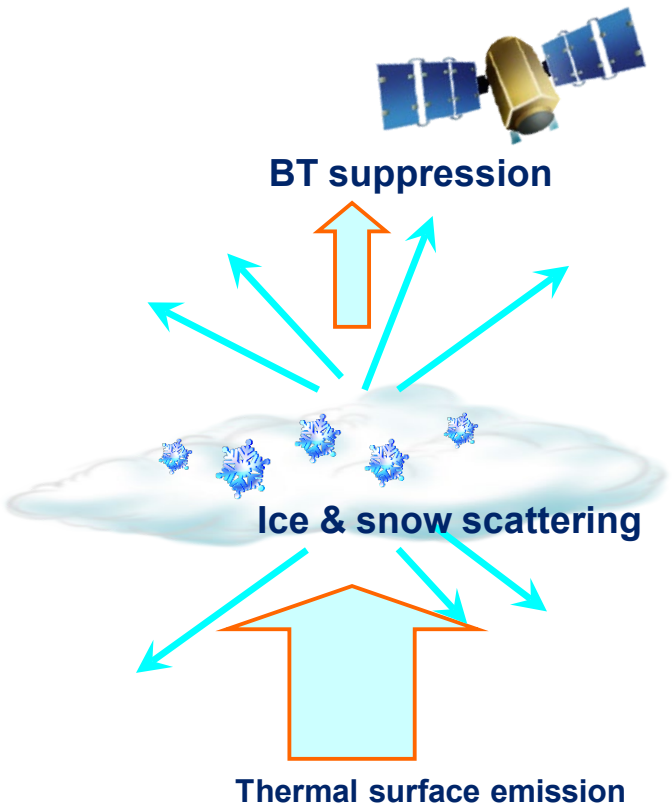
EPS-SG 3MI: a new vision of the atmosphere

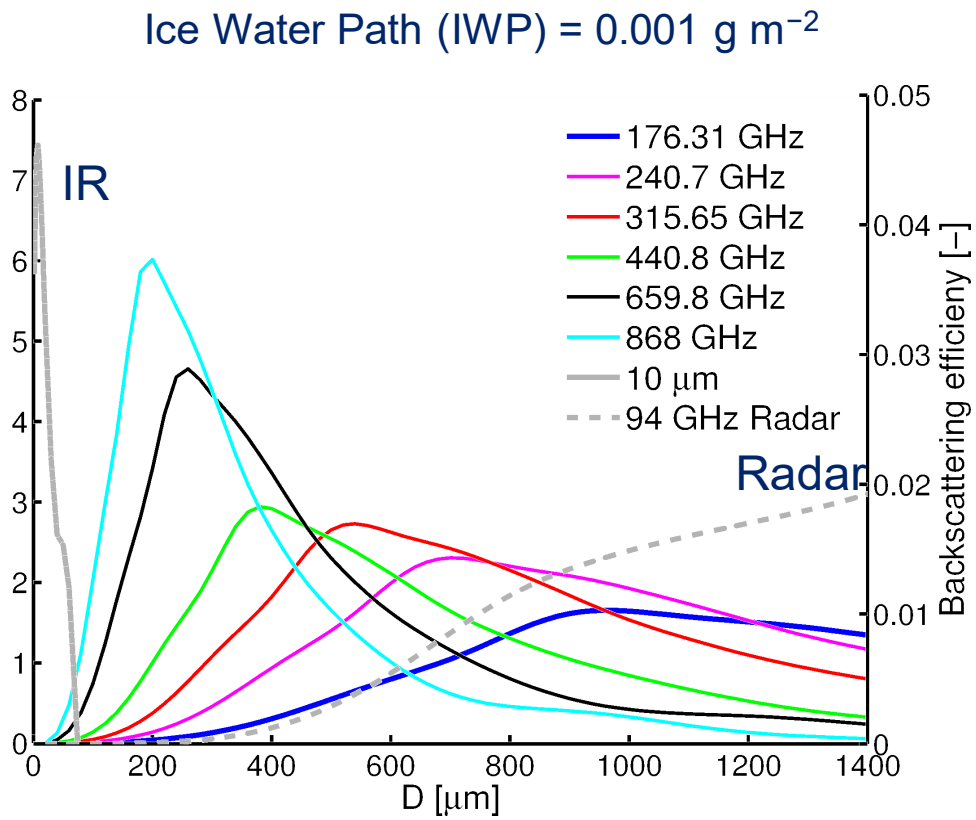


- The 3MI hyper-pixel contains multi-spectral, multi-polarisation, multi-angle and multi-resolution data.
- Will need R&D to fully exploit, tools to handle the complex data, and end-user training.



EPS-SG ICI will fill an observational gap





Buehler et al., 2007

Submm waves sense different particle sizes and fill the gap between IR and radar

New capabilities of MTG for climate monitoring

- By 2040 Meteosat imaging provides >60 years time series;
- Improved imaging capability contributes to:
  - research on the global circulation (storm tracks including hurricanes, life cycle of storms, long term change in polar front position, etc.);
  - better fire detection products and an increase in the quality of climate-relevant products such as fire radiative energy and power, which can be used to calculate carbon dioxide emissions from fires.
- MTG IR sounder opens new opportunities:
  - for 3D AMV time series in conjunction with IASI/IASI-NG and AVHRR/MetImage contributing to research on global circulation;
  - for reanalyses with NWP models operating at regional scale and assimilating high resolution temperature, humidity and cloud information.
- Lightning imager may contribute to quantification of naturally occurring NO_x to better estimate additional aircraft-induced NO_x;
- The frequency, intensity, and duration of extreme weather events is changing as our climate changes. Improved spatiotemporal sampling addresses analysis of extreme events at local scale and provides statistics on long term;
- Hurricane research in combination with altimetre and passive microwave imaging (wave height, wind speed, rain, SST) measurements.

EPS Second Generation – Instruments' Heritage

Metop-SG A Optical Imagery and Sounding	Instrument	Predecessor on Metop	Predecessor
Infrared Atmospheric Sounding (IASI)	IASI-NG	IASI	AIRS, HIRS
Microwave Sounding (MWS)	MWS	AMSU-A, MHS	MSU, AMSU-B, ATMS
Visible-infrared Imaging (VII)	METimage	AVHRR	AVHRR&VHRR
Radio Occultation (RO)	RO	GRAS	CHAMP, COSMIC
UV/VIS/NIR/SWIR Sounding (UVNS)	Sentinel-5	GOME-2	GOME
Multi-viewing, -channel, -polarisation Imaging (3MI)	3MI	-/-	POLDER

Metop-SG B Microwave Laboratory	Instrument	Predecessor on Metop	Predecessor
Scatterometer (SCA)	SCA	ASCAT	ERS-1 Scat
Radio Occultation (RO)	RO	GRAS	CHAMP, COSMIC
Microwave Imaging for Precipitation (MWI)	MWI	-/-	SSMIS, SSM/I, SMMR
Ice Cloud Imager (ICI)	ICI	-/-	-/-
Advanced Data Collection System (ADCS)	Argos-4	A-DCS	Argos/DCS

New capabilities of EPS-SG for climate monitoring

- Addressing key questions about how changing cloud cover and precipitation will affect climate, weather, and Earth's energy balance in the future, advancing understanding of the movement of air and energy in the atmosphere and its impact on weather, precipitation, and severe storms (all instruments also in combination with MTG and other missions);
- Understanding the effect of clouds on the radiative heating of Earth's atmosphere (MetImage, IASI-NG, 3MI, ICI, MWI);
- Understanding of aerosols and their influences on clouds (MetImage, IASI-NG, 3MI, ICI, MWI) consistently monitoring the distribution of aerosols and clouds with potential to support development of climate model parameterizations;
- Increased knowledge of rain formation processes in clouds (3MI, MWI, ICI);
- Provision of cloud and aerosol information to specific convective systems, e.g., MCS, exporing the role of such systems for extreme precipitation distribution and impacts on radiation budget (3MI, MetImage, ICI) together with MTG imaging capability;
- Tracking land use change and ecosystem responses to climate variations, which improve the understanding of the carbon cycle, while methods to quantify carbon stocks and fluxes are rapidly evolving (MetImage, SCA).
- Continuation of daily observations documenting the reductions in Arctic sea-ice extent and thinning of multi-year ice (MWI, VII);
- Monitoring changes in the atmospheric composition and geographical distributions of climate-influencing atmospheric trace gases (S5 UVNS);
- Analysis of changes in surface properties, e.g., due to impacts of changing cloud cover and precipitation and consequences for radiation budget, aerosol load, etc. (MetImage, 3MI, MWI, ICI).