The EUMETSAT contribution to the Global Space-based Observing System and Initial Joint Polar System

Dr Ken Holmlund, Chief Scientist, EUMETSAT

EUMETSAT – an intergovernmental organization with 30 Member States

- AUSTRIA
- BELGIUM
- BULGARIA
- CROATIA
- CZECH REPUBLIC
- DENMARK
- ESTONIA
- FINLAND
- FRANCE
- GERMANY
- GREECE
- HUNGARY
- ICELAND
- IRELAND
- ITALY
- LATVIA
- LITHUANIA
- LUXEMBOURG
- THE NETHERLANDS
- NORWAY
- POLAND
- PORTUGAL
- ROMANIA
- SLOVAK REPUBLIC
- SLOVENIA
- SPAIN
- SWEDEN
- SWITZERLAND
- TURKEY
- UNITED KINGDOM

EUMETSAT strategy

Services
Deliver services responding to evolving user requirements.

Continuity
Secure continuity and improvement of data services to users for another decade and beyond.

Deployment
Ensure full deployment of the new MTG, EPS-SG and Copernicus Sentinel-3, -4, -5 and -6 missions.

Cooperation
Build on European and global partnerships involving the EU, ESA and national space agencies, and on a portfolio of bilateral cooperation with other satellite operators.

And NESDIS Mission and Vision

OUR MISSION

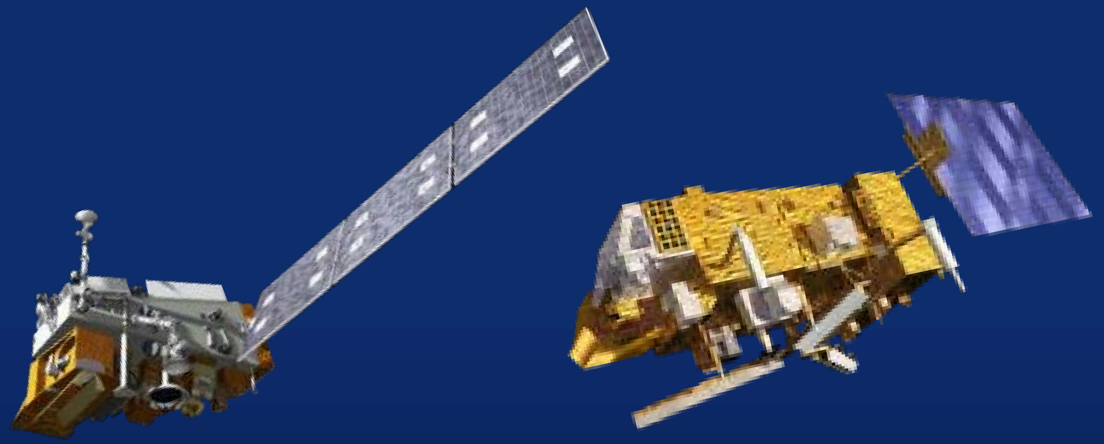
NESDIS' mission is provide secure and timely access to global environmental data and information from satellites and other sources to both promote and protect the Nation's environment, security, economy quality of life.

OUR VISION

Our vision is to expand understanding of our dynamic planet as the **Trusted** source of **Environmental** data.

The EUMETSAT Polar System is part of the Initial Joint Polar System shared with the US

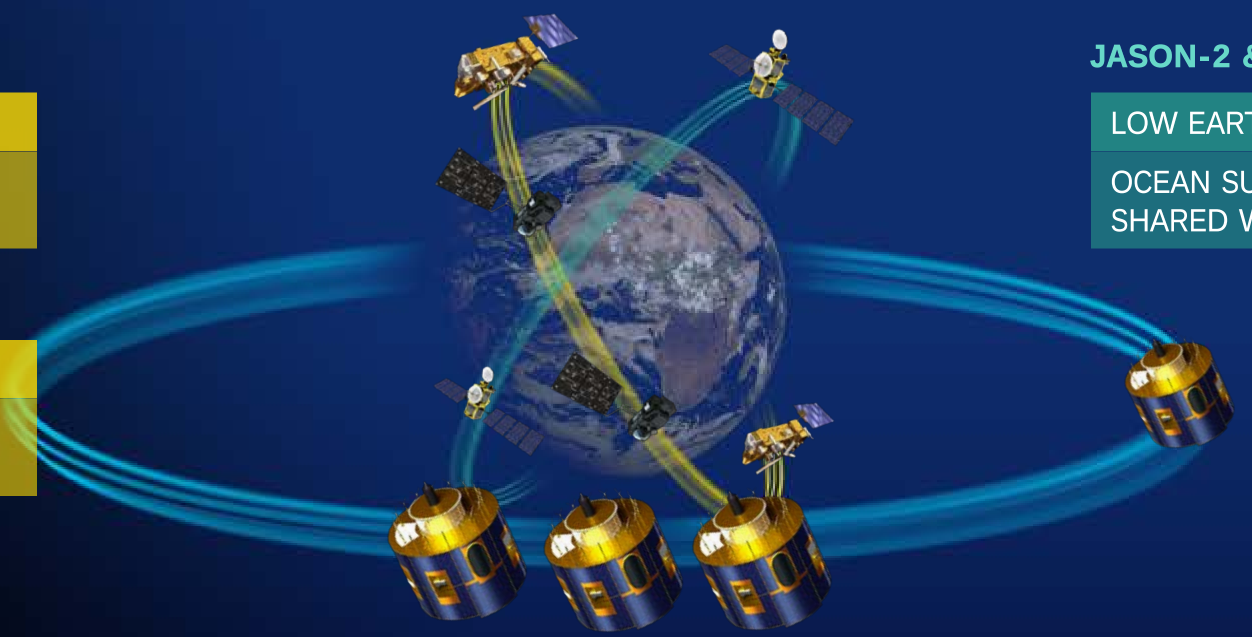
Leads to
The need for two types of meteorological satellites



Geostationary orbit
Vital for forecasts up to a few hours

Polar orbit
Critical for forecasts up to 10 days

Current EUMETSAT satellites



METOP-A, -B and -C (98.7° incl.)

LOW EARTH, SUN-SYNCHRONOUS ORBIT

EUMETSAT POLAR SYSTEM (EPS) /
INITIAL JOINT POLAR SYSTEM

SENTINEL-3A & -3B (98.65° incl.)

LOW EARTH, SUN-SYNCHRONOUS ORBIT

COPERNICUS SATELLITES DELIVERING
MARINE AND LAND OBSERVATIONS

JASON-2 & -3 (63° incl.)

LOW EARTH, NON-SYNCHRONOUS ORBIT

OCEAN SURFACE TOPOGRAPHY MISSION,
SHARED WITH CNES/NOAA/EU

METEOSAT-9, -10, -11

GEOSTATIONARY ORBIT

METEOSAT 2ND GENERATION

TWO-SATELLITE SYSTEM

FULL DISC IMAGERY MISSION (15 MINS) (METEOSAT-10 (0°))
RAPID SCAN SERVICE OVER EUROPE (5 MINS) (METEOSAT-9 (9.5° E))

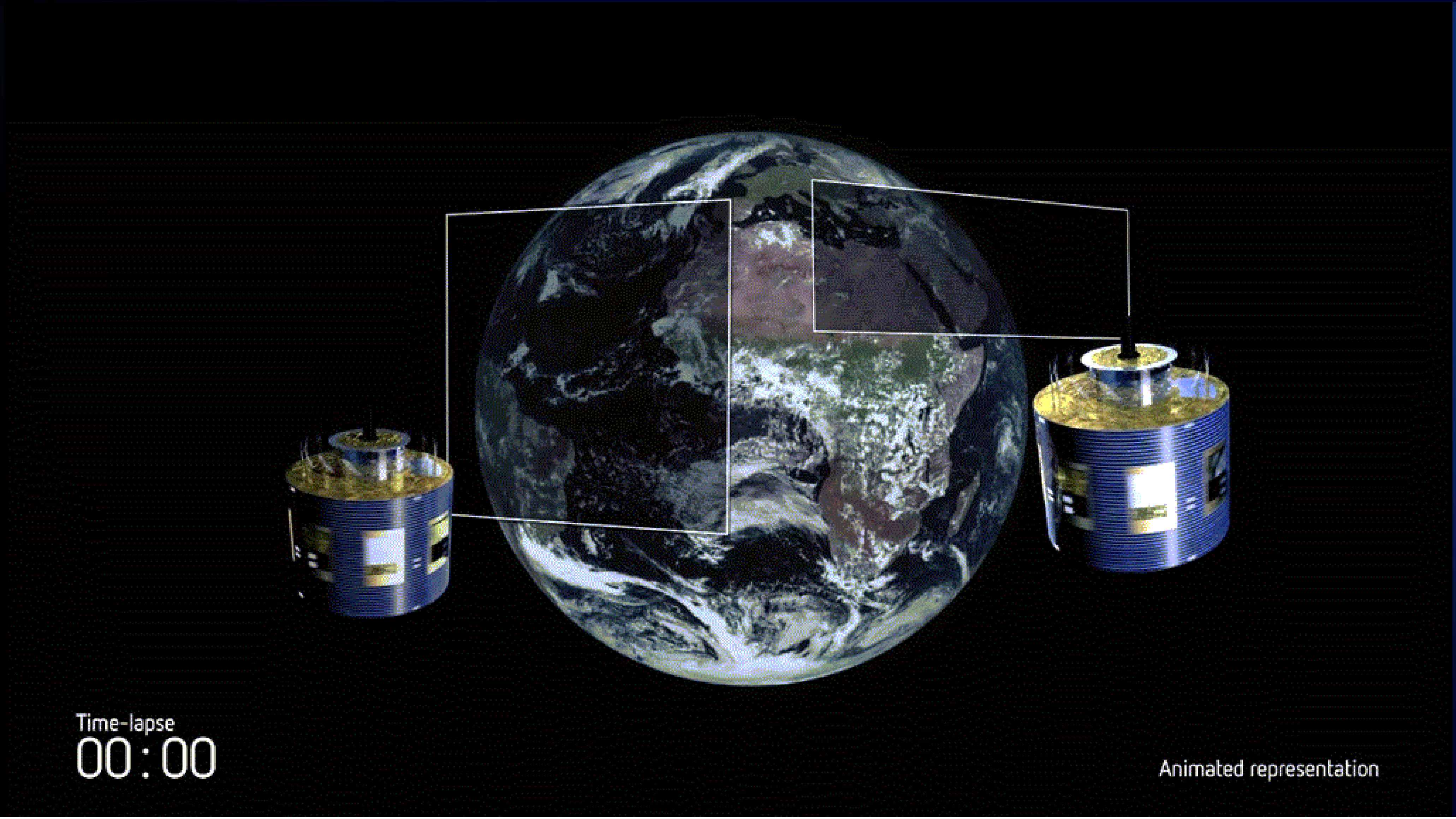
METEOSAT-11 STORED IN ORBIT (UNTIL MID-2018)

METEOSAT-8 (41.5° E)

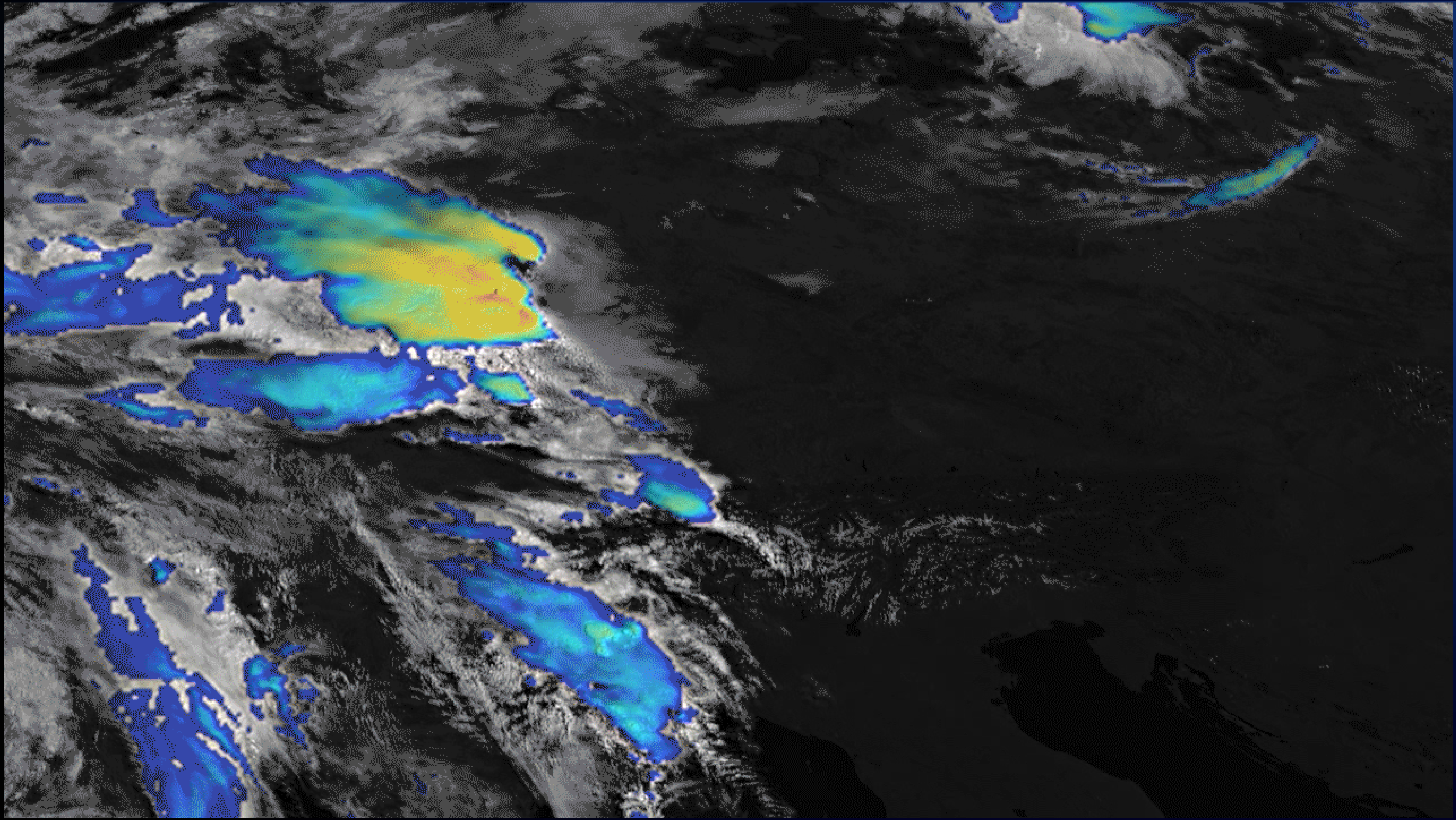
GEOSTATIONARY ORBIT

METEOSAT 2ND
GENERATION PROVIDING
IODC FROM FEBRUARY
2017 – MID-2020

Meteosat Second Generation: a two-satellite operational system



MSG for nowcasting of severe weather: thunderstorms



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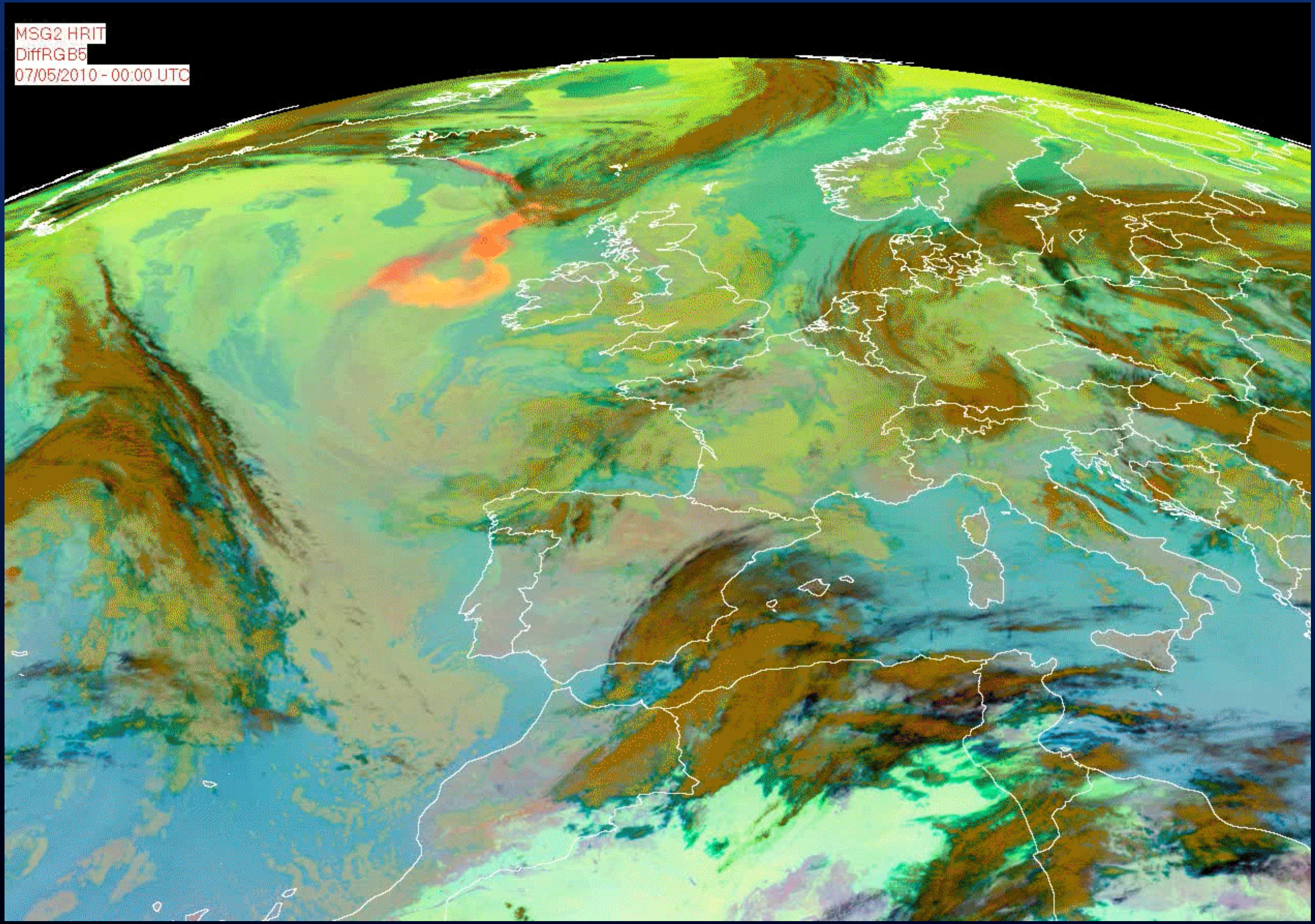
MSG for transport: aviation

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



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Future: MTG-I imaging mission

- 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 2021
- Operational exploitation: 2021-2042

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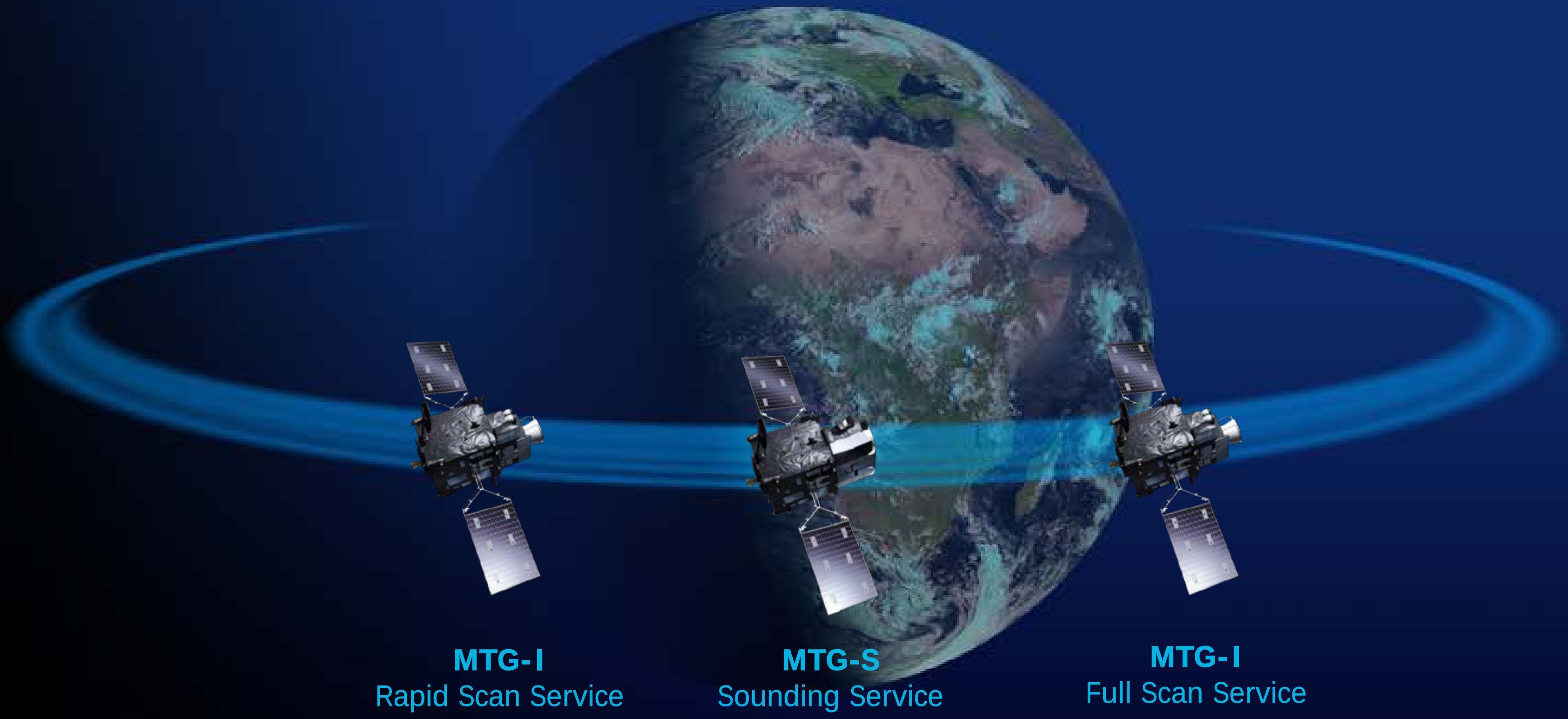
Future: MTG-S sounding mission

- 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 2023
- Operational exploitation: 2023-2042

MTG full operational configuration



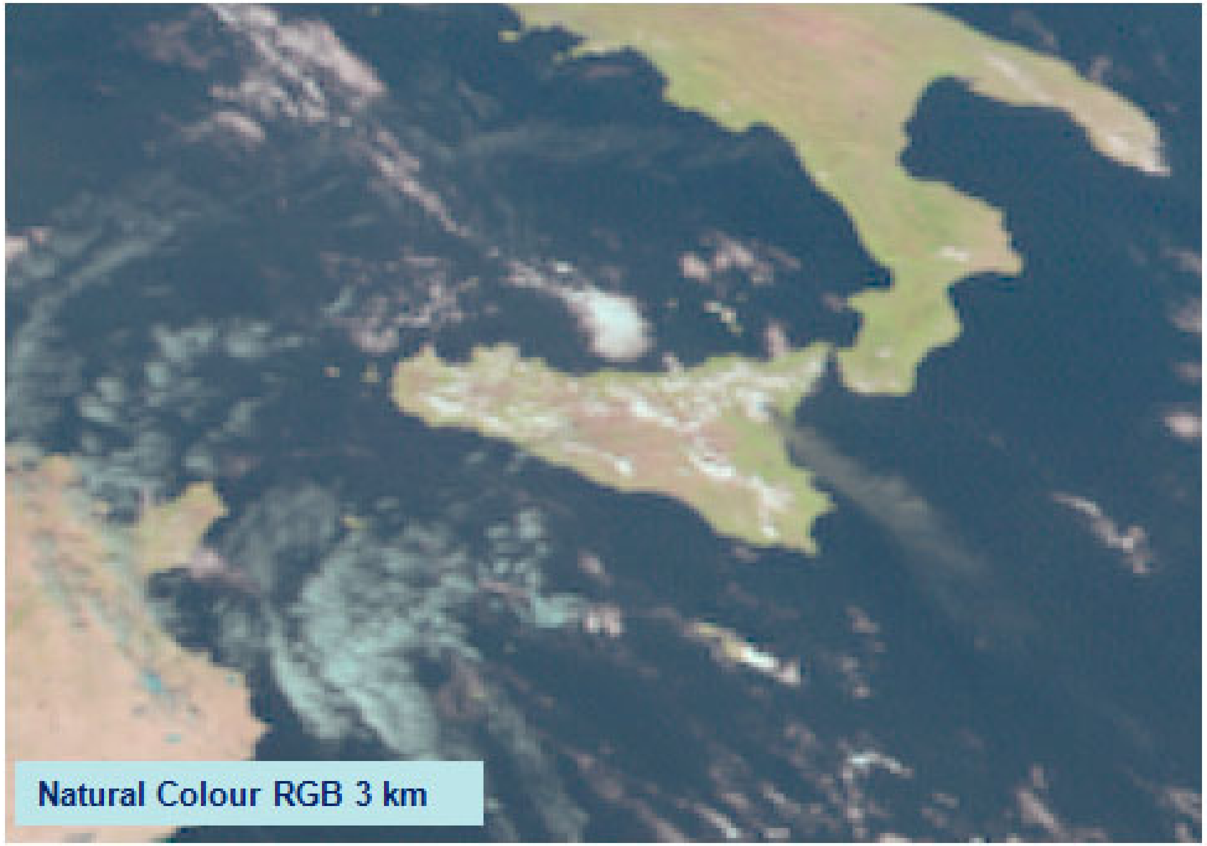
The GEO-RING

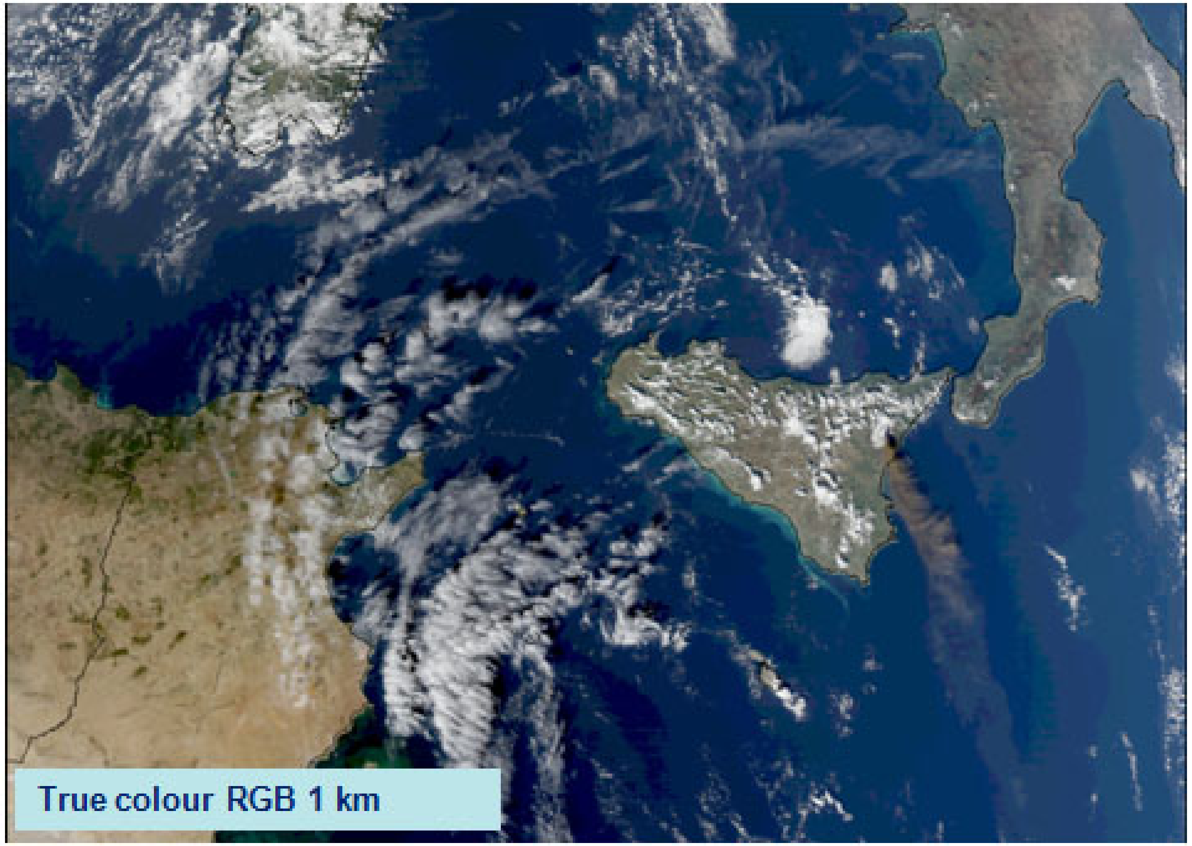
Geo-Leo Corresponding VIS-IR Imagery Bands (µm)

	2014/16			2020	2018	2016	2016/17						
#	Himawari -8/ AHI	MTSAT-2/ IMAGER	MSG/ SEVIRI	MTG/ FCI	KOMPSAT -2A/AMI	FY-4/ AGRI	GOES-R/ABI	GOES -15	GOES -11	SNPP,JPSS/ VIIRS	Terra, Aqua/ MODIS	GCOM-C/SGLI	NOAA/ AVHRR
1	0.47			0.444	0.455	0.47	0.47			0.488 (M03)	0.488	0.490 (VN4)	
2	0.51			0.510	0.511					0.555 (M04)	0.531	0.530 (VN5)	
3	0.64	0.68	0.635	0.640	0.642	0.65	0.64	0.65	0.65	0.672 (M05) 0.64 (I01)	0.667	0.6735 (VN7,VN8,P1)	0.630
4	0.86		0.81	0.865	0.860	0.825	0.86			0.865 (M07) 0.865 (I02)	0.870	0.8685 (VN10, VN11, P2)	0.862
				0.914							0.905		
				1.380	1.38	1.375	1.38			1.378 (M09)	1.375	1.380 (SW2)	
5	1.6		1.64	1.610	1.61	1.61	1.61			1.610 (M10) 1.61 (I03)	1.640	1.630 (SW3)	1.61
6	2.3			2.250		2.25	2.26			2.250 (M11)	2.130	2.210 (SW4)	
7	3.9	3.7	3.92	3.80	3.85	3.75	3.90	3.90	3.90	3.70 (M12) 3.74 (I04)	3.750		3.74
8	6.2	6.8	6.25	6.30	6.24	6.25	6.15	6.55	6.75		6.715		
9	6.9				6.95	7.1	7.00						
10	7.3		7.35	7.35	7.34		7.40				7.325		
11	8.6		8.70	8.70	8.60	8.5	8.50			8.55 (M14)	8.550		
12	9.6		9.66	9.66	9.63		9.70				9.730		
13	10.4	10.8	10.8	10.50	10.43	10.7	10.3	10.70	10.70	10.763 (M15)		10.8 (T1)	10.80
14	11.2				11.20	11.0	11.2			11.45 (I05)	11.030		
15	12.4	12.0	12.0	12.30	12.30		12.3		11.95	12.013 (M16)	12.020	12.0 (T2)	12.00
16	13.3		13.4	13.30	13.30	13.5	13.3	13.35			13.335		

Simulated lightning for MTG

MTG higher resolution imagery

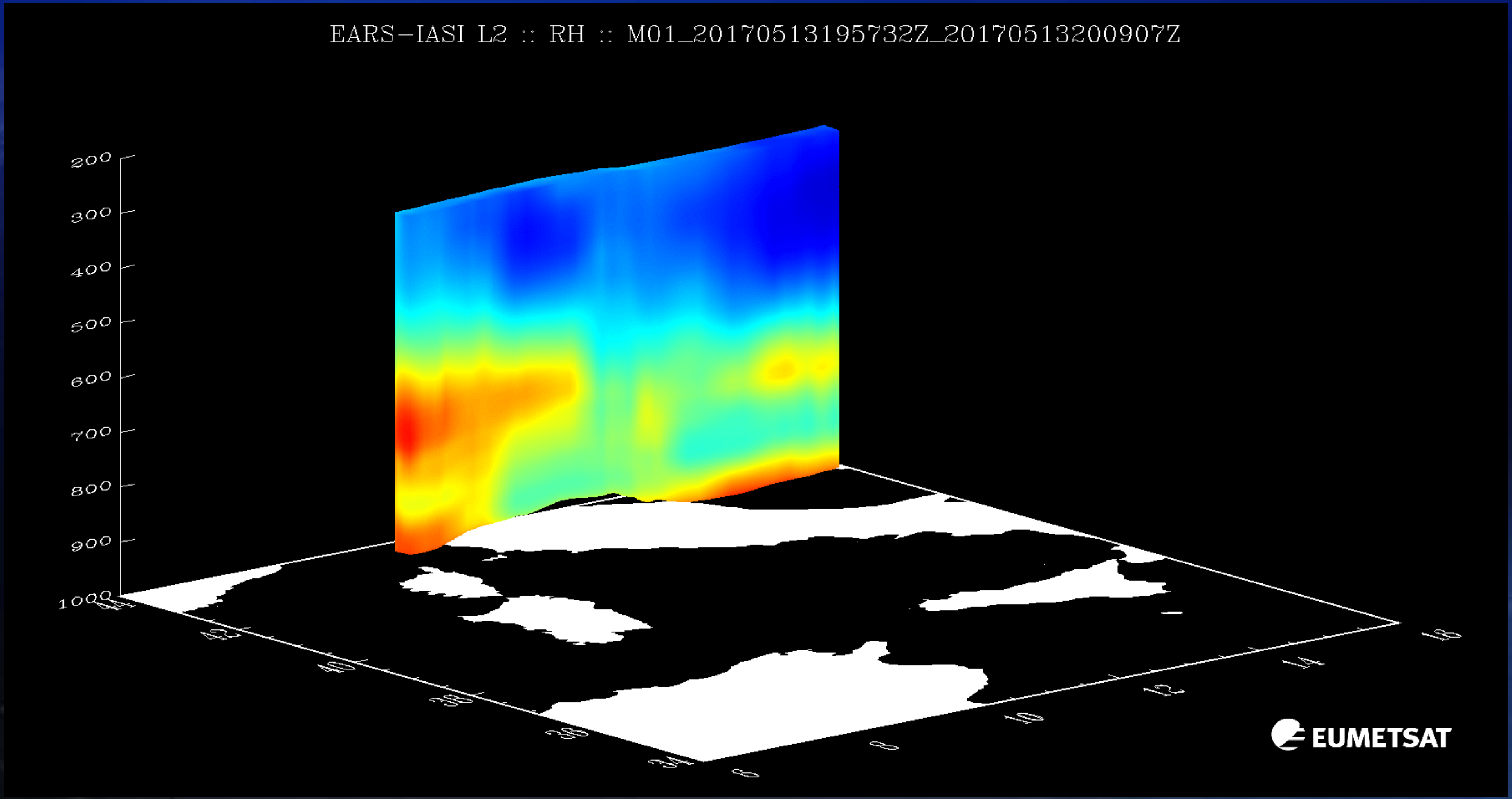




Example of ash detection, SEVIRI Natural Colour RGB, 12:15 UTC, 26 November 2006 (left), MODIS True Colour RGB, 12:20 UTC, 26 November 2006

Three dimensional structures with hyperspectral data
From IASI (this example) to IRS

3D humidity fields (%RH) with IASI L2 ‘all-sky’ processor



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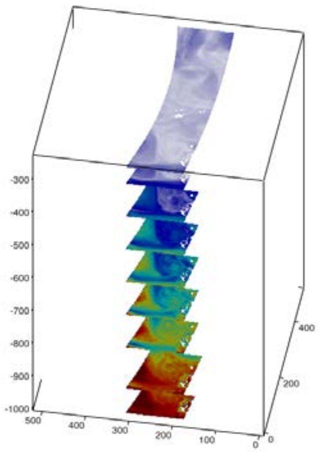
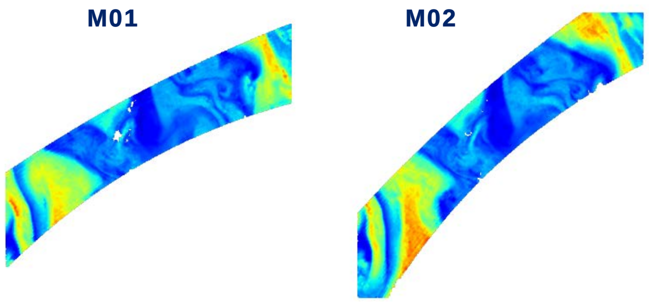
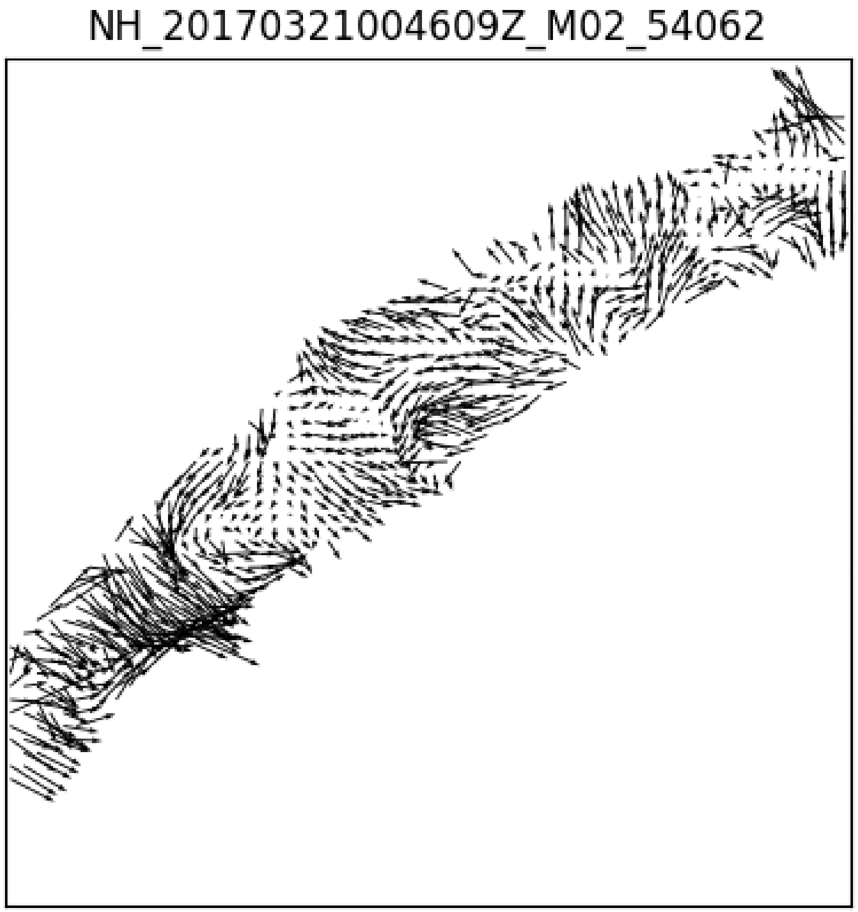
IASI 3D winds product







- Based on IASI Level 2 products:
  - Water vapour and ozone 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 3D model:
  - Tracking based only on data
  - No circulation model embedded
  - Levels consistency ensured by the full global inversion
  - ➢ Wind profiles retrieved at each point location

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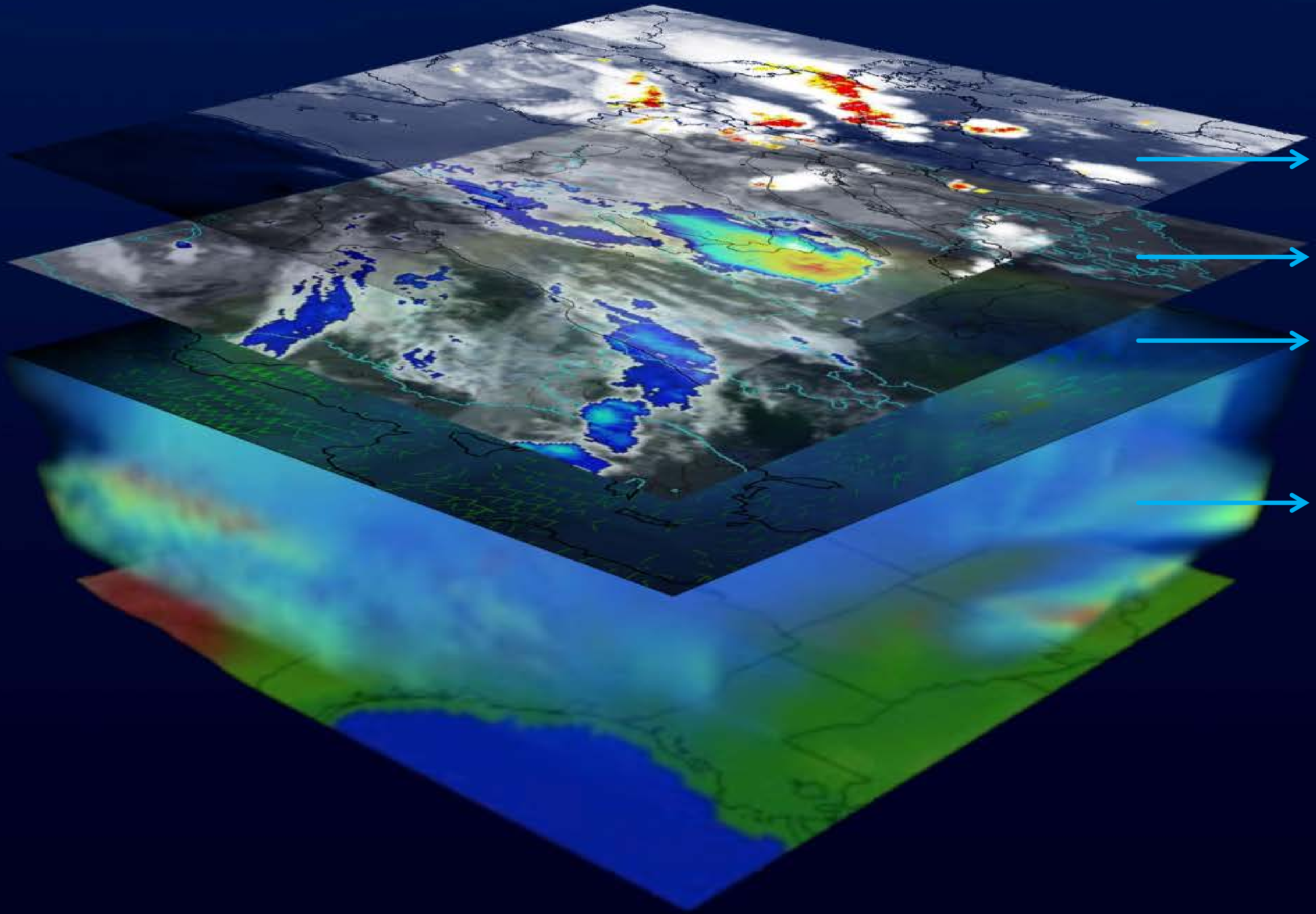
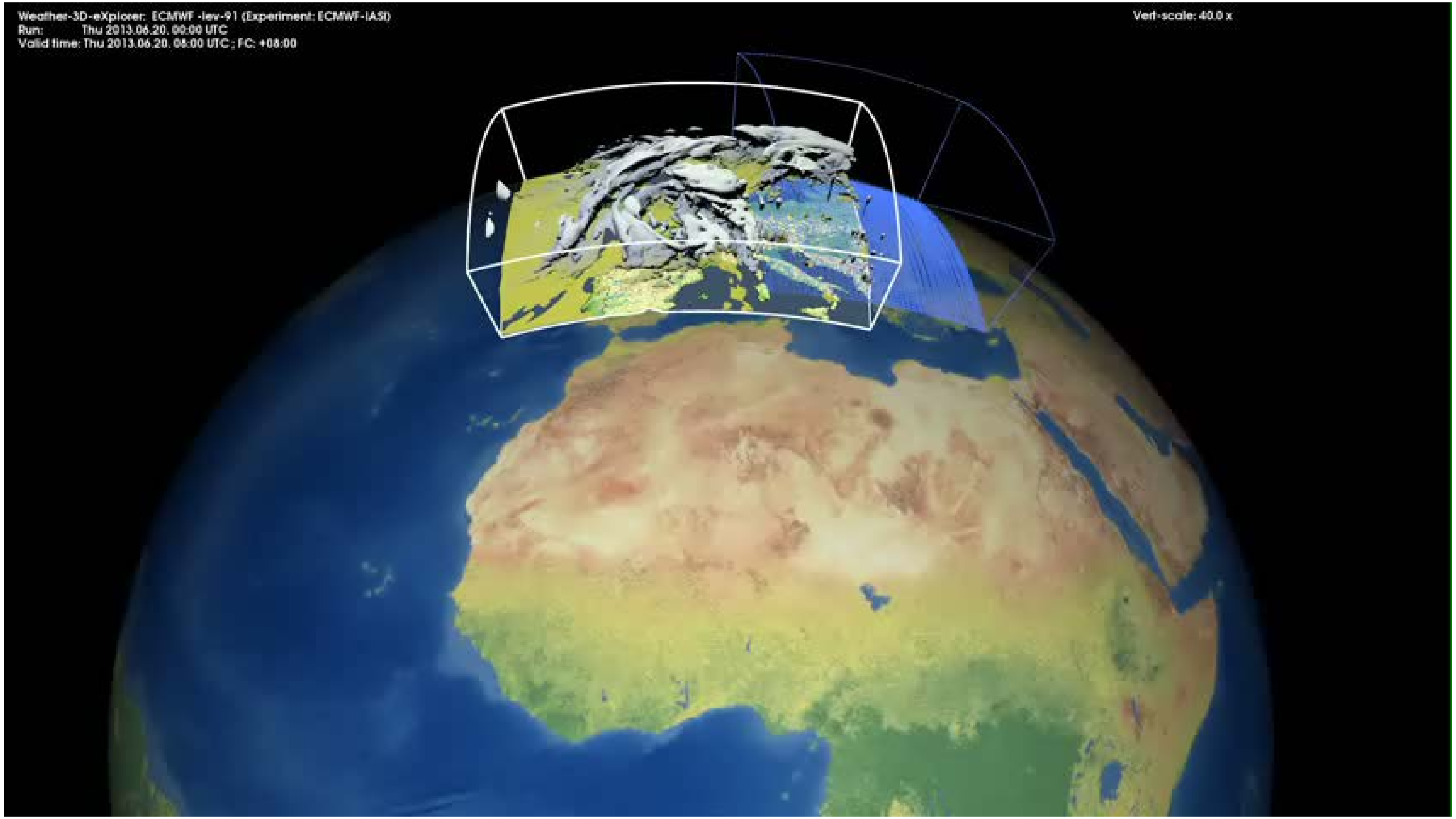
4D weather cube with MTG-I and MTG-S



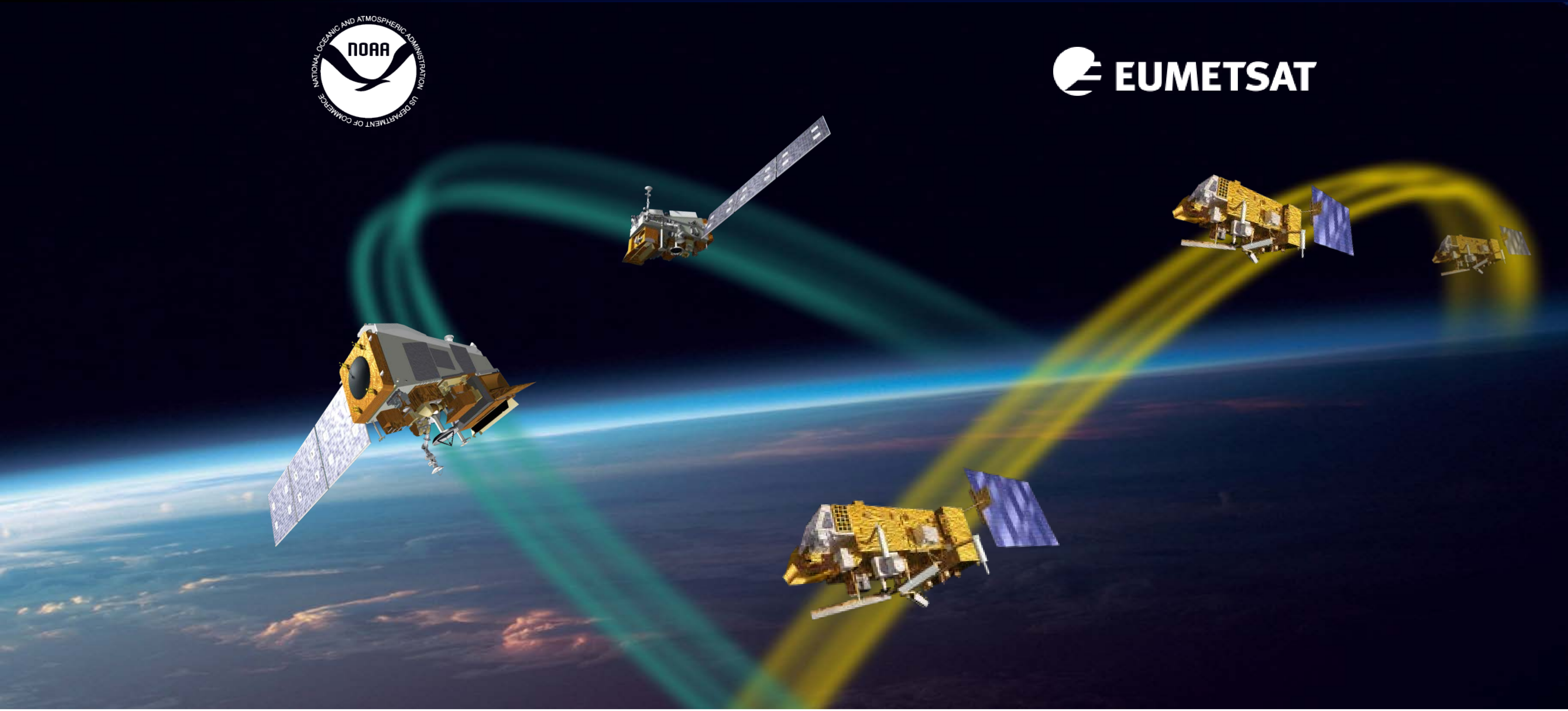
- Lightning
- Convection
- Winds
- Atmosphere

W3DX (KNMI)

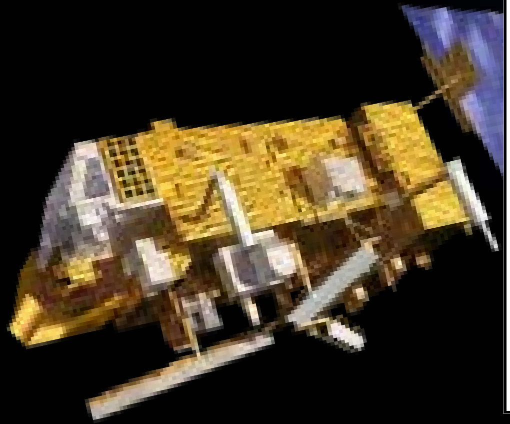


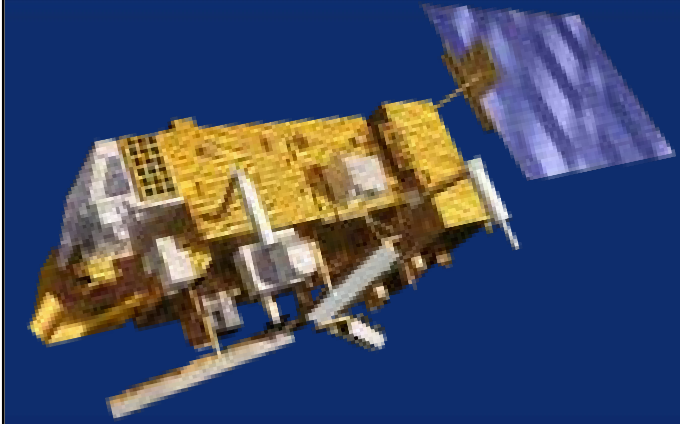
Weather-3D-eXplorer: ECMWF -lev-91 (Experiment: ECMWF-IASI)
Run: Thu 2013.06.20. 00:00 UTC
Valid time: Thu 2013.06.20. 08:00 UTC ; FC: +08:00
Vert-scale: 40.0 x

EUMETSAT Polar System:
part of the Initial Joint Polar System shared with the US

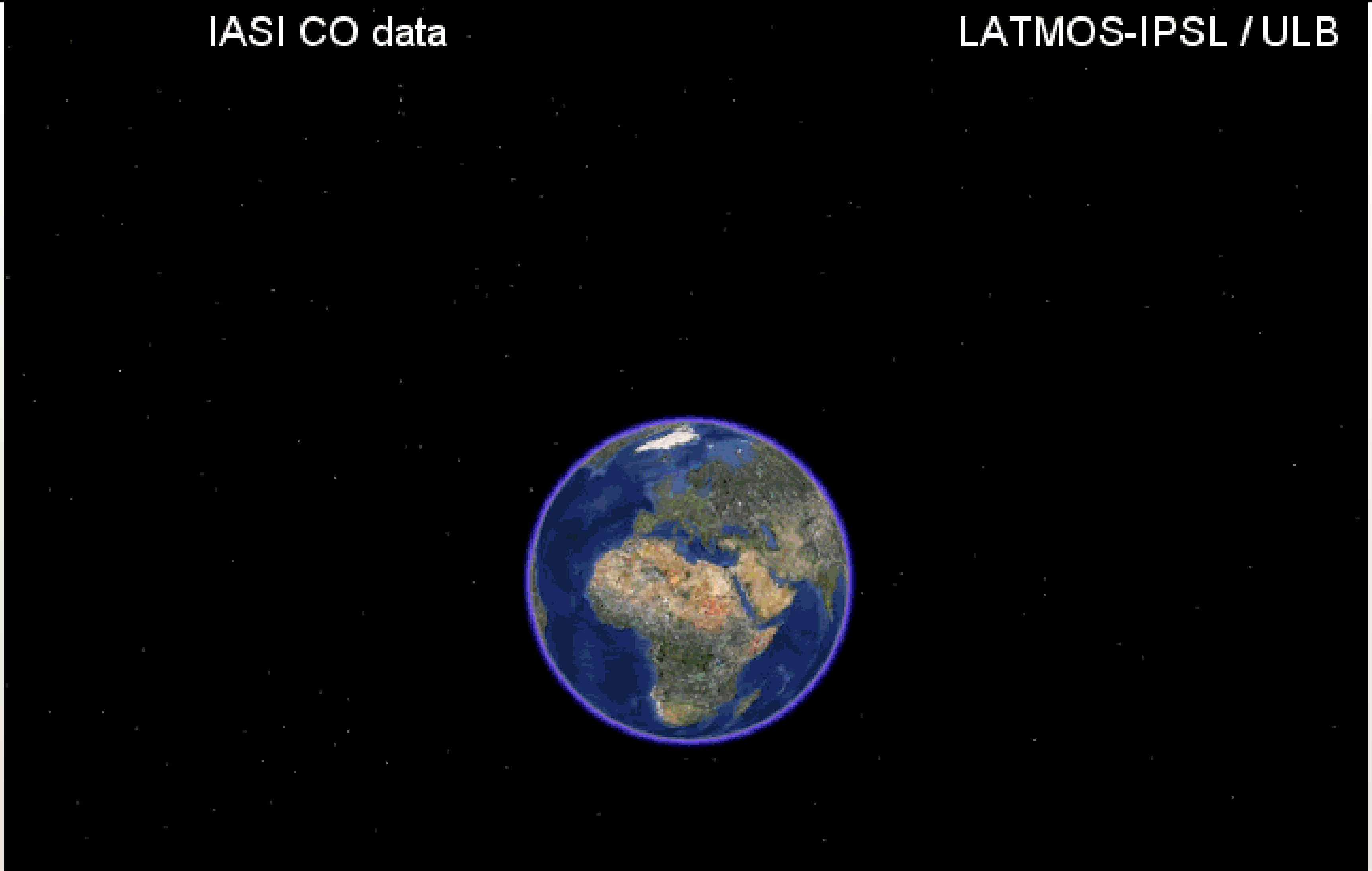


Polar orbit : Global observations from 800 km

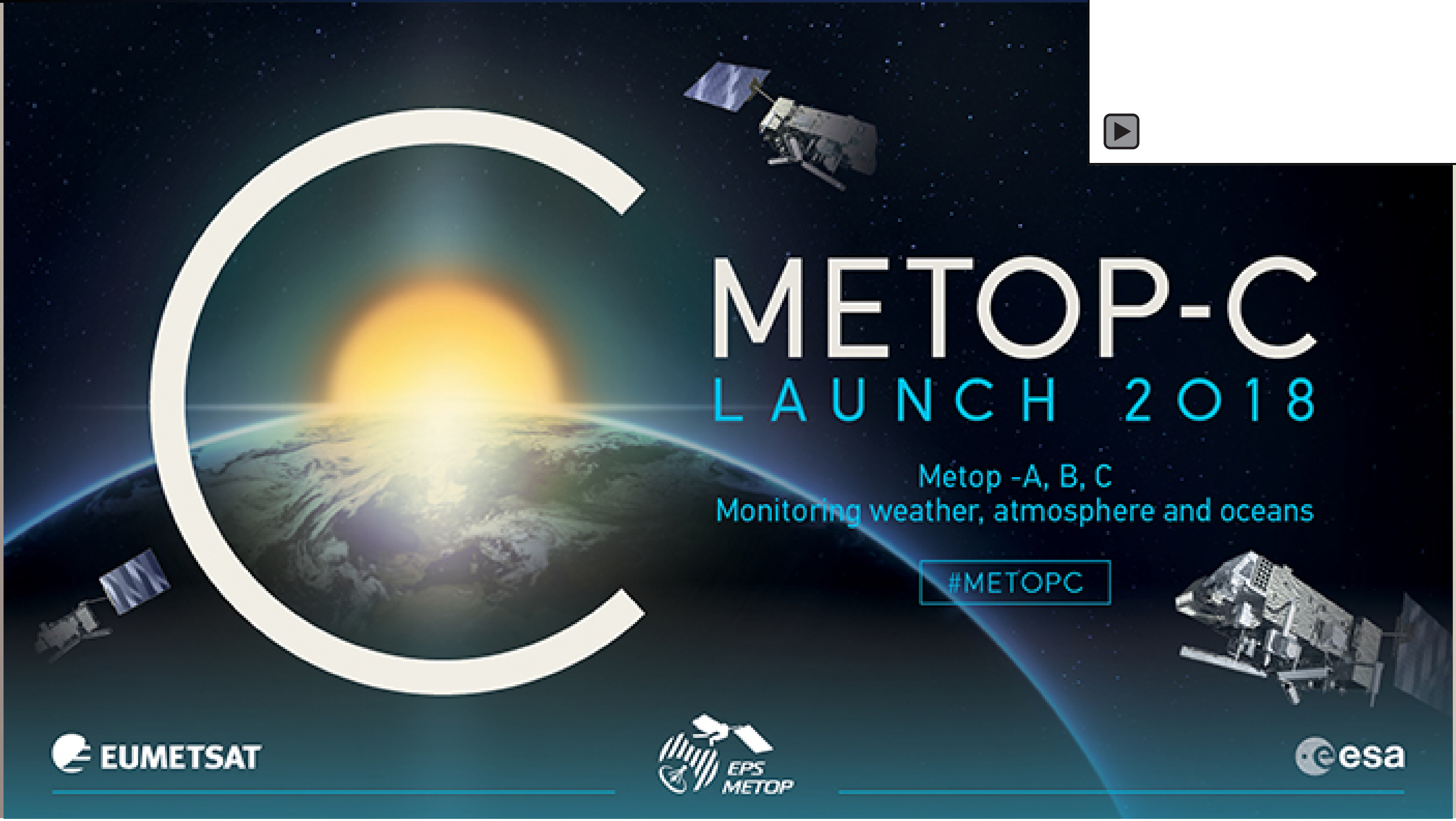




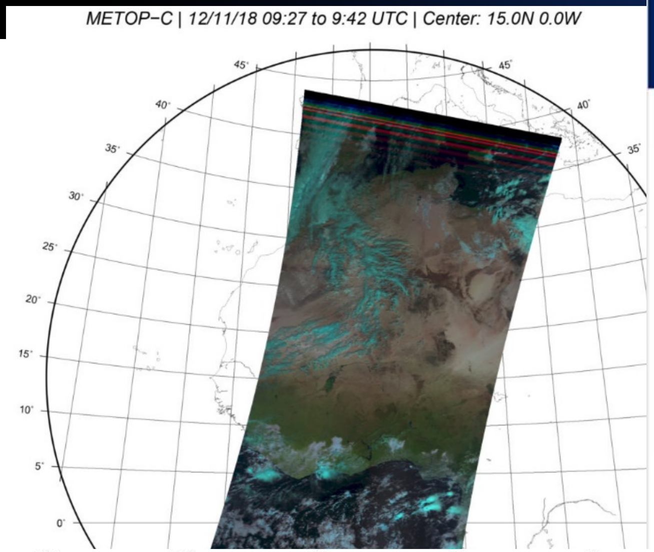
Fire Emissions – Russian Fires August 2010

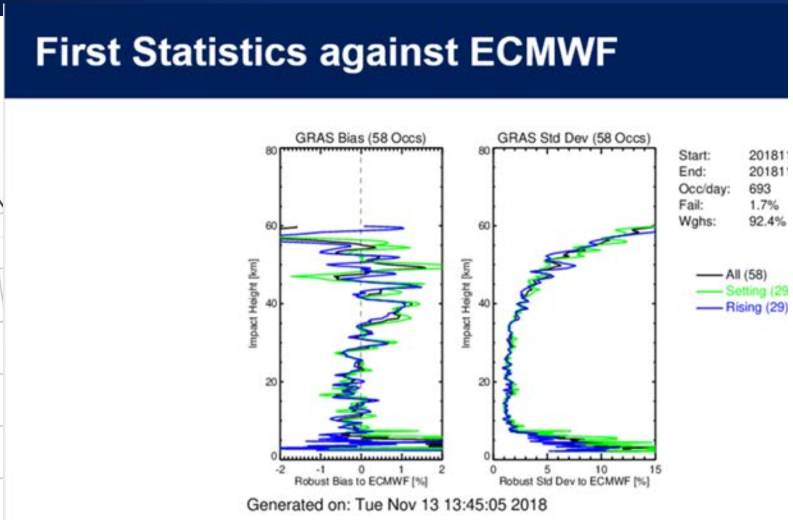


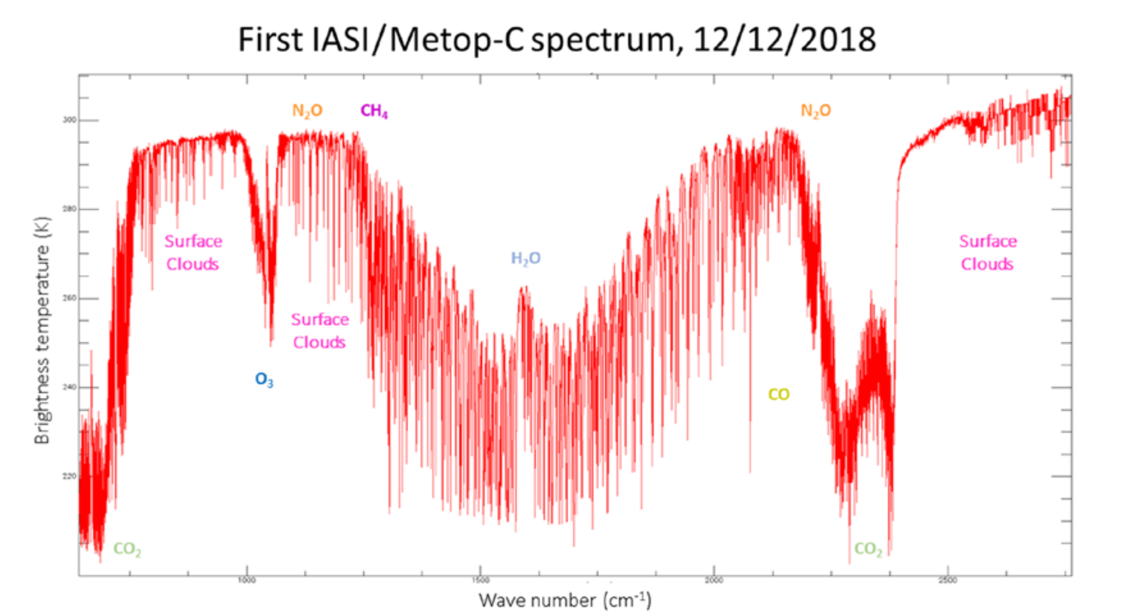
Metop-C (Last first gen Metop) – Launched 7 November 2018

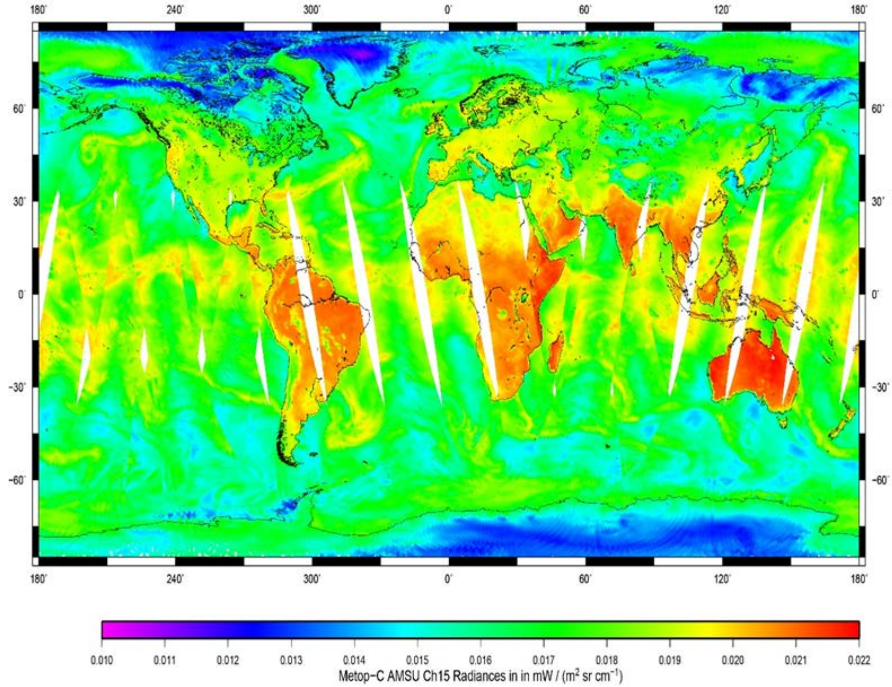


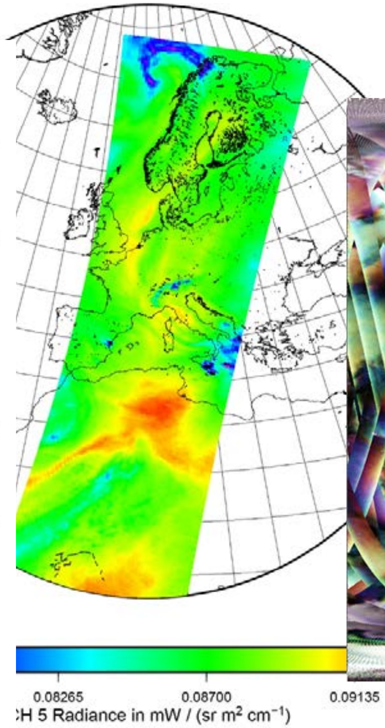
Metop-C Commissioning is finishing

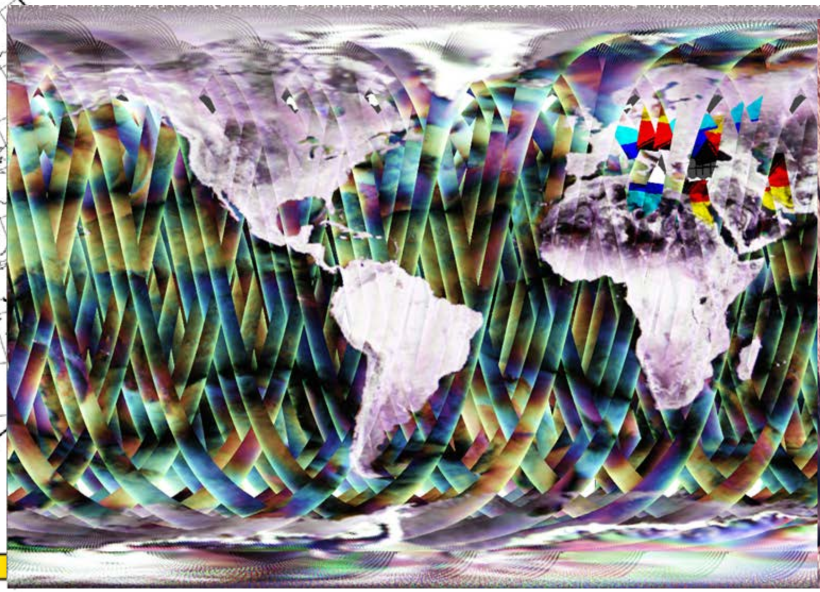












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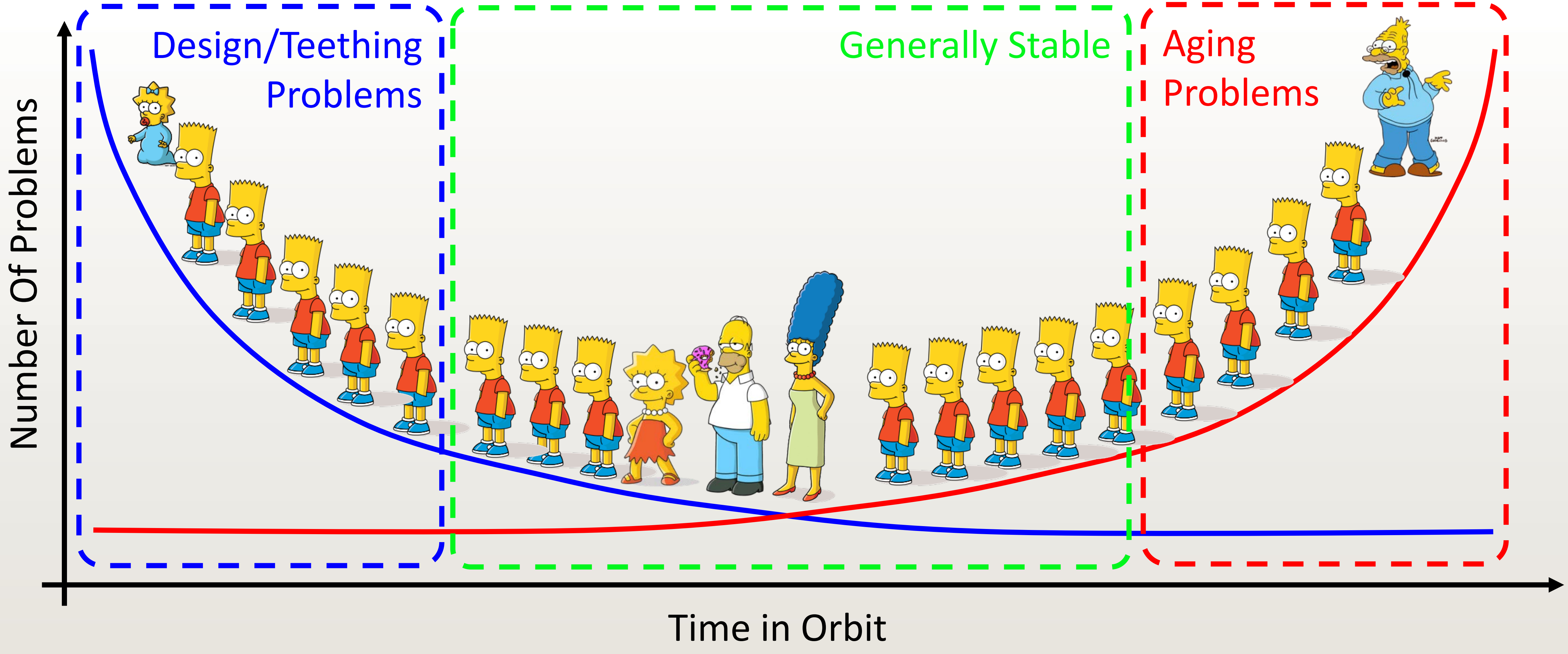
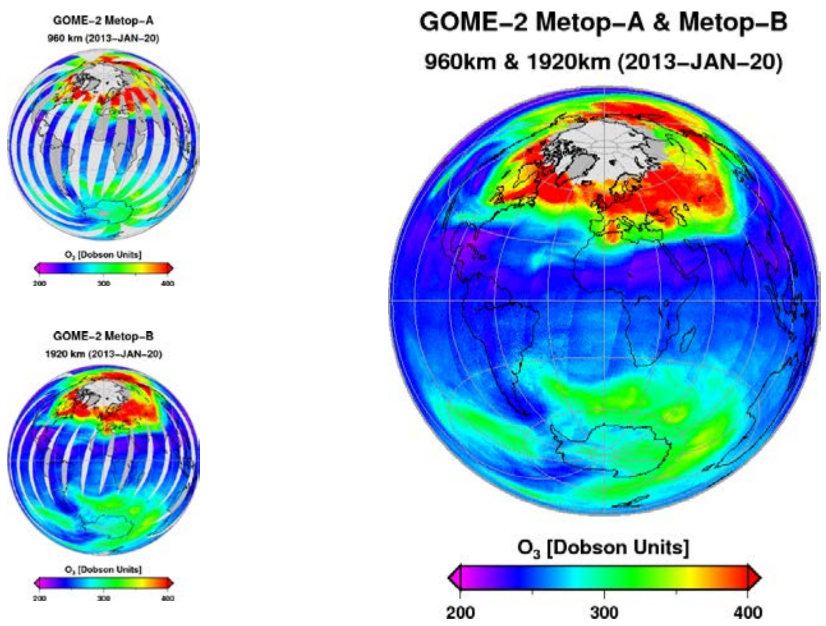
The Metops are like any normal family….

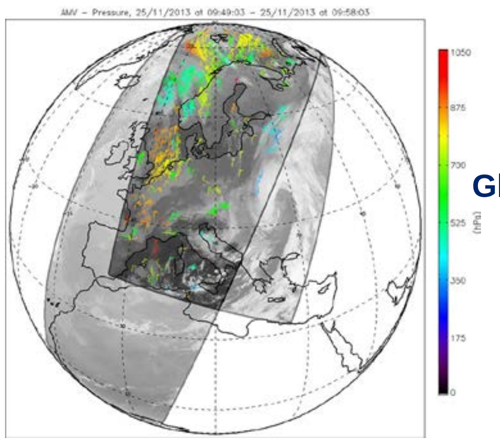


Current Baseline Dual-Metop Operations Service

- In 2013, Council 78 approved the proposed Dual-Metop Operations Service, taking benefit from the extended Metop-A lifetime.
- It may be possible to achieve a seamless transition between Metop-B/A and Metop C/B configurations.
- Subject to continued good performance of Metop-A and no satellite anomalies using the fuel resources.



GOME-2 Tandem Operations (O3MSAF / DLR)



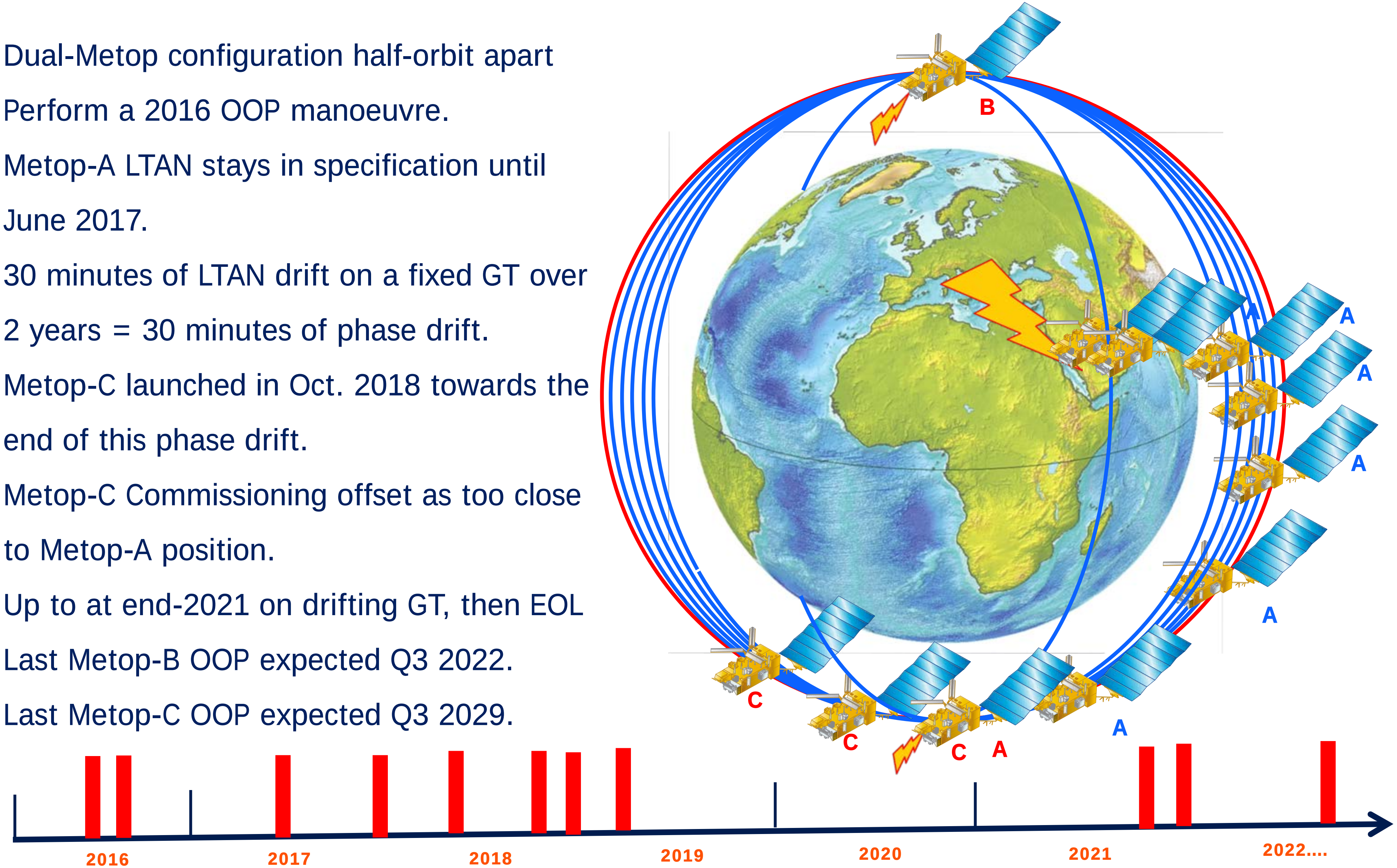
Global AVHRR Winds

Alternative to the Baseline Metop Lifetime Scenario

Animated slide – review on slideshow only

- Dual-Metop configuration half-orbit apart
- Perform a 2016 OOP manoeuvre.
- Metop-A LTAN stays in specification until June 2017.
- 30 minutes of LTAN drift on a fixed GT over 2 years = 30 minutes of phase drift.
- Metop-C launched in Oct. 2018 towards the end of this phase drift.
- Metop-C Commissioning offset as too close to Metop-A position.
- Up to at end-2021 on drifting GT, then EOL
- Last Metop-B OOP expected Q3 2022.

Last Metop-C OOP expected Q3 2029.



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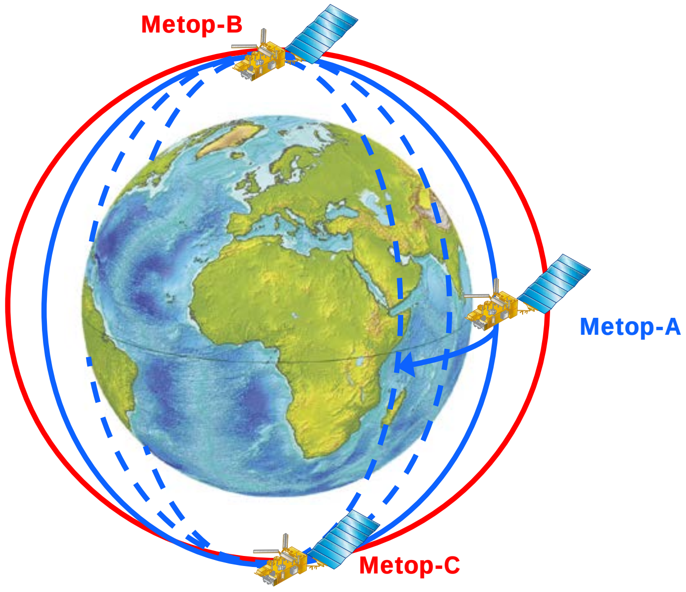
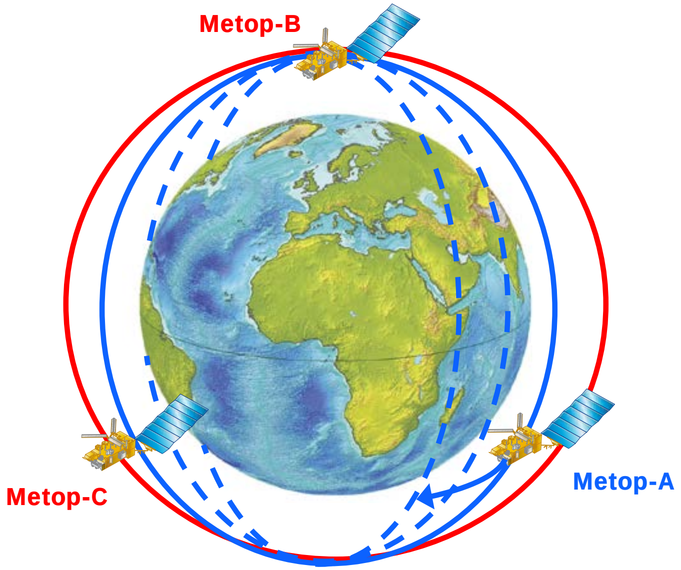
Phasing of 3 Metops: Trident or Tristar

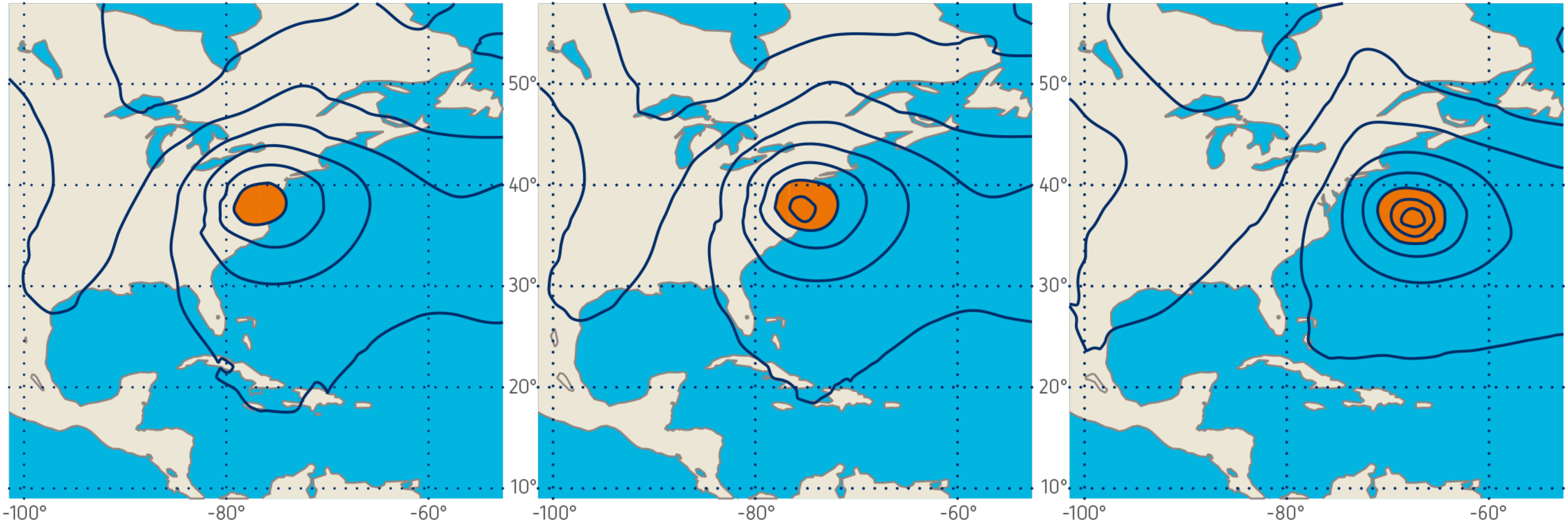
- Trident configuration:
  - Focus on continuity of dual-mission benefits.
  - Optimizing NWP impact
  - Simpler transition to EPS-SG



- Tristar configuration:
  - Better coverage for scatterometer data
  - NWP impact TBC



EPS contribution to numerical weather prediction



Five-day forecast of cyclone Sandy landfall on the US coast by the ECMWF global model, with (left) and without (right) ingestion of observations from polar orbiting satellites, compared to the operational analysis (best approximation of ground truth, centre)

Source: ECMWF

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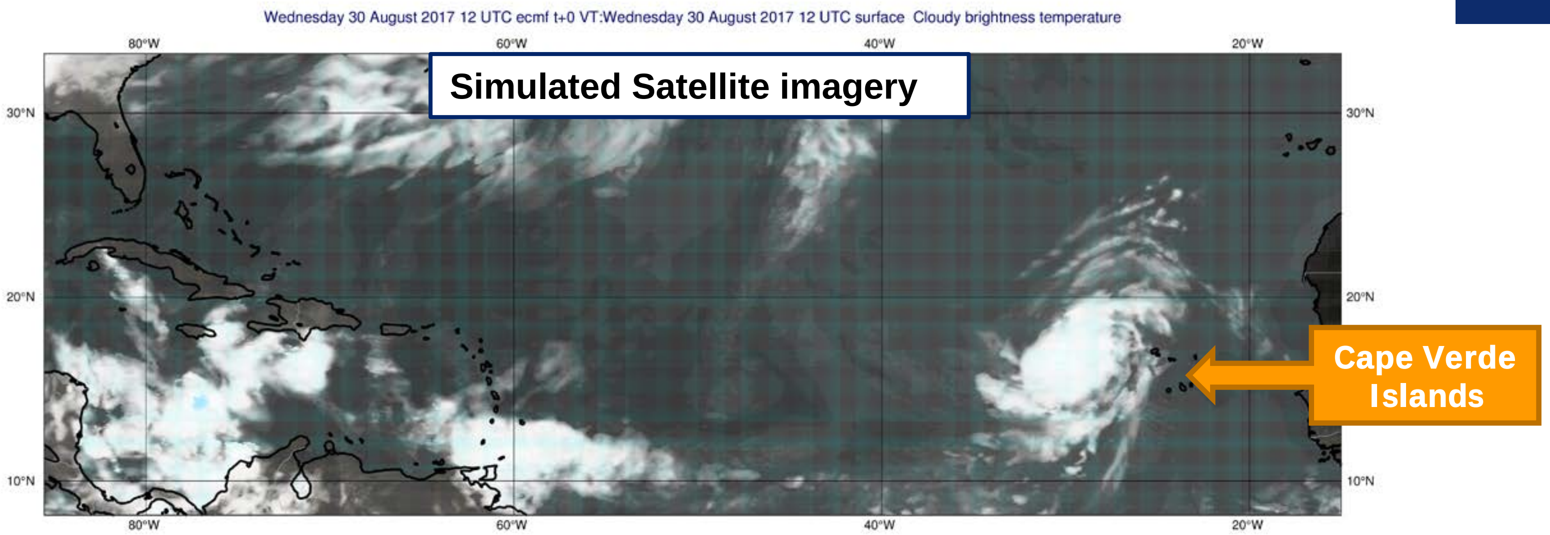
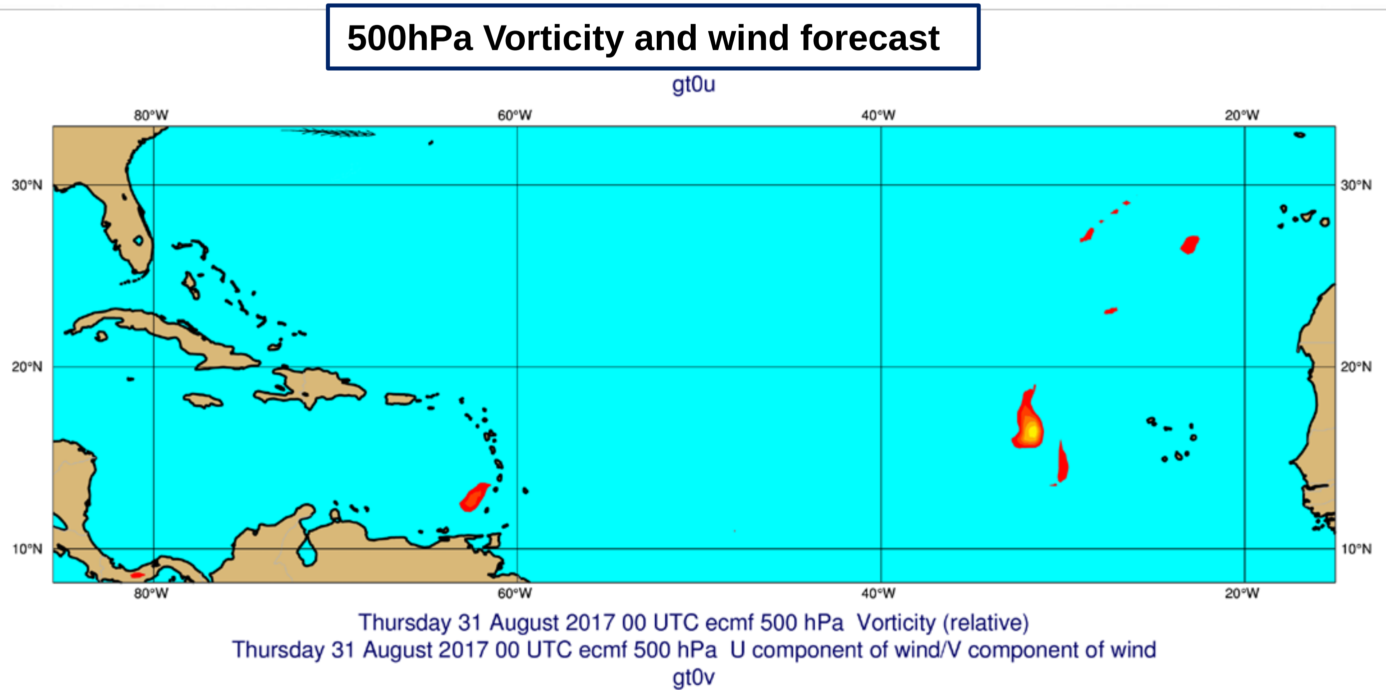
IRMA - up to 8 day forecast





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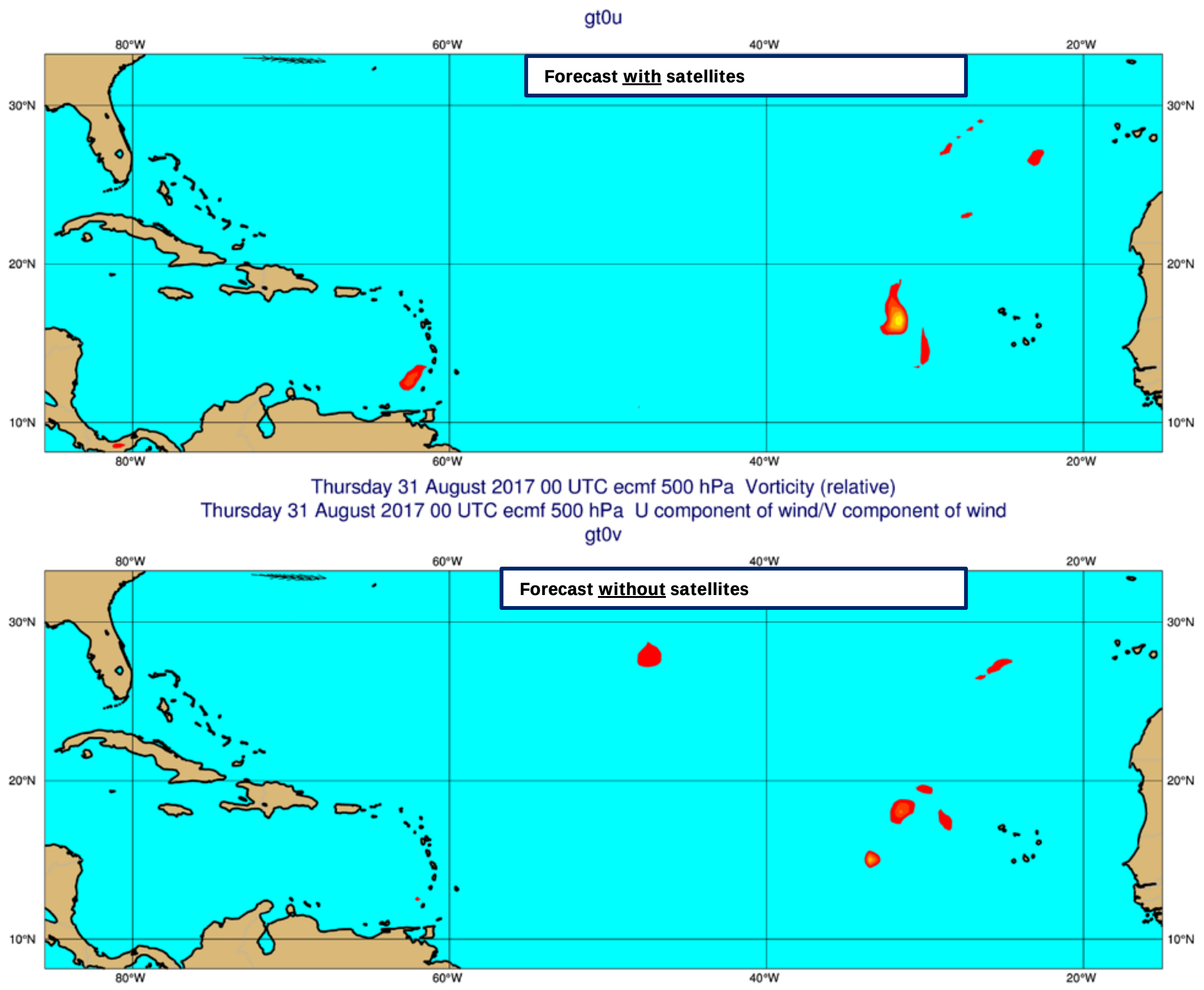
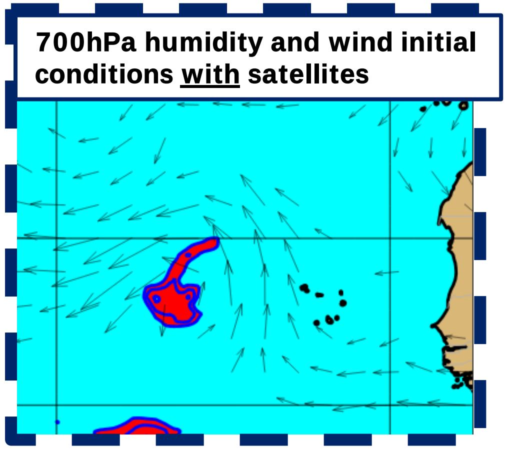
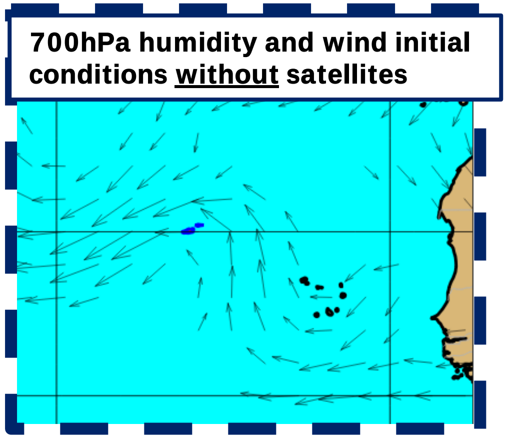
Satellite contribution to forecasting IRMA





Red shading humidity > 95 %



Source: ECMWF

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EPS-SG A sounding and imagery mission

1. **IASI-NG**
   Infrared Atmospheric Sounding
2. **MWS**
   Microwave Sounding
3. **METImage**
   Visible-Infrared Imaging
4. **RO**
   Radio Occultation
5. **3MI**
   Multi-viewing, -channel, -polarisation Imaging
6. **Copernicus Sentinel-5**
   UN/VIS/NIR/SWIR Sounding

EPS-SG B microwave imagery mission

1. **SCA**
   Scatterometer
2. **RO**
   Radio Occultation
3. **MWI**
   Microwave Imaging for Precipitation
4. **ICI**
   Ice Cloud Imager
5. **ARGOS-4**
   Advanced Data Collection System

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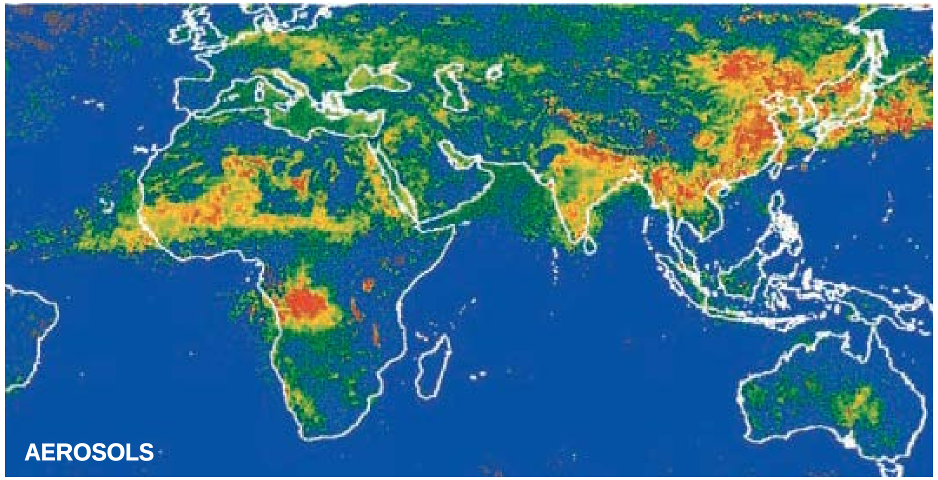
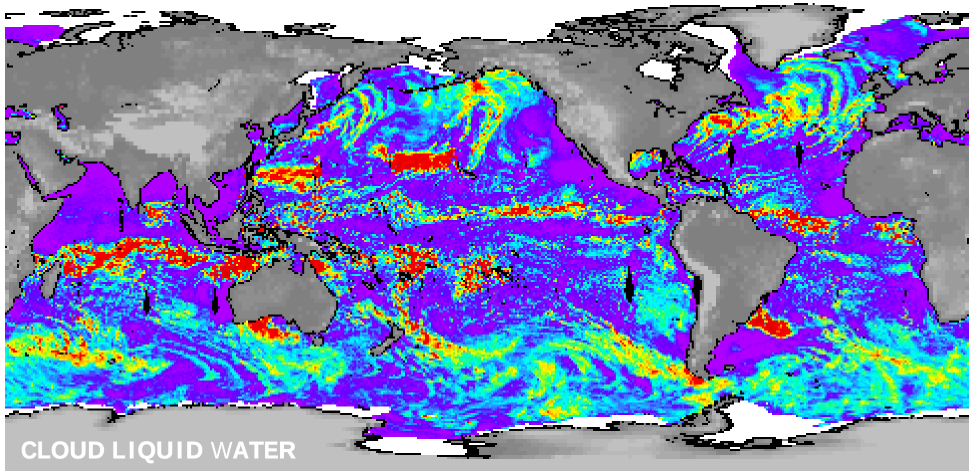
EPS-SG mission capabilities

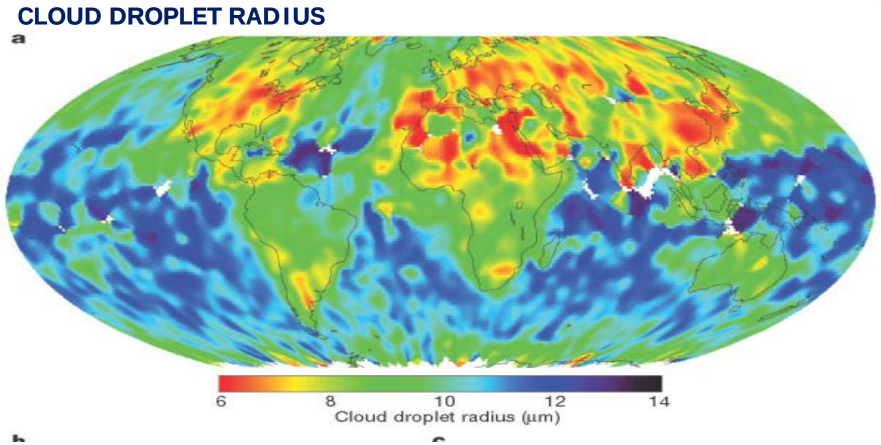
- Major improvements to all EPS observation missions
  - Infrared and microwave sounding
  - Optical imagery (METImage, developed by DLR)
  - Scatterometer
  - Radio occultation

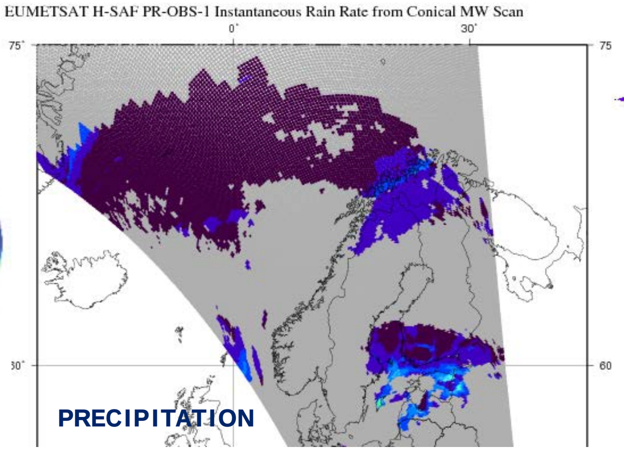
- New imagery missions:
  - 3MI: first operational imaging polarimeter
  - MWI: microwave imagery of precipitation
  - ICI: Ice Cloud imagery

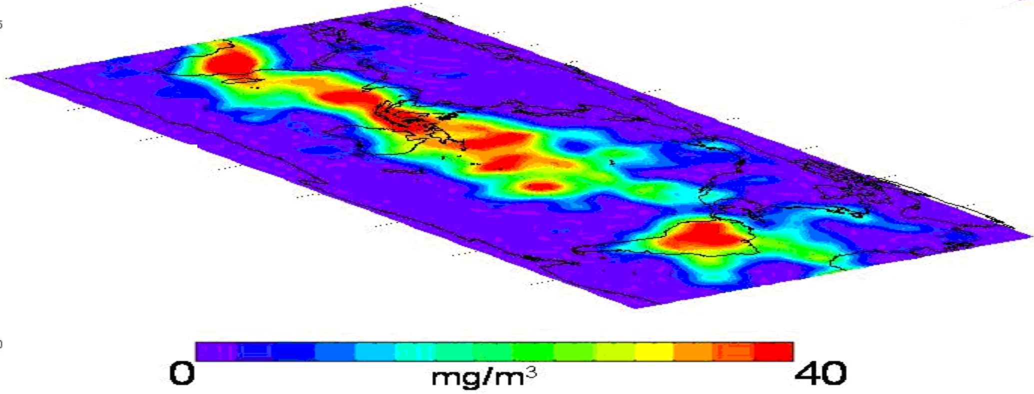
New measurements from EPS-SG – ICI, MWI, 3MI











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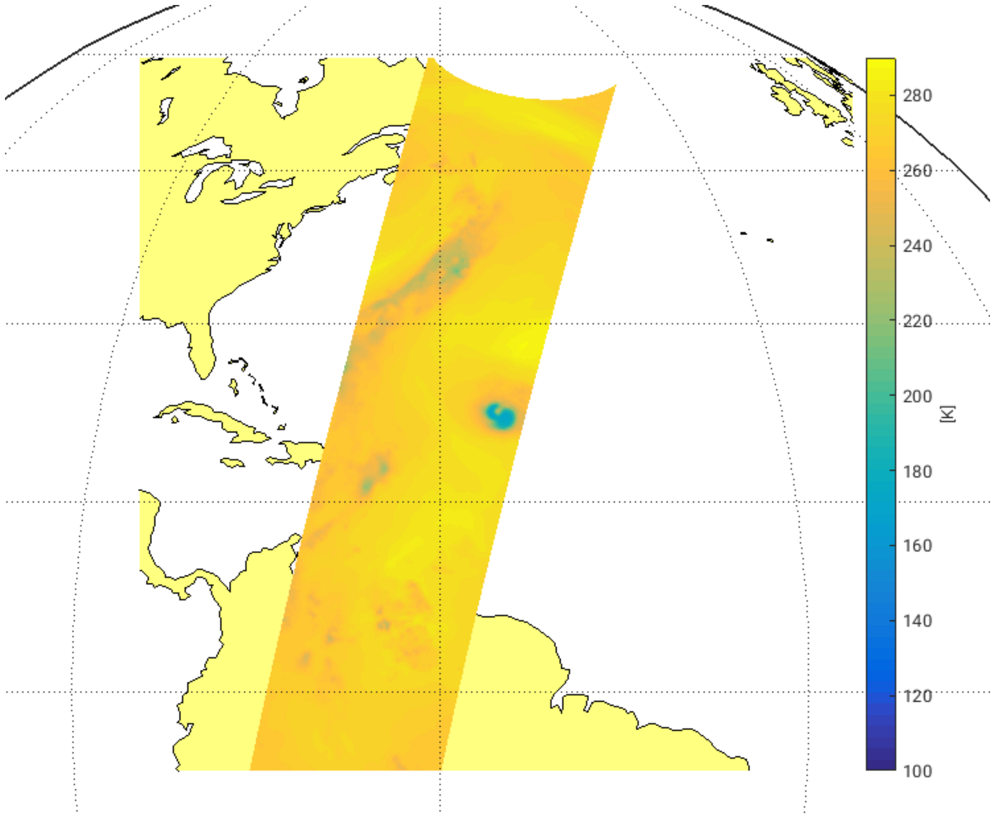
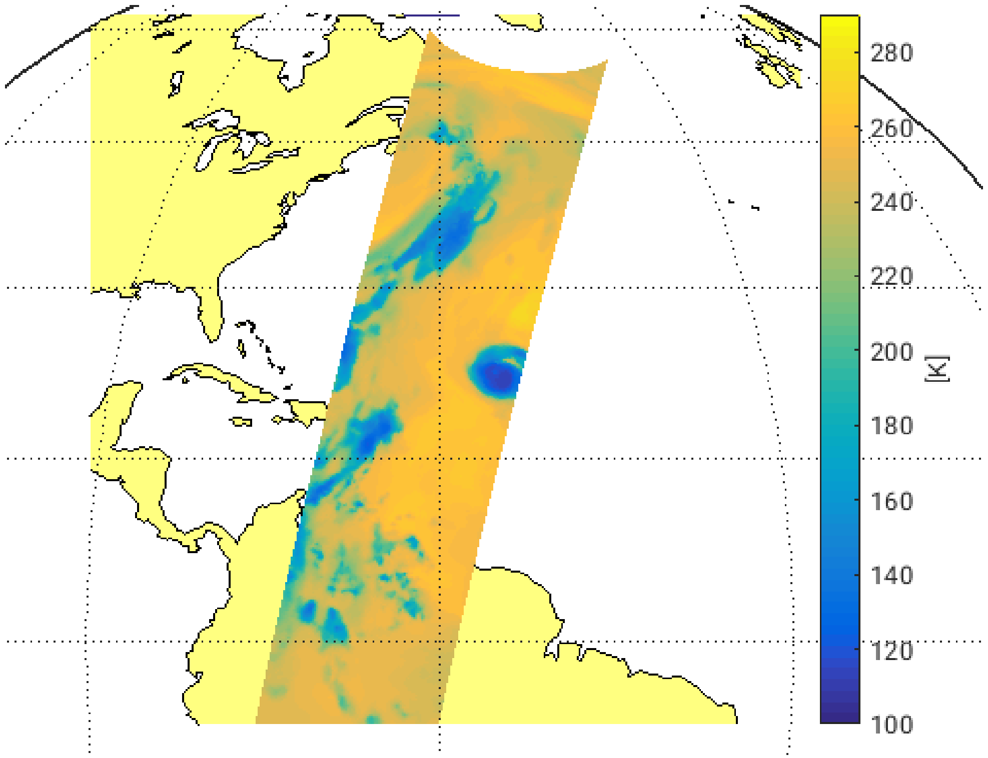
Ice cloud imaging (ICI) : Novel Mission on EPS-SG

- **Establishes operational ice-cloud imaging mission ; 11 channels: 183 – 664 GHz**
- **Support of weather forecast, hydrology, and climate monitoring**

Simulations of hurricane “IKE” , sept 2008, as it would have been seen by MHS at 183.3 +/-7 GHz

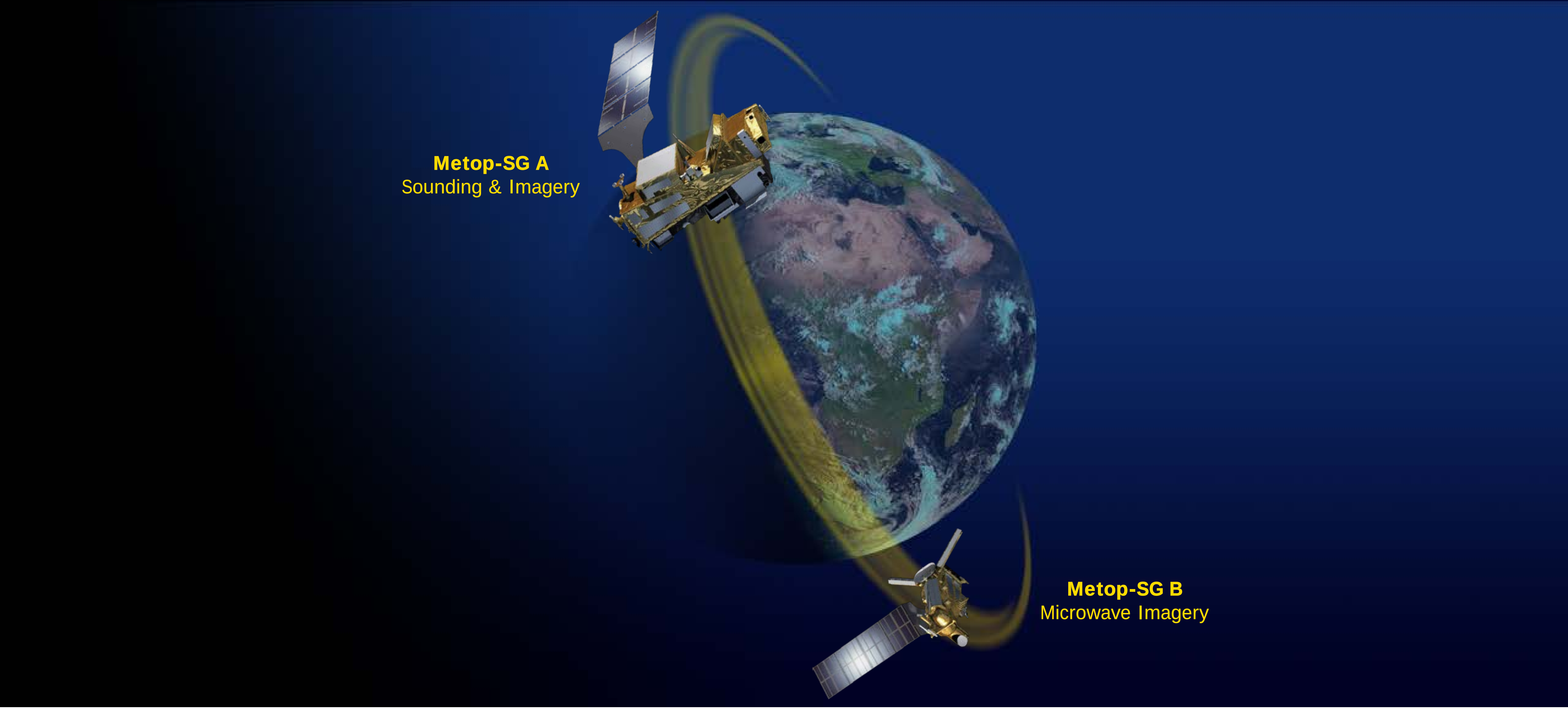


Simulations of hurricane “IKE” , sept 2008, as it would have been seen by ICI CH 11 at 664 GHz



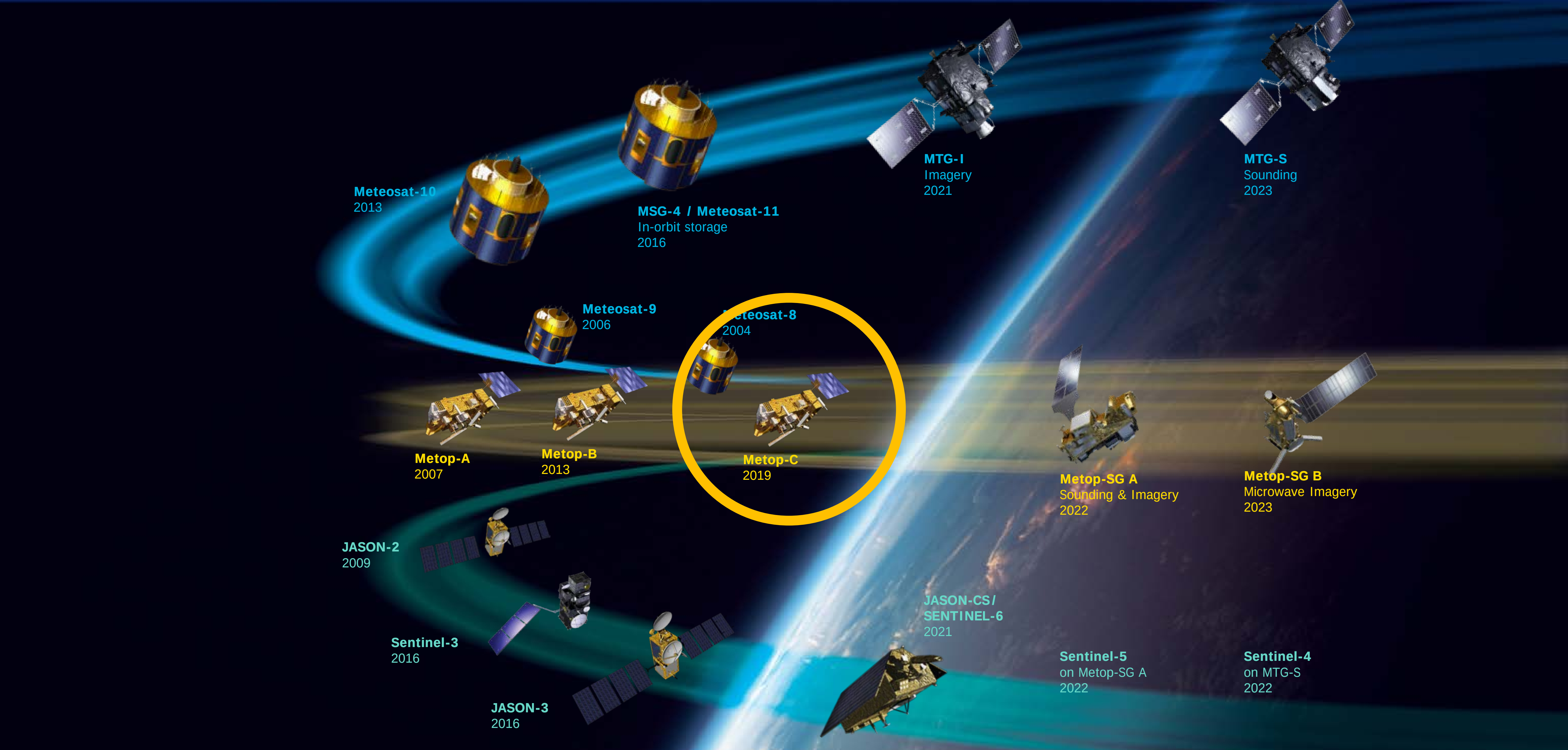
V. Mattioli, EUMETSAT

EPS-SG full operational configuration

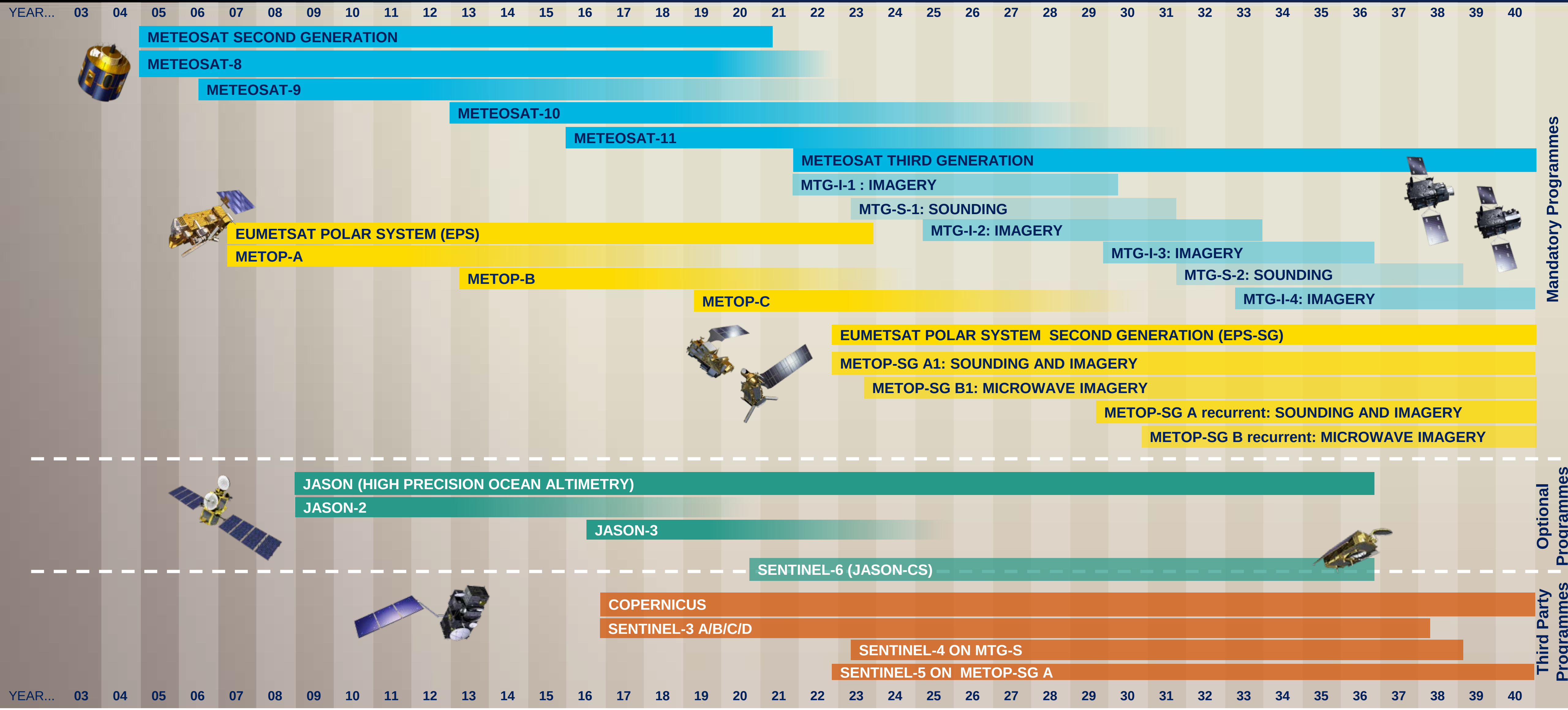


EUMETSAT

EUMETSAT Mission Planning

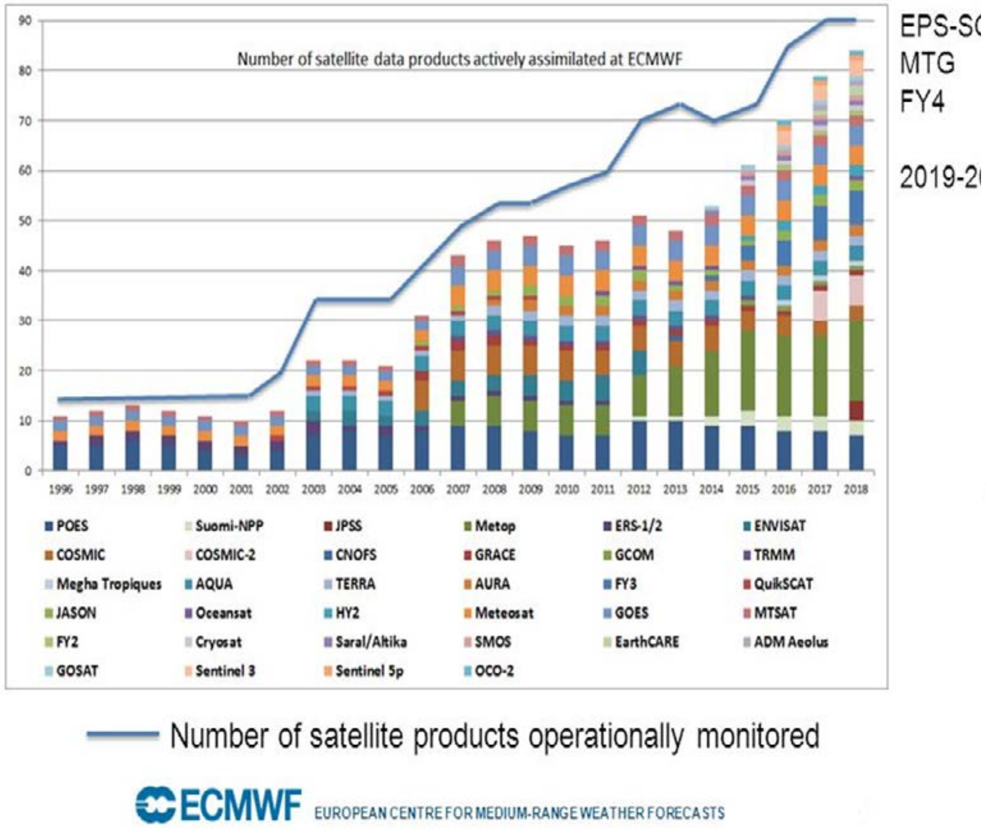


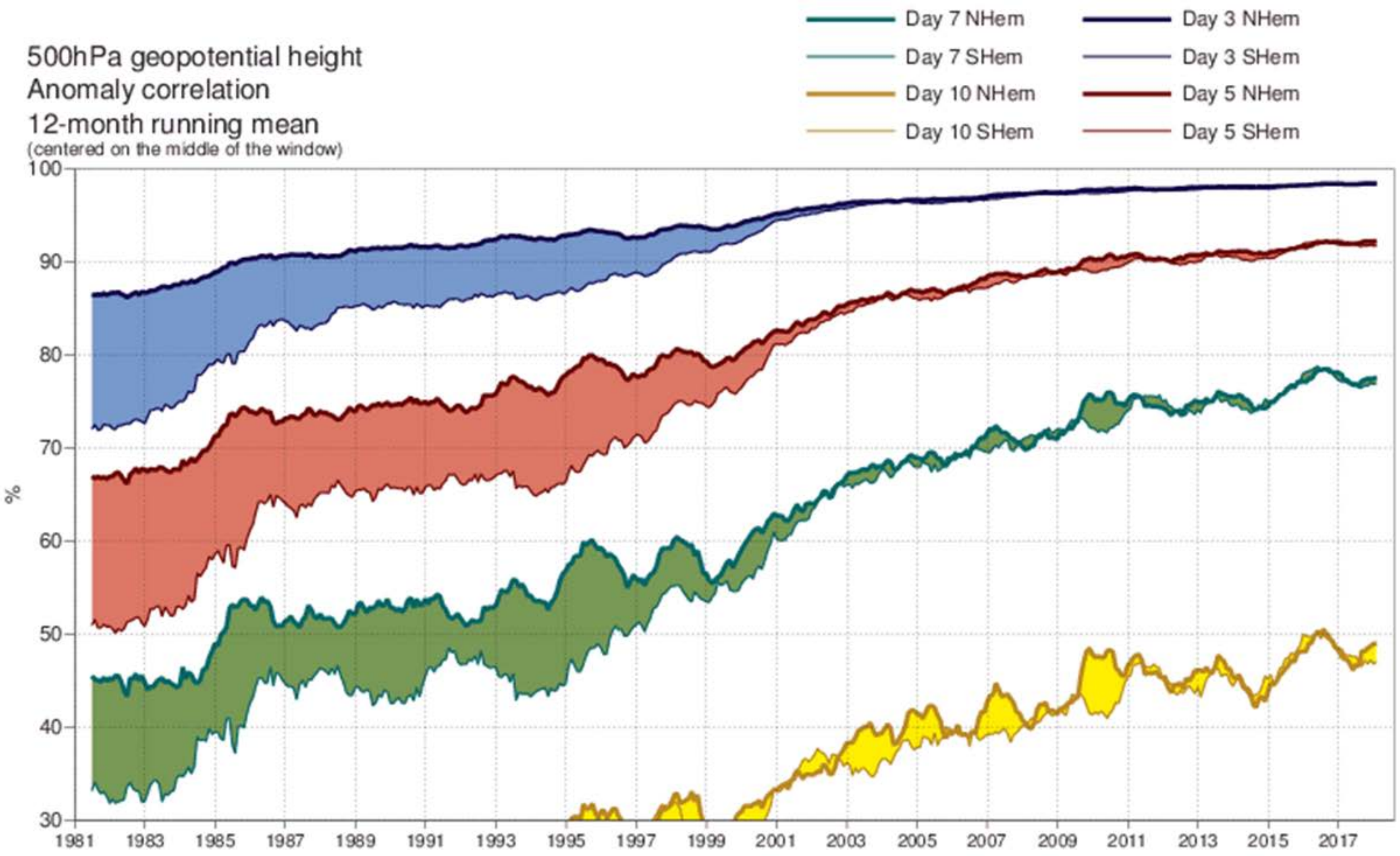
EUMETSAT Mission Planning



Explosion of use of Satellite Data in NWP

ECMWF is a world leader of medium-range numerical weather prediction

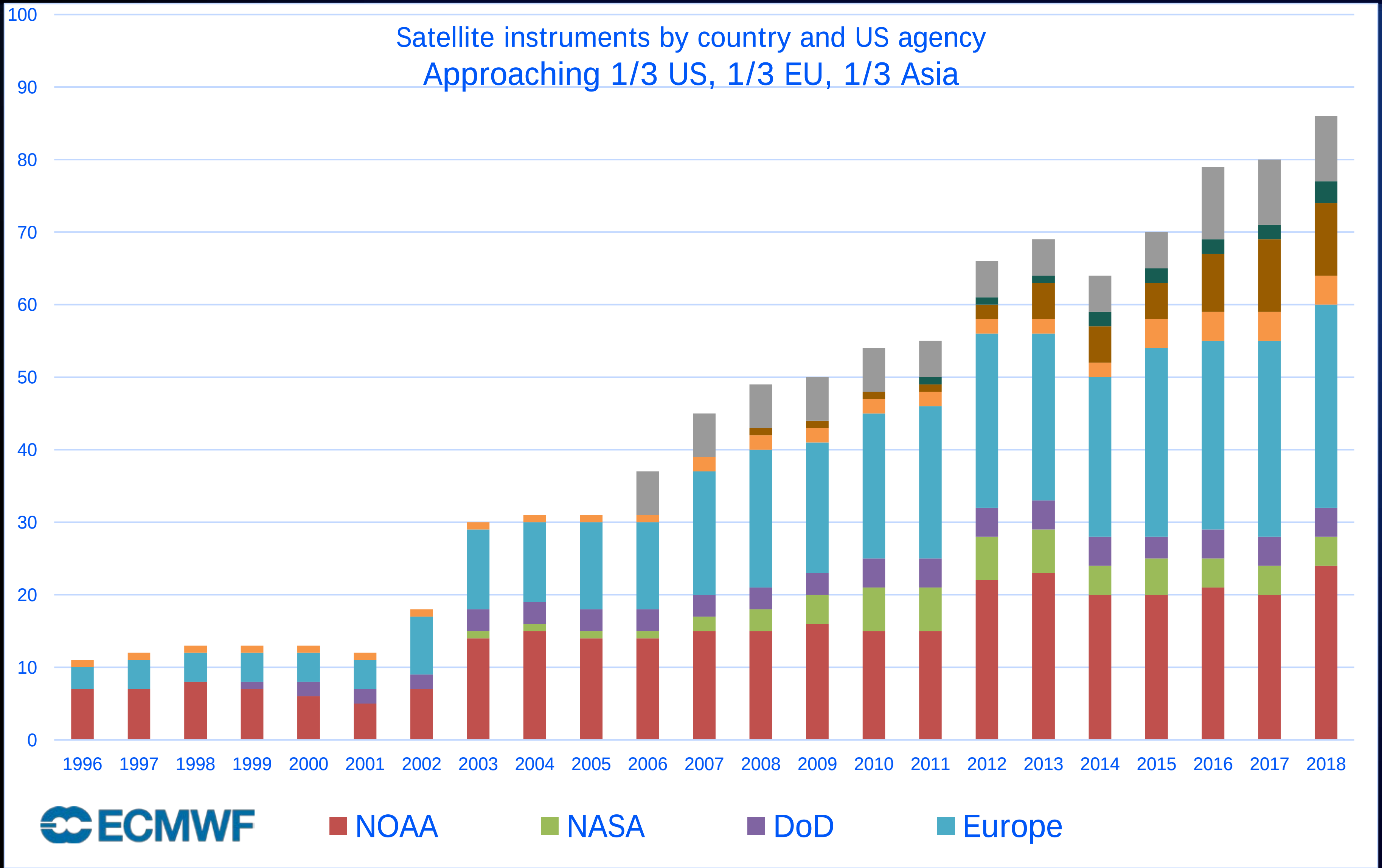




Source: ECMWF

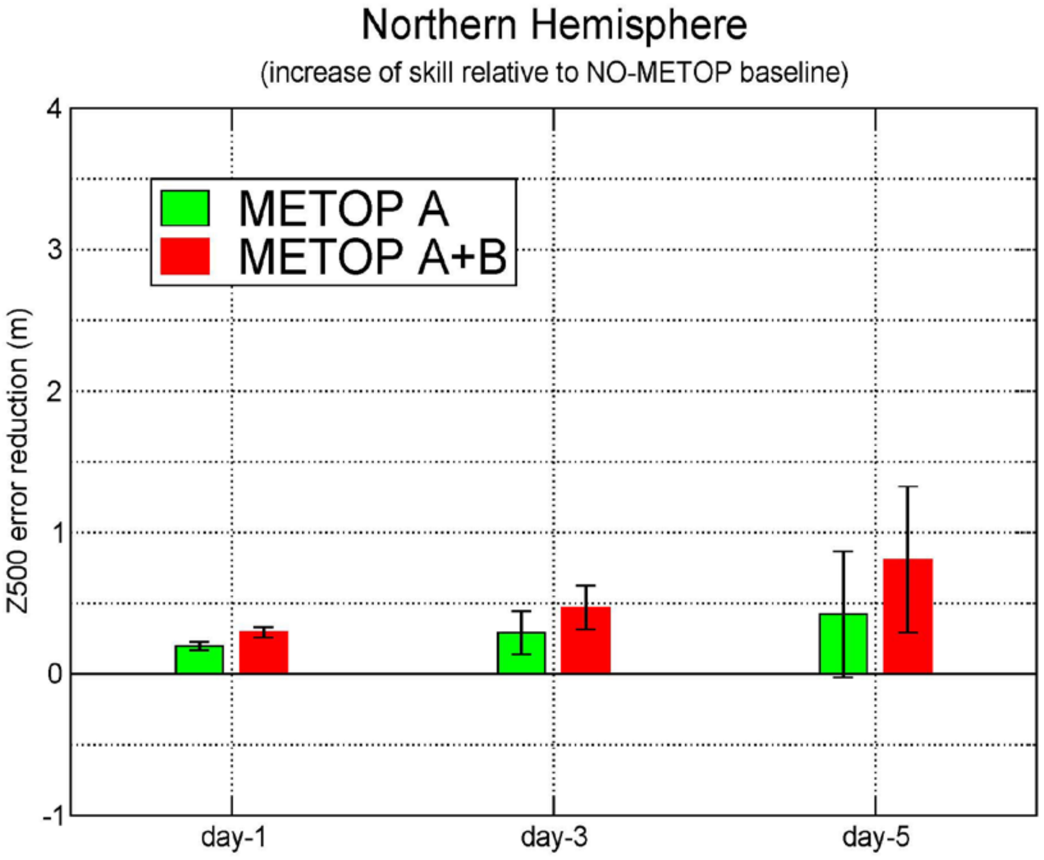
EUMETSAT

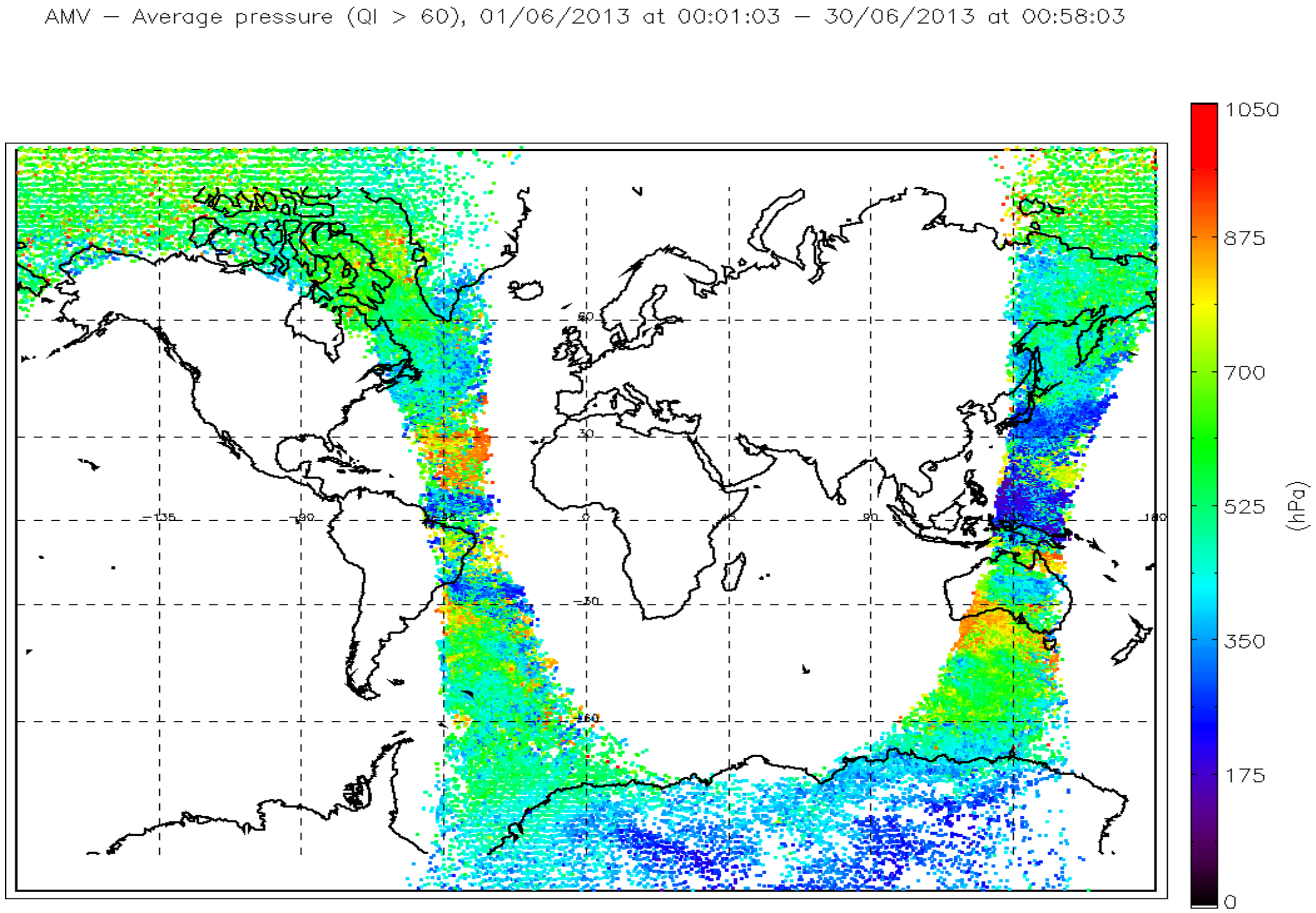
EUMETSAT contributes to 1/3 of all Data Assimilated at ECMWF



EUMETSAT

Multiple Metops



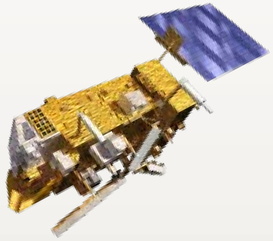
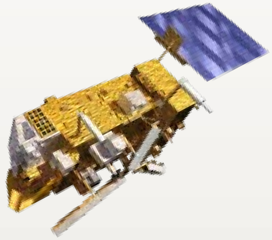


ECMWF

Metop Satellites' contribution to Error reduction for 1 Day F/C

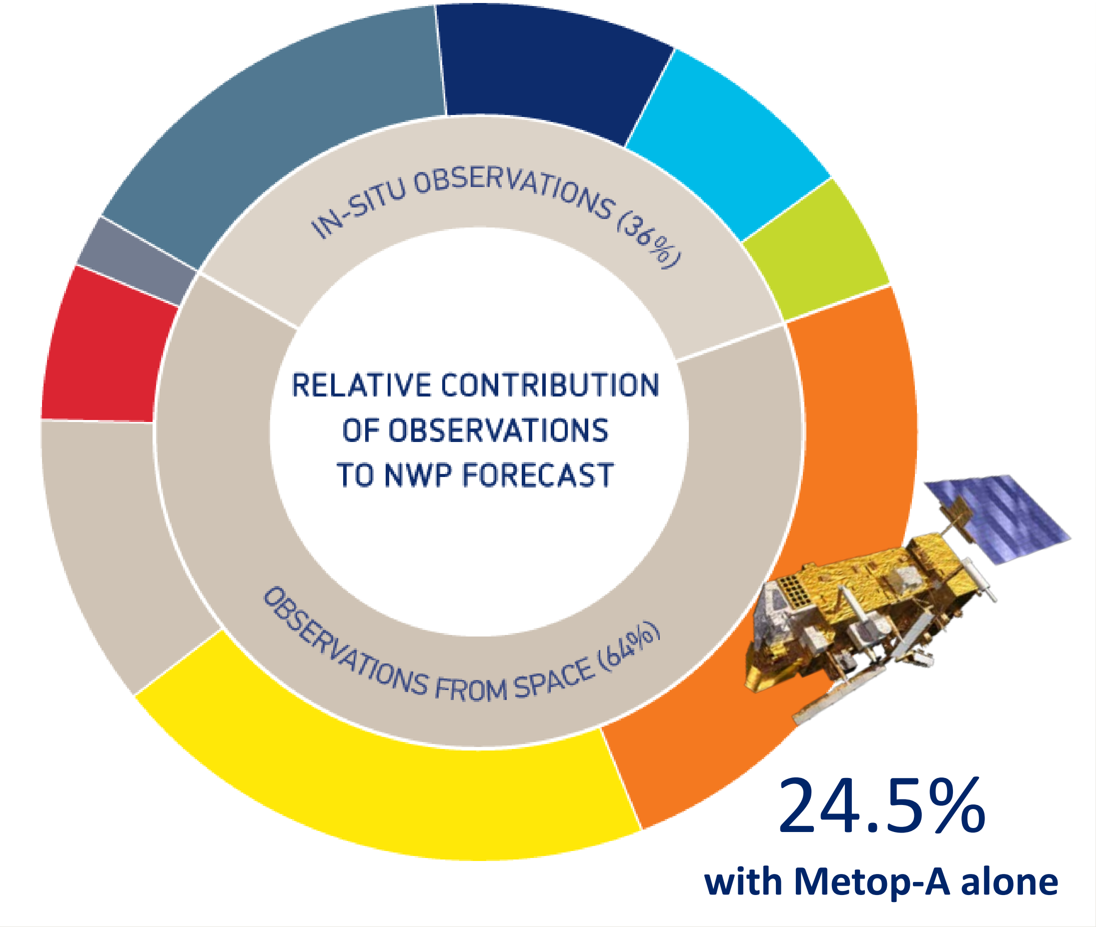
Today

Metop-A	Metop-B

 +  = **27%**

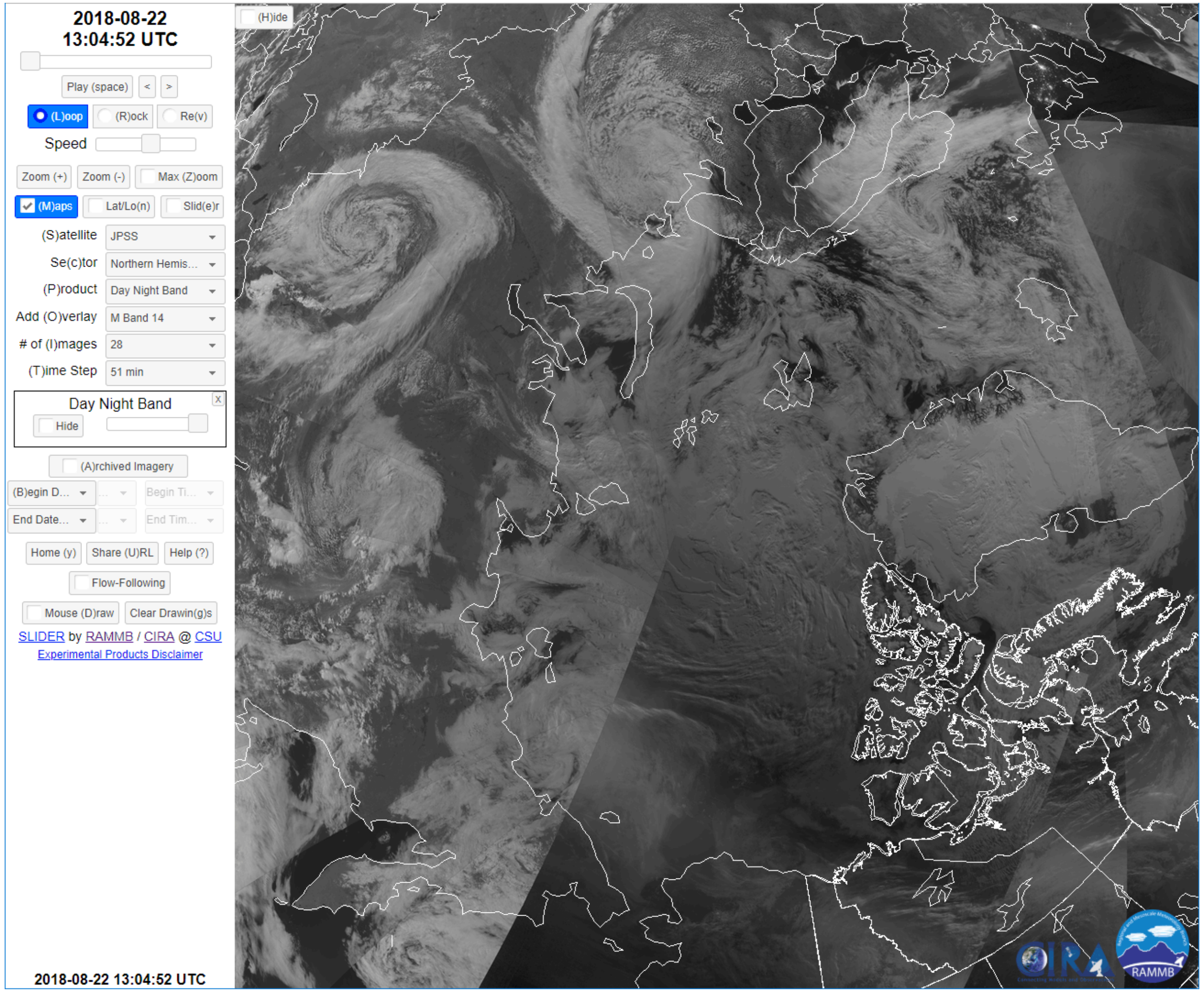
\+  = **?**

Metop-C



Source: Met Office, UK

Twice the VIIRS



Better with two satellites

GOES-R and JPSS Proving Ground Demonstration at the Hazardous Weather Testbed 2018 Spring Experiment Final Evaluation

Project Title: GOES-R and JPSS Proving Ground Demonstration at the 2018 Spring Experiment - Experimental Warning Program (EWP)

Organization: NOAA Hazardous Weather Testbed (HWT)

Evaluator(s): National Weather Service (NWS) Forecasters, Broadcast Meteorologists, Storm Prediction Center (SPC), National Severe Storms Laboratory (NSSL), University of Oklahoma (OU), Cooperative Institute for Mesoscale Meteorological Studies (CIMMS)

Duration of Evaluation: 30 April 2018 – 25 May 2018

Prepared By: Michael Bowlan (OU/CIMMS and NOAA/SPC) and Kristin Calhoun (OU/CIMMS and NSSL)

Submitted Date:

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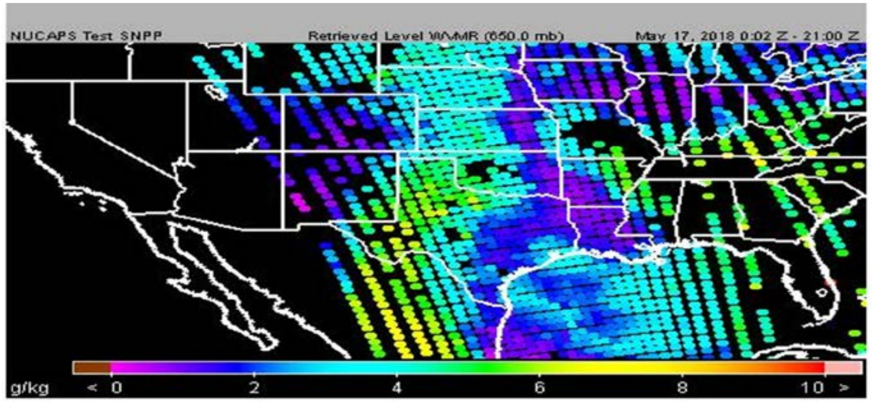
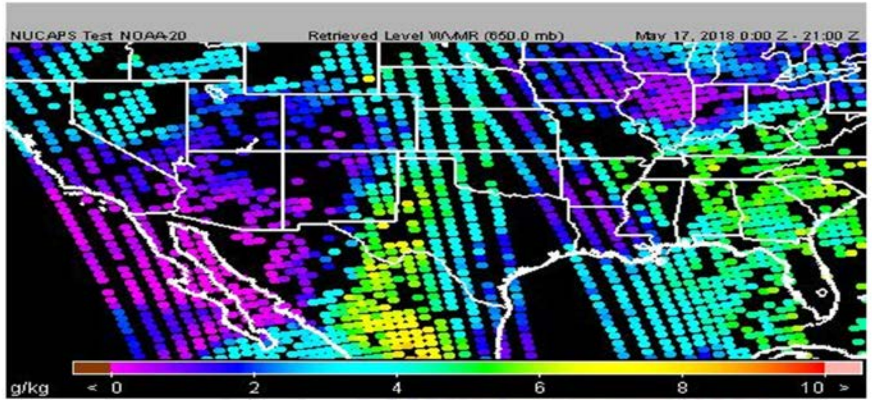
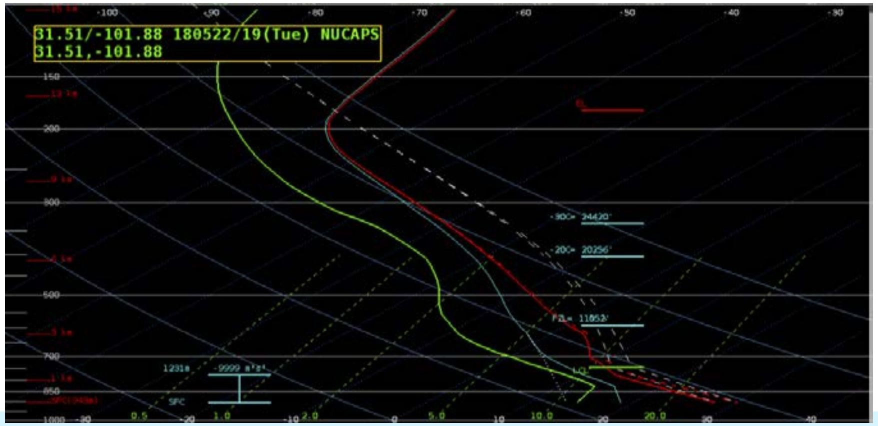
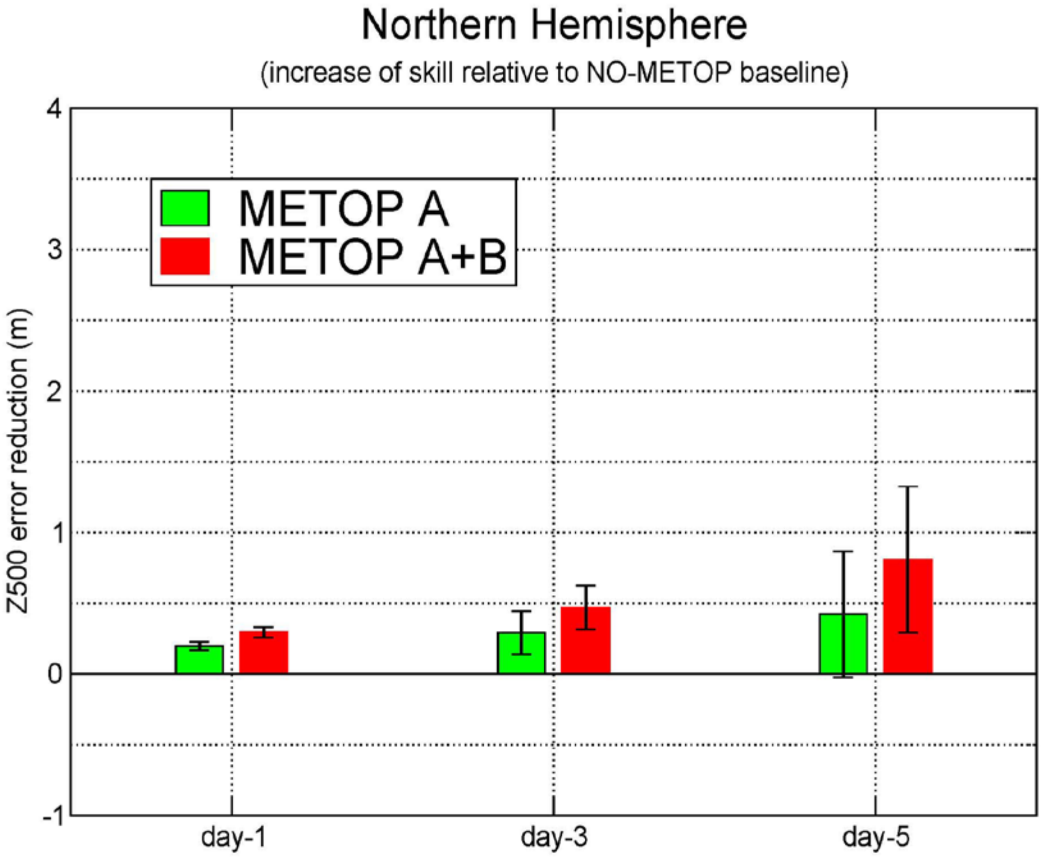
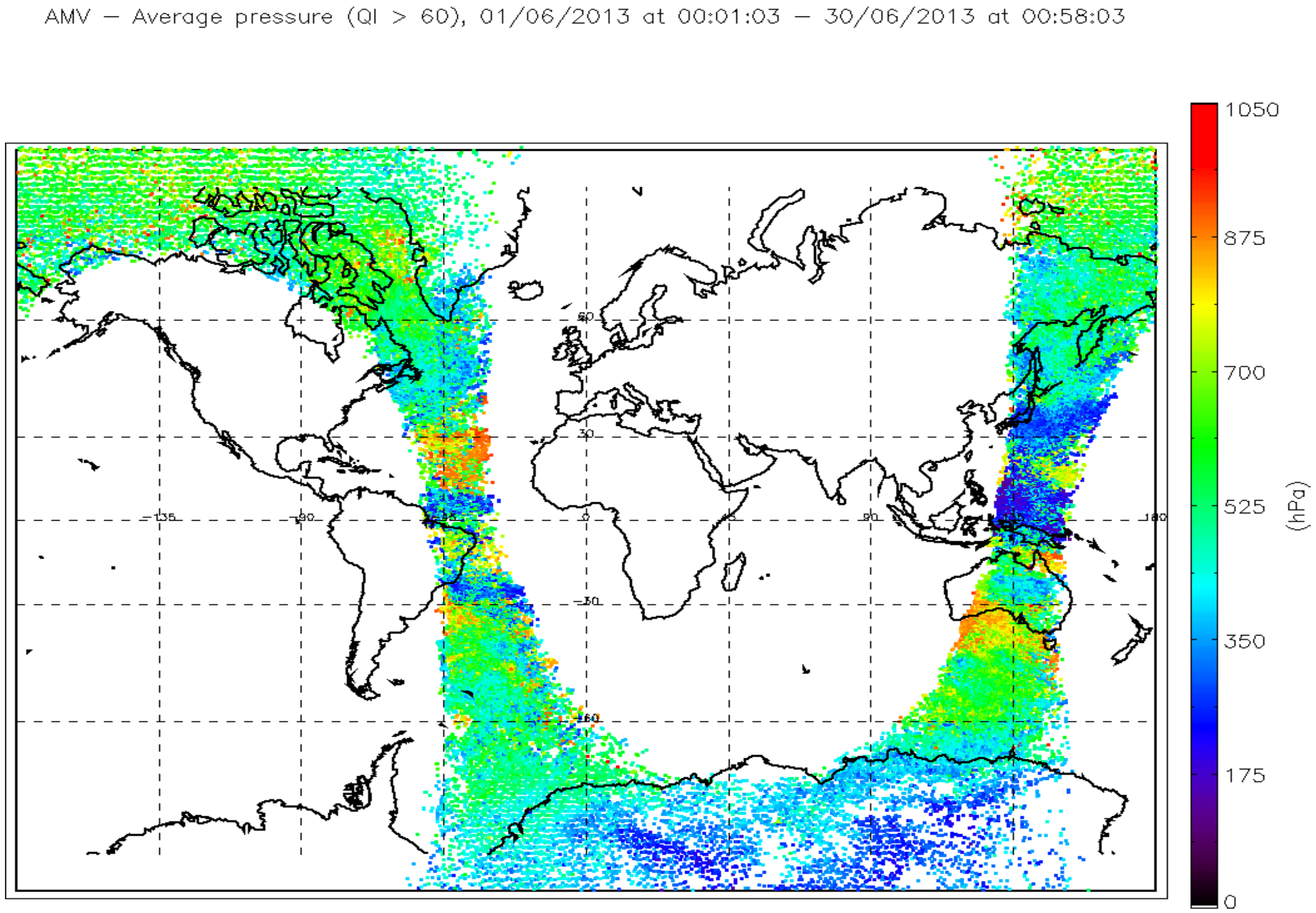




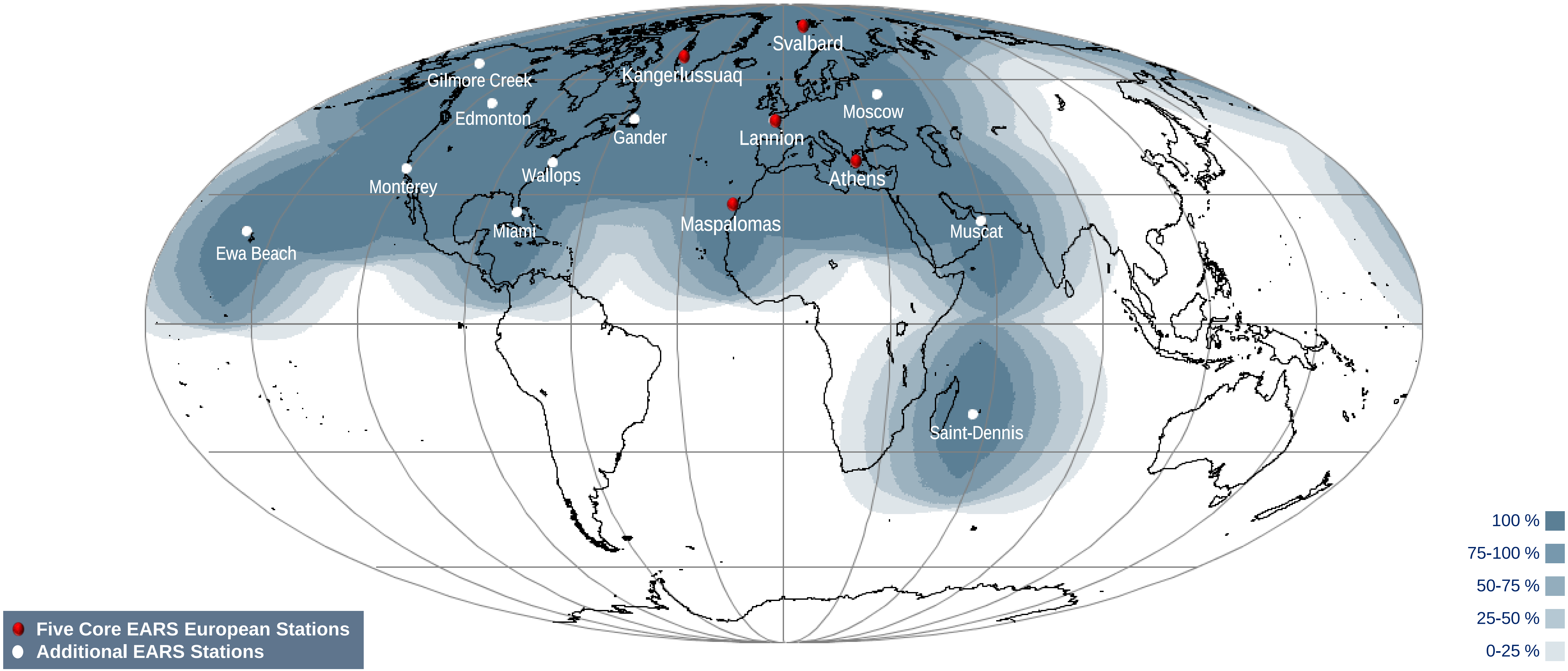


Multiple Metops



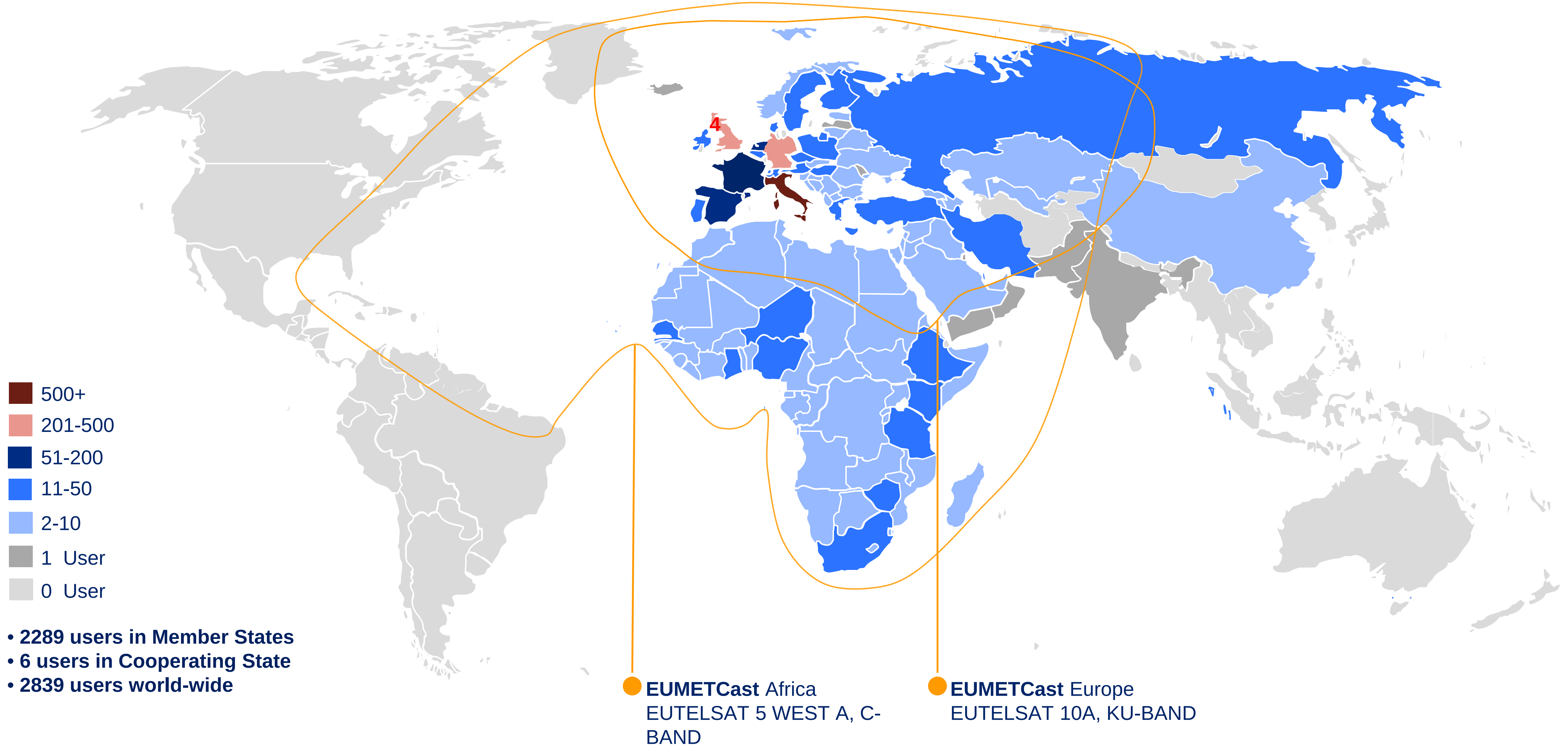


EARS ground station network



EUMETSAT

EUMETCast global user community



- **2289 users in Member States**
- **6 users in Cooperating State**
- **2839 users world-wide**

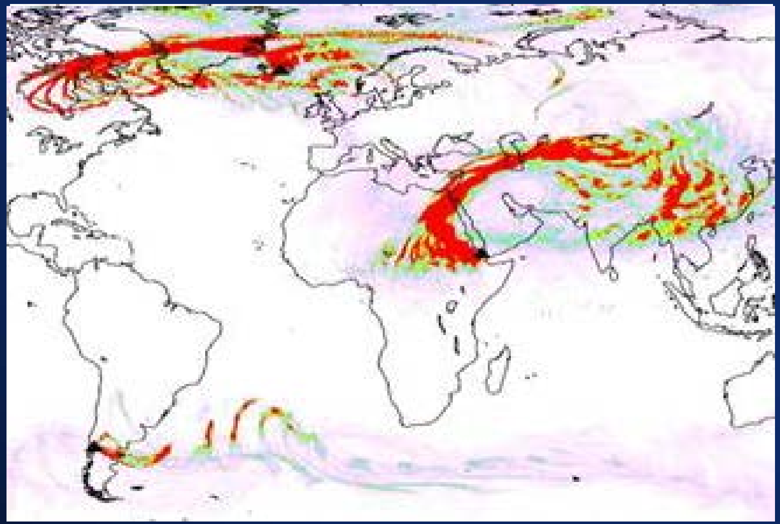
EUMETSAT Network of Satellite Application Facilities

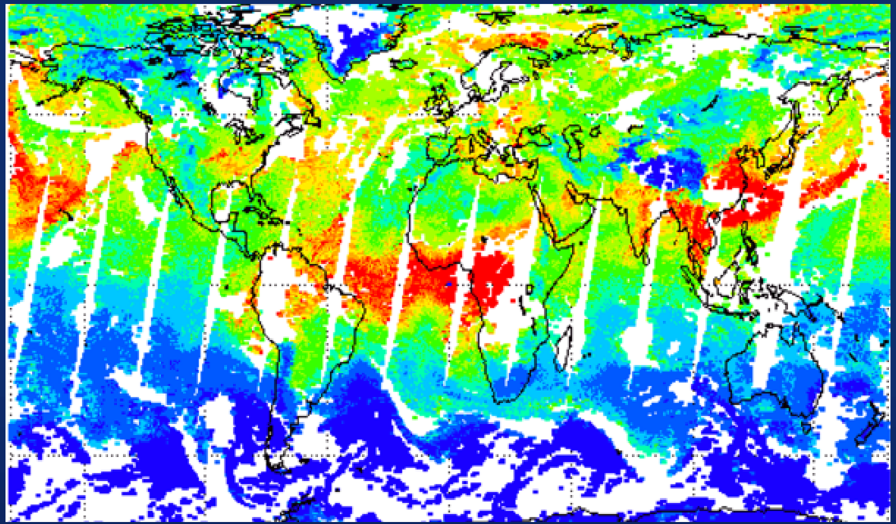
Atmospheric Composition Monitoring SAF

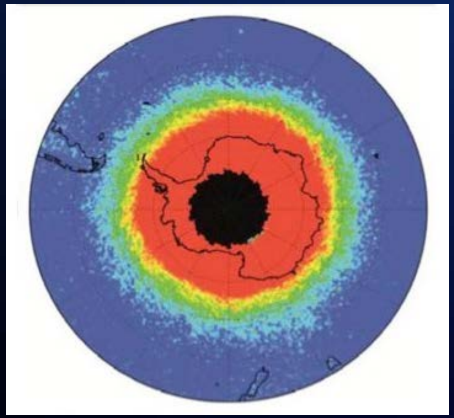
EUMETSAT
AC SAF
ATMOSPHERIC COMPOSITION MONITORING

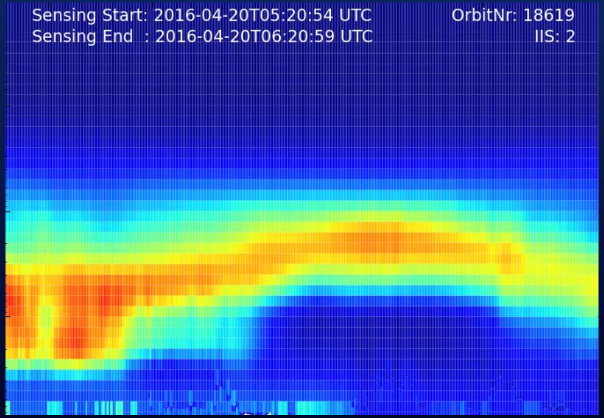
Develops, produces, archives, validates and disseminates ozone and atmospheric chemistry products, to support weather forecasting, as well as monitoring of ozone depletion, air quality and surface UV radiation.

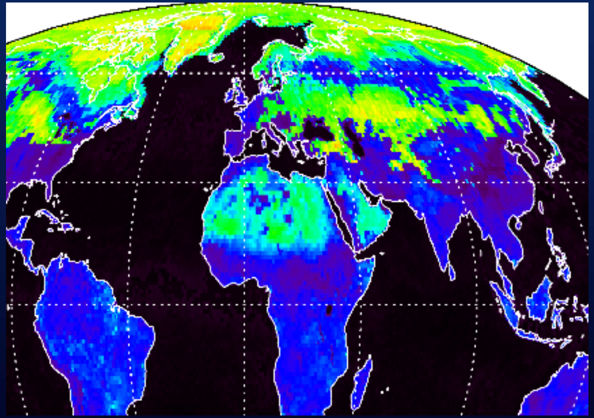
In addition, these products contribute to the implementation of the EUMETSAT strategy in environmental monitoring of the atmosphere. This is achieved at the European level by contributing to the Copernicus activities, and in the global scale by implementing the global observations of the key atmospheric parameters, as recommended by the Integrated Global Atmospheric Chemistry Observations Theme (IGACO) within the IGOS framework.











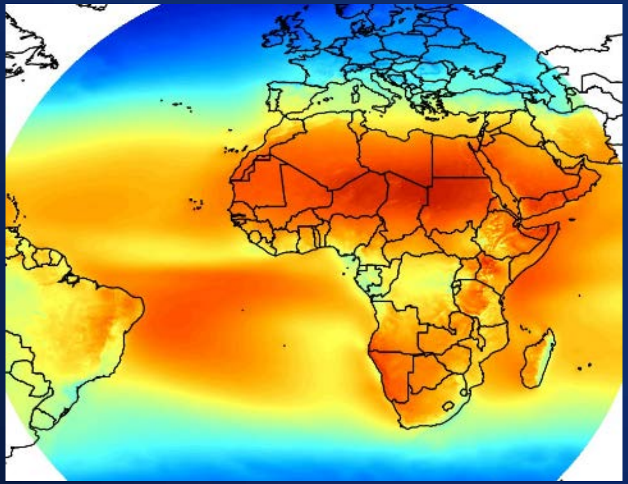
Climate Monitoring SAF

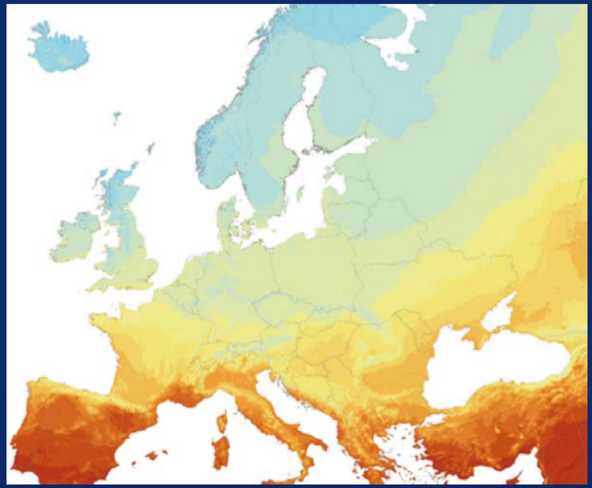
EUMETSAT CM SAF CLIMATE MONITORING

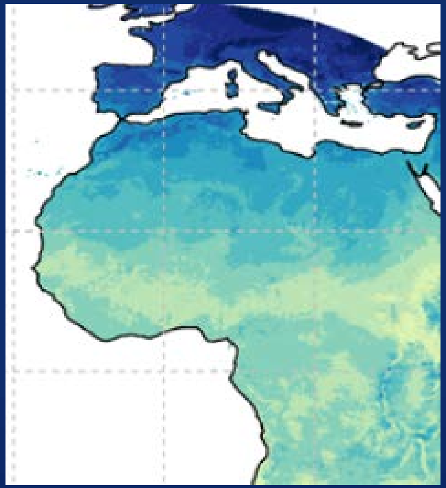
Generates and archives high-quality datasets for specific climate application areas to derive information about the climate variables of the Earth system.

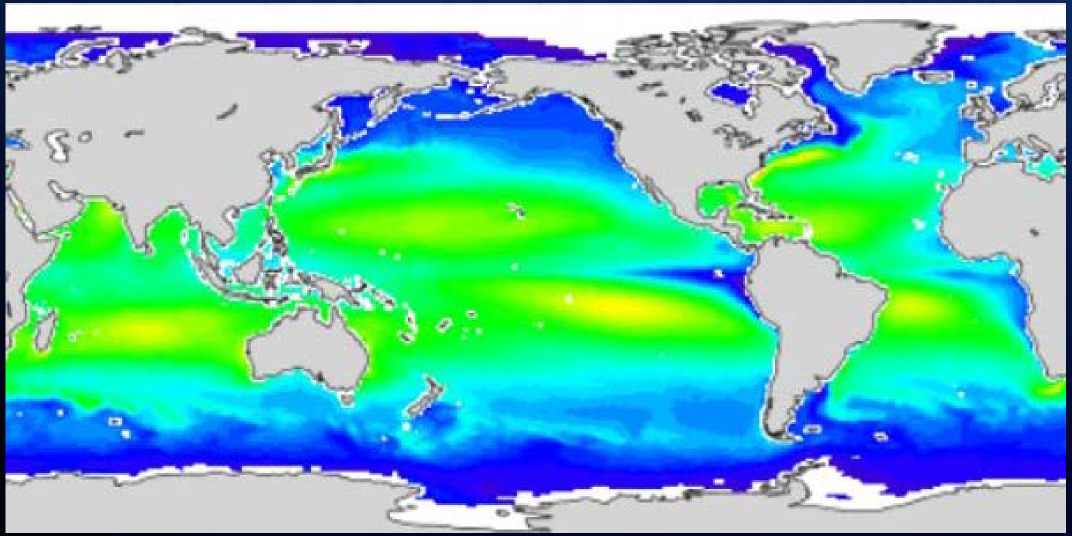
It aims to provide data that can be further used to assess the current climate, e.g. for infrastructure planning; to assess the climate variability and change, including climate change detection and attribution; to support the development of climate models; by validating long-range and short-term climate forecasts; to assess the impact of changing environment, and to provide evidence for policy actions.

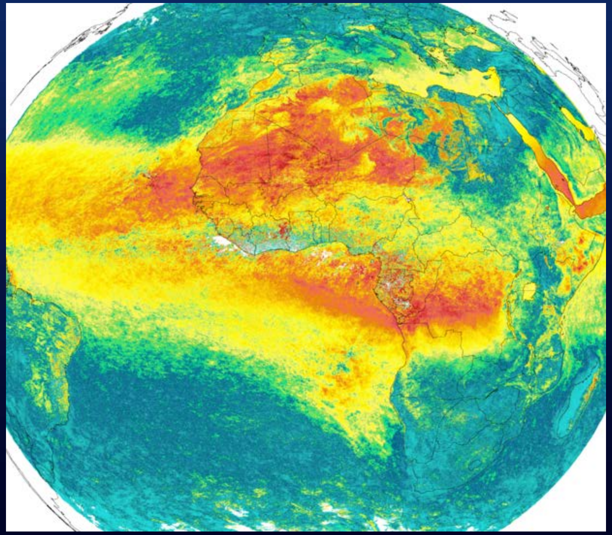
The applications cover the objectives of various international programs — such as Global Climate Observing System (GCOS), World Climate Programme (WCP) and World Climate Research Programme (WCRP) — and are also vital for activities within the Group on Earth Observations (GEO) and Copernicus framework.









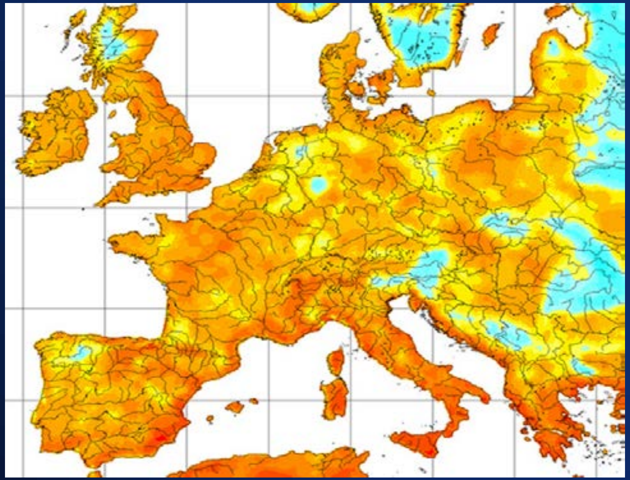


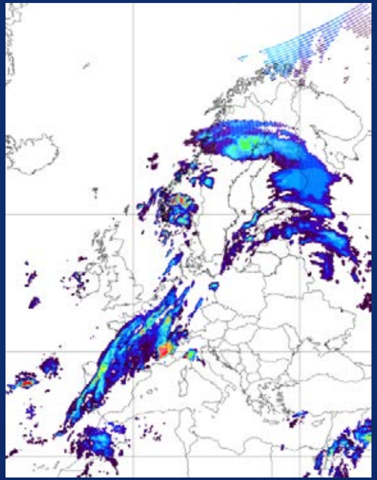
Support to Operational Hydrology and Water Management SAF

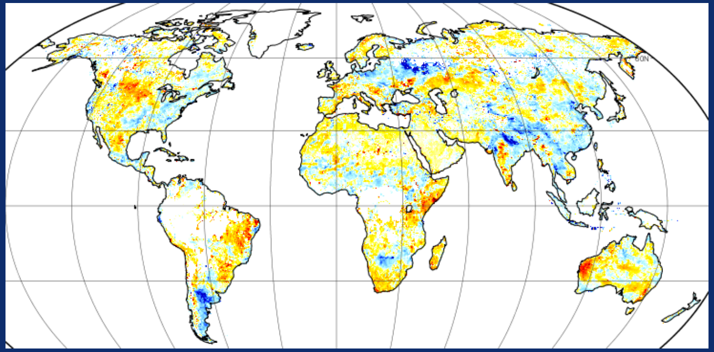
EUMETSAT
H SAF
SUPPORT TO OPERATIONAL HYDROLOGY AND WATER MANAGEMENT

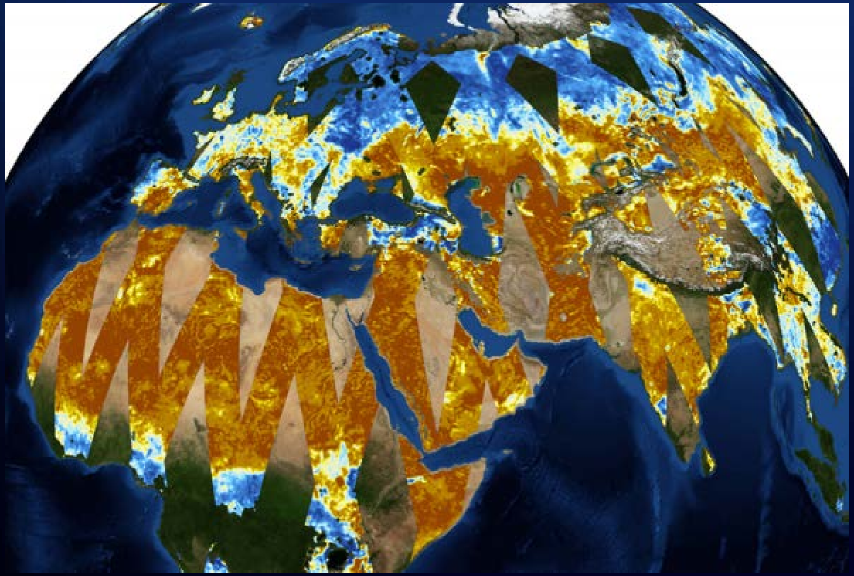
Operationally generates, validates, distributes and archives high-quality datasets and products for operational hydrological applications, starting from the acquisition and processing of data from Earth observation satellites in geostationary and polar orbits. The retrieval of products uses data from microwave and infrared instruments for the best possible accuracy compatible with satellite systems available now, or in the near future.

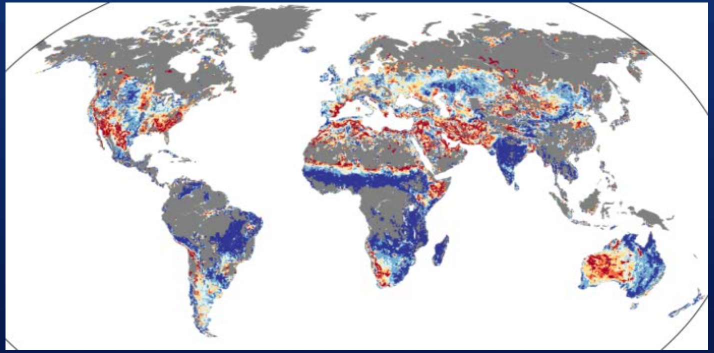
H SAF applications are foreseen to fit with the objectives of other European and international programmes — such as PREVIEW, CYCLOPS and Copernicus fast tracks — with special relevance to those initiatives which want to mitigate hazards and natural disasters, such as flash floods, forest fires, landslides and drought conditions, and improve water management.

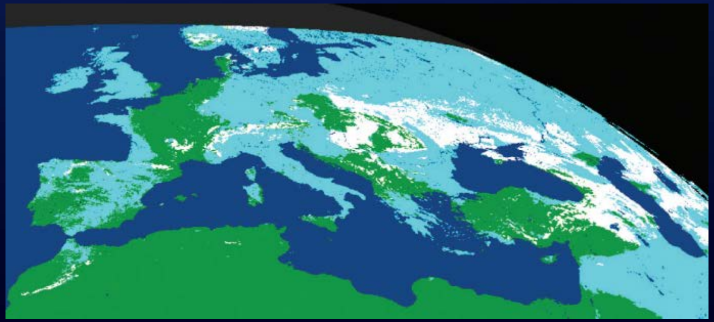










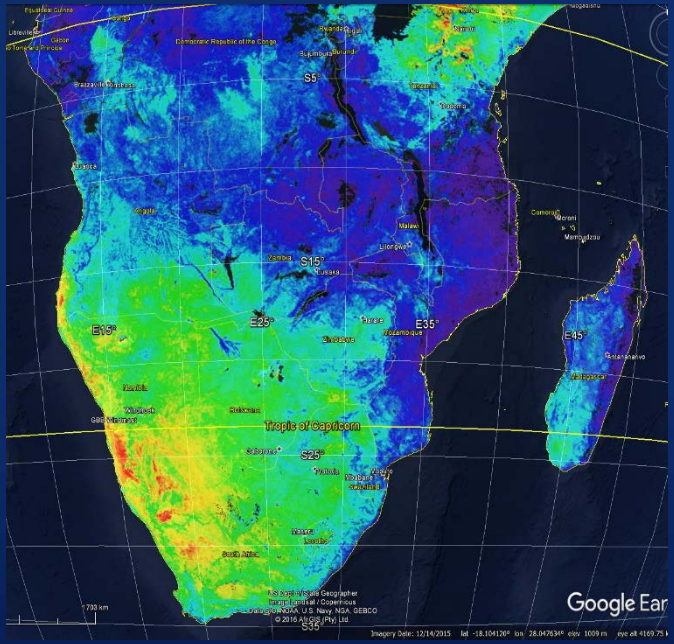


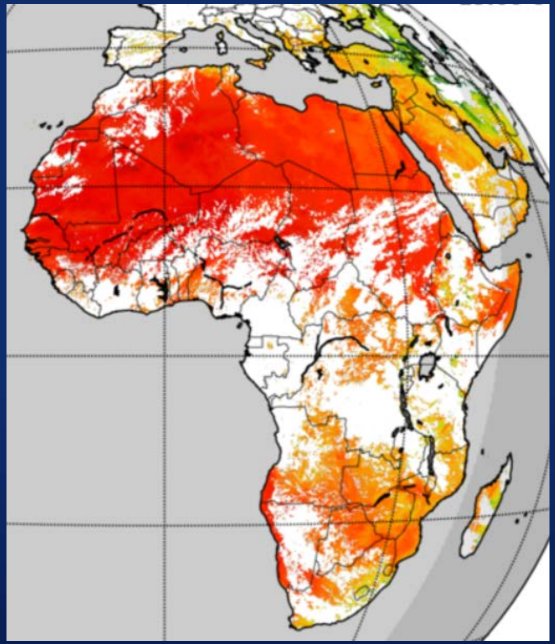
Land Surface Analysis SAF

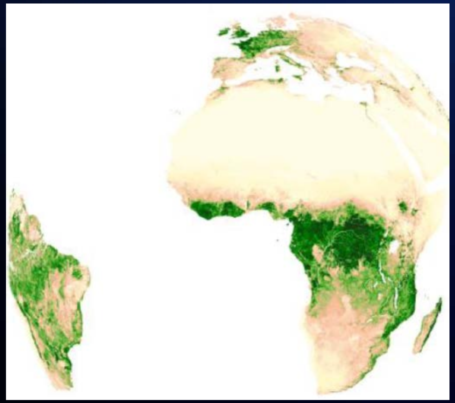
EUMETSAT LSA SAF LAND SURFACE ANALYSIS

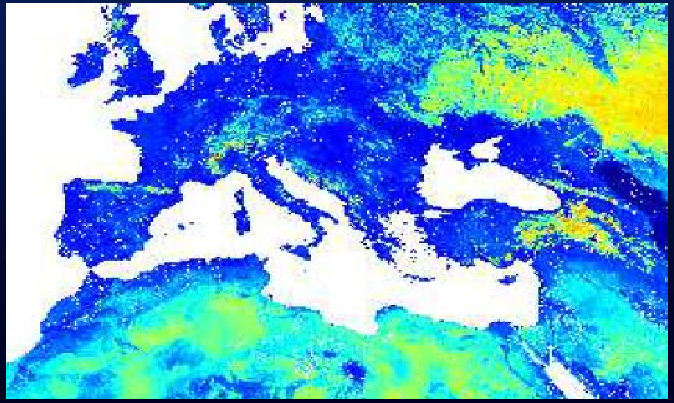
The aim of the LSA SAF is to take full advantage of remotely sensed data on land, land-atmosphere interactions and biosphere applications. A strong emphasis is put on developing and implementing algorithms that will allow an operational use of data from EUMETSAT satellites. The LSA SAF system, mainly centralised at Instituto Português do Mar e Atmosfera (IPMA), Portugal, generates, archives and disseminates, on an operational basis, a set of parameters involved in the surface radiation budget, evapotranspiration, vegetation cover and and fire-related products.

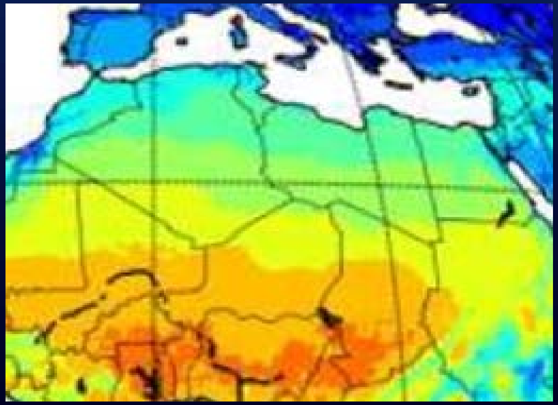
The LSA SAF addresses a wide user community, ranging from surface processes modelling e.g. Numerical Weather Prediction (NWP), seasonal forecasting and climate models to agriculture and forestry applications e.g. fire hazards, food production and hydrology. Users benefit from products generated from a reliable observing system, designed to ensure long-term operations.







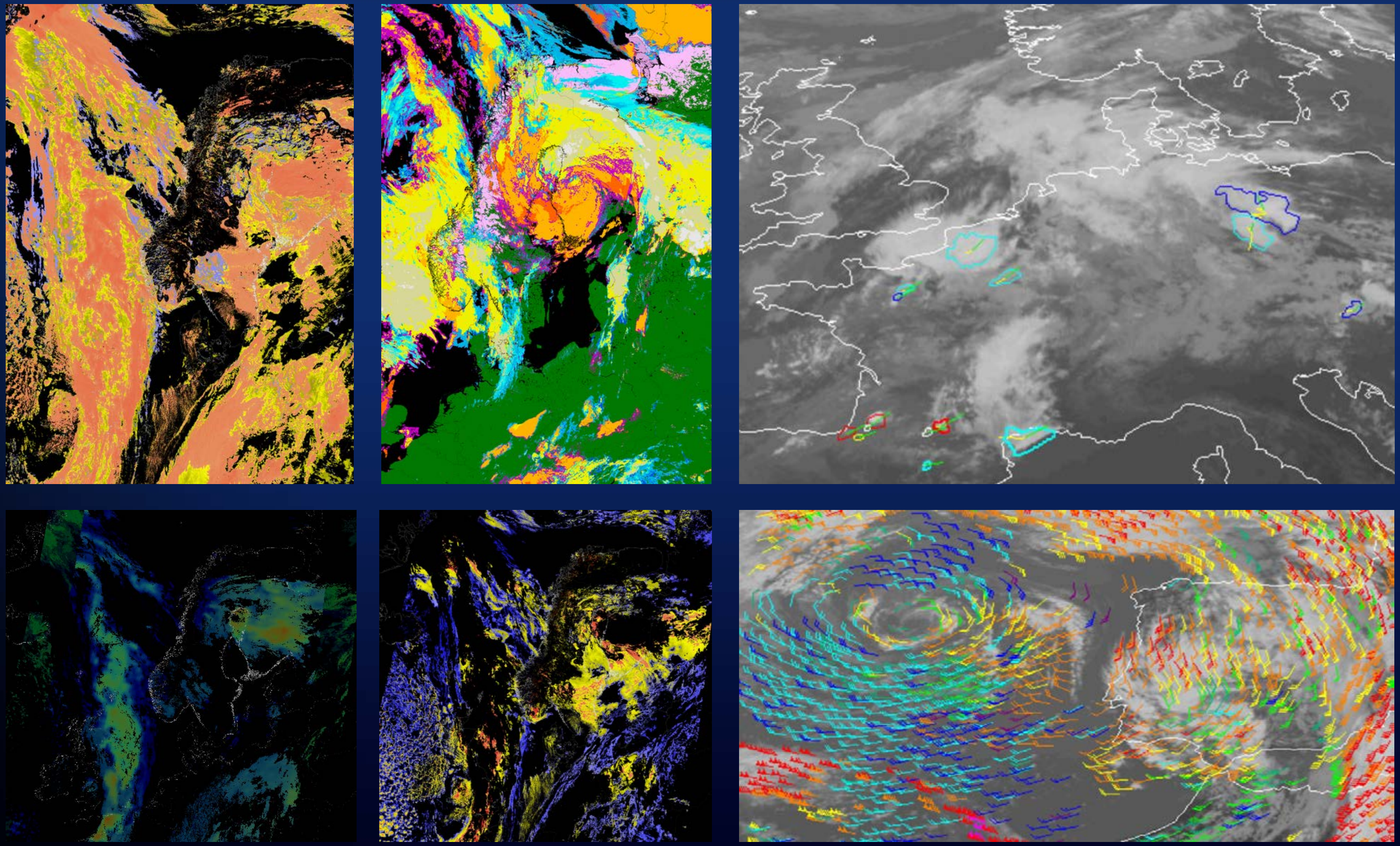




Support to Nowcasting and Very Short Range Forecasting SAF

The main goal of the NWC SAF is to produce software packages that support Nowcasting and Very Short Range Forecasting. The software, which is for local installation at the user's site, processes data from operational meteorological satellites flying in geostationary orbits (e.g. Meteosat Second Generation (MSG)) or polar orbits (e.g. Metop or NOAA).

The logic for the second Continuous Development and Operations Phase (CDOP-2) is to consolidate the use of the software packages in the related, interested organisations by means of promotion and user support — mainly through the help desk and improvement of the software, according to user-oriented development and validation activities. The activities in the CDOP-2 also encompass the extention of the applicability to new satellite systems, including the Meteosat Third Generation (MTG) and Soumi NPP.

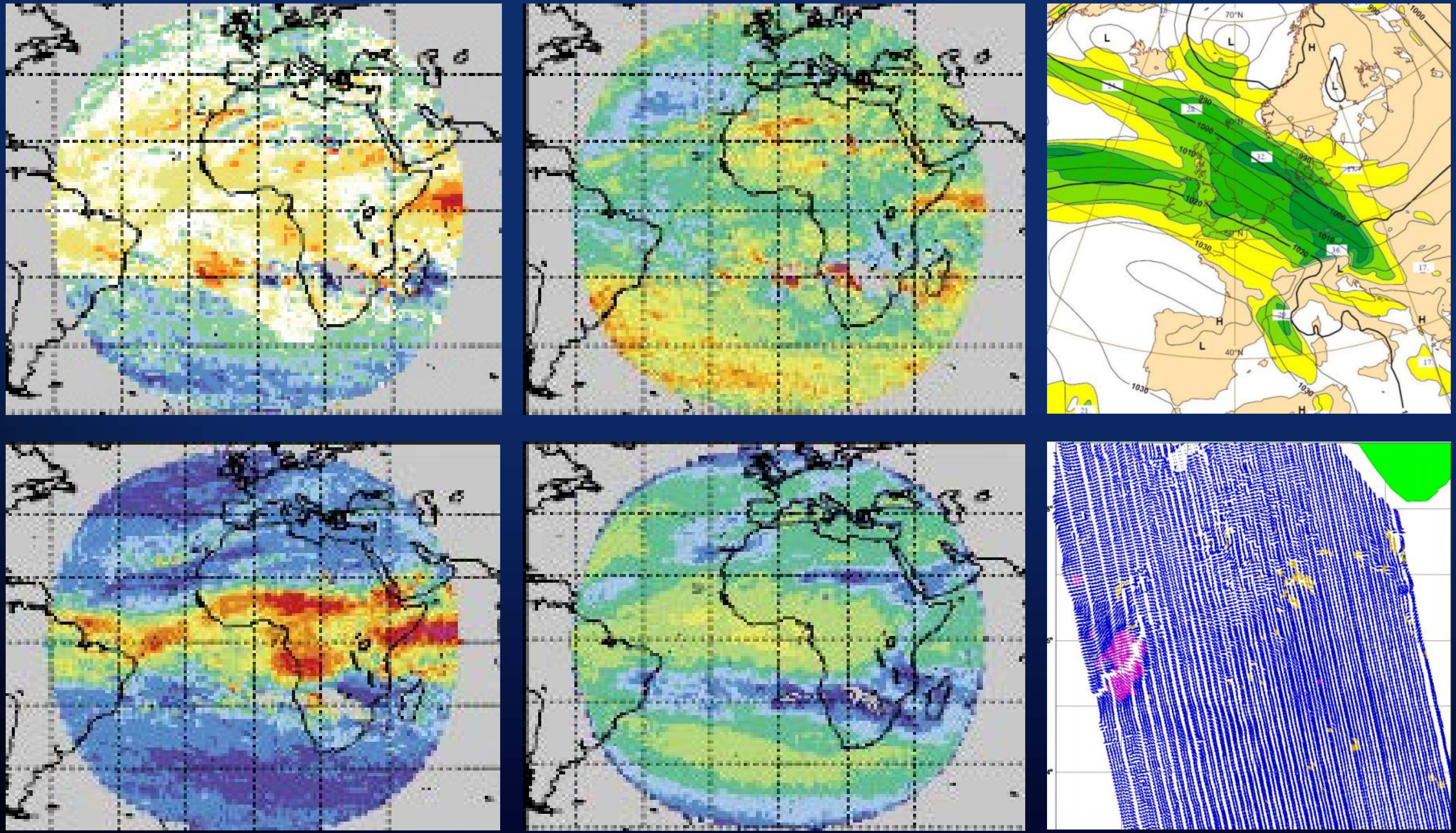


Numerical Weather Prediction SAF

EUMETSAT NWP SAF
NUMERICAL WEATHER PREDICTION

The NWP SAF exists to increase the benefits derived from numerical weather prediction by developing techniques for more effective use of satellite data, and to improve the exploitation of data and products from EUMETSAT satellites programmes, and related programmes of other agencies.

To achieve these objectives, the NWP SAF updates, assesses and prioritises user requirements and develops the satellite data processing modules needed to meet those requirements. These include: pre-processing; retrieval and assimilation modules; modules for monitoring, tuning and quality control, and modules for validation of satellite products and of observation operators. It also monitors the quality of many satellite data streams and makes the results available on the web. European National Meteorological Services are the NWP SAF's primary users, but the tools it develops have found a worldwide community of users, with a wide range of research and operational applications extending well beyond NWP. NWP SAF products also underpin activities in international programmes, such as the Copernicus programme.

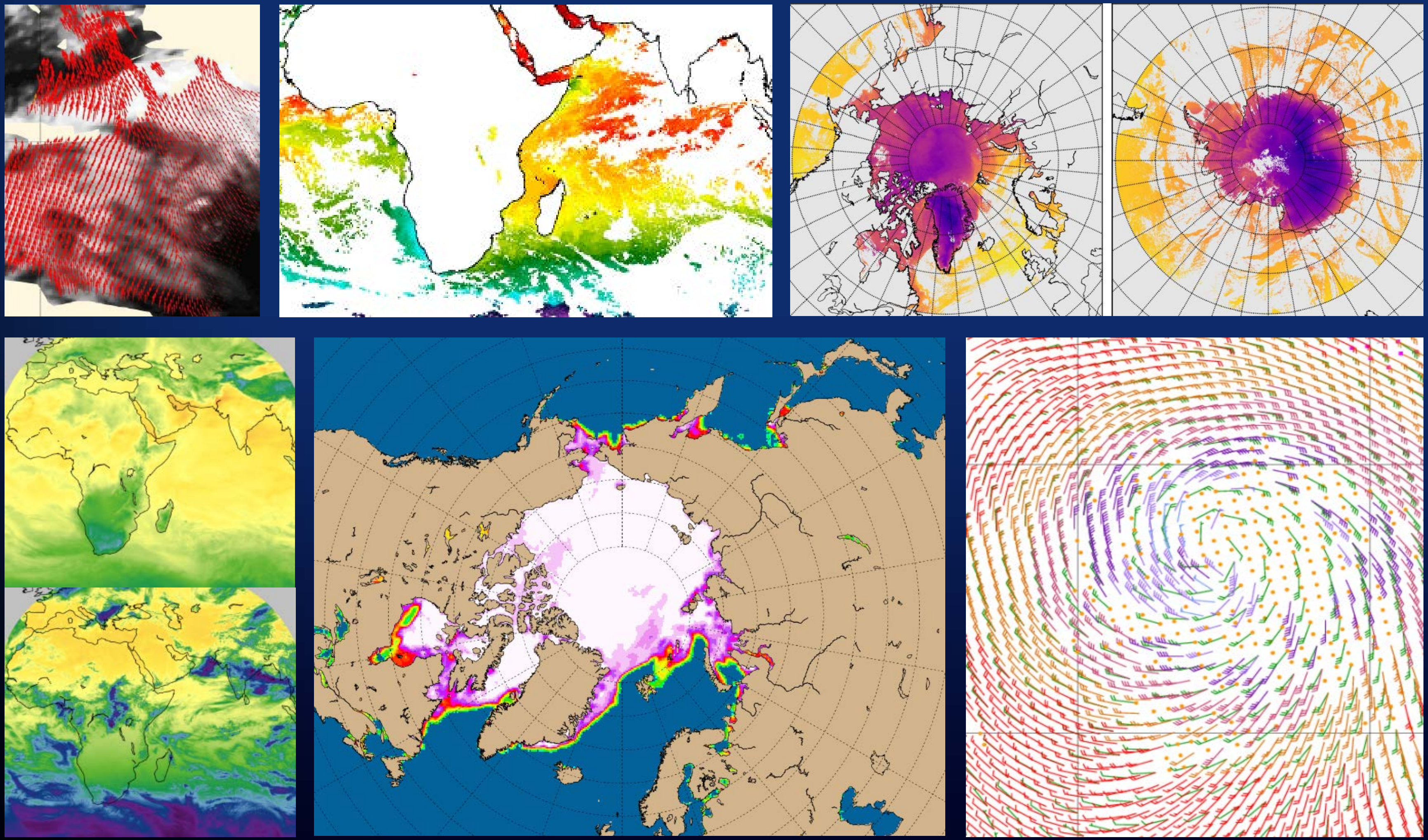


Ocean and Sea Ice SAF

EUMETSAT OSI SAF OCEAN AND SEA ICE

The OSI SAF is an answer to requirements, from the meteorological and oceanographic communities of EUMETSAT Member and Cooperating States, for comprehensive information derived from meteorological satellites at the ocean-atmosphere interface. The OSI SAF offers a precious complement to in-situ data, based on continuously increasing temporal and geographical resolution products from coastal to global coverage.

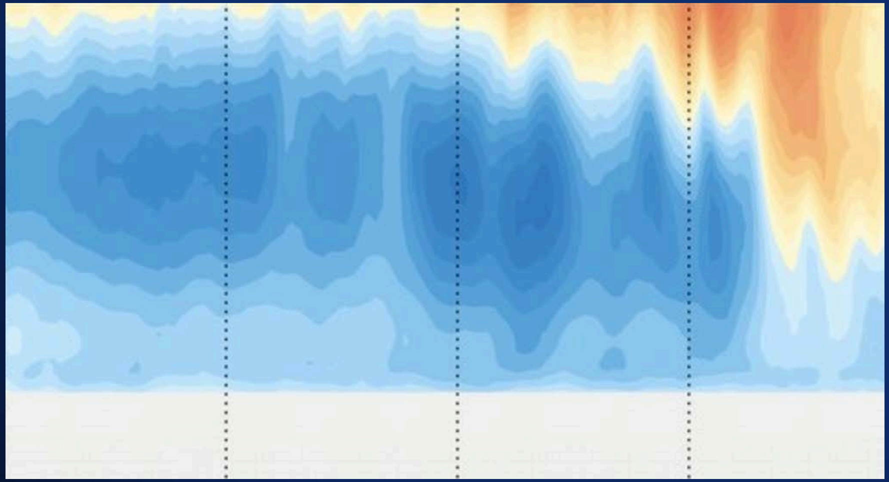
It takes into account, in particular, the requirements expressed in the framework of the World Meteorological Organization (WMO), Global Climate Observing System (GCOS), Group for High Resolution Sea Surface temperature (GHRSST), and finally, Copernicus and its Marine Environment Monitoring Service (CMEMS).

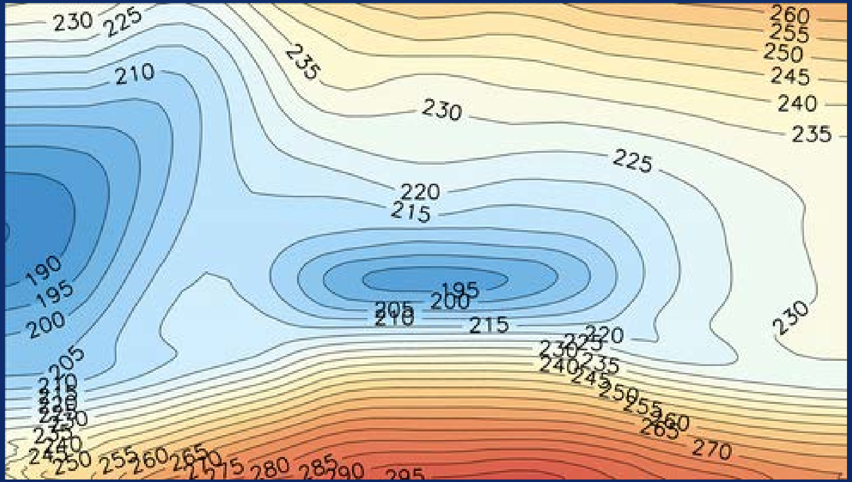


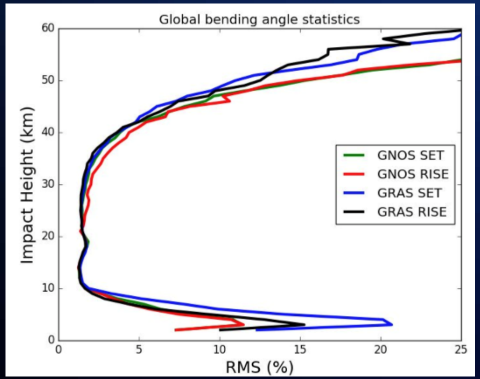
Radio Occultation Meteorology SAF

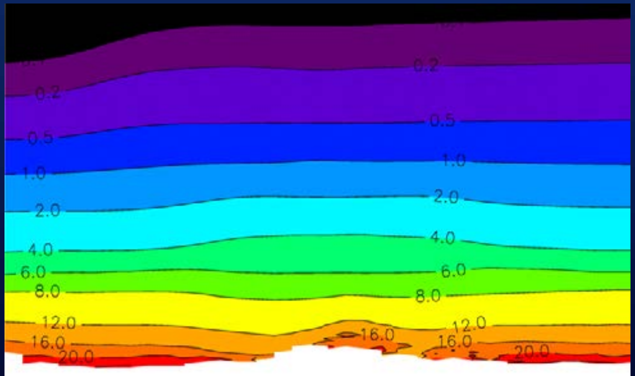
The ROM SAF generates and archives high-quality GPS Radio Occultation (RO) datasets for Numerical Weather Prediction (NWP) applications and specific climate application areas, through the exploitation of satellite measurements with state-of-the-art algorithms, to derive information about the atmosphere and climate variables of the Earth system. The ROM SAF is also engaged in developing an RO processing software package containing modules for assimilation of RO data in NWP models.

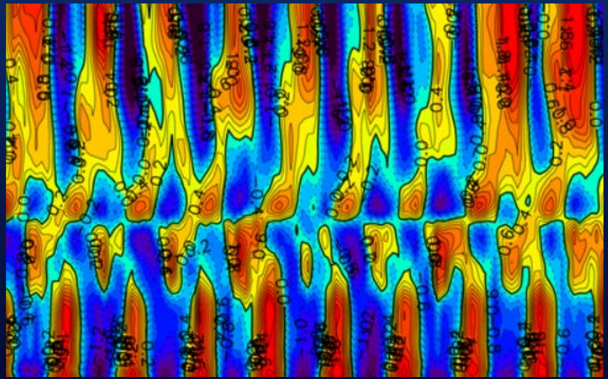
The activities encompass continued developments of the processing algorithms, in order to enhance the information of atmosphere variables and for improving the products. Raw GPS radio occultation data are calibration-free, with known assumptions, and are also well-suited for climate investigations and monitoring. The applications cover construction of an accurate single-source climate database with known error characteristics of the data.



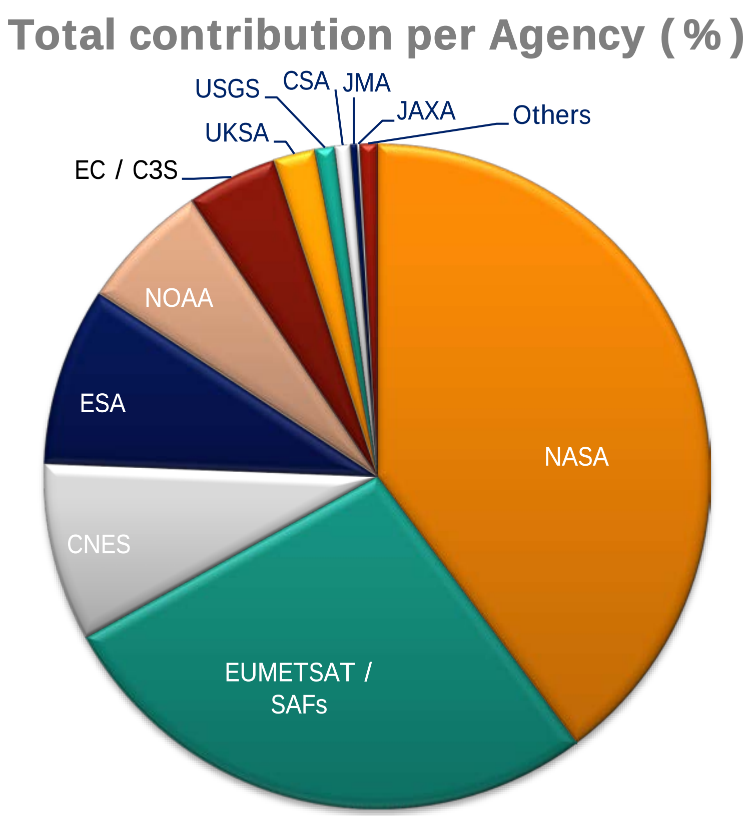








EUMETSAT and its SAFs produce 26% of Climate Records of Essential Climate Variables observable from space

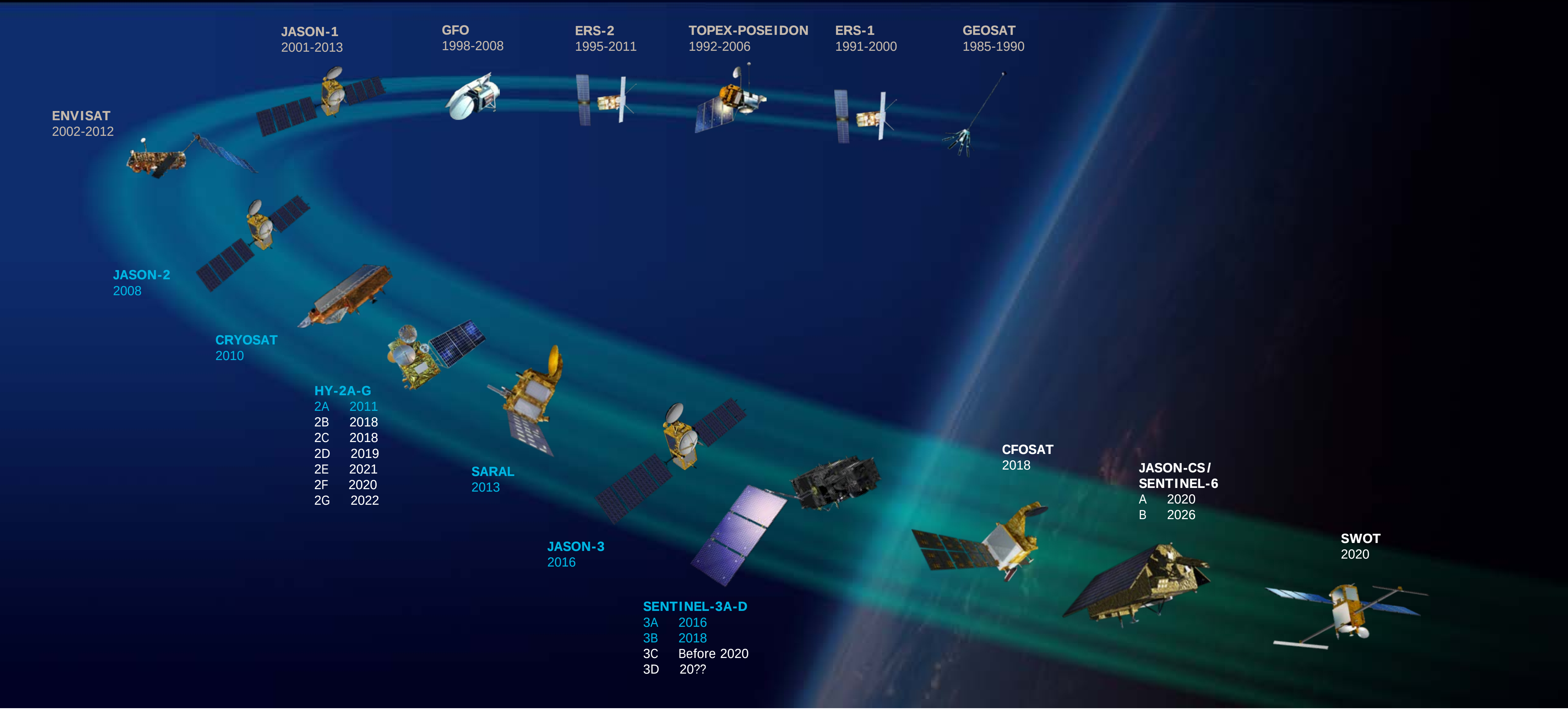


- Existing & planned records
- Entries from 11 space agencies
- 913 entries
  - 496 existing records
  - 417 planned records
- 26% from EUMETSAT and its SAFs
- 30 ECVs covered, out of 37 possible

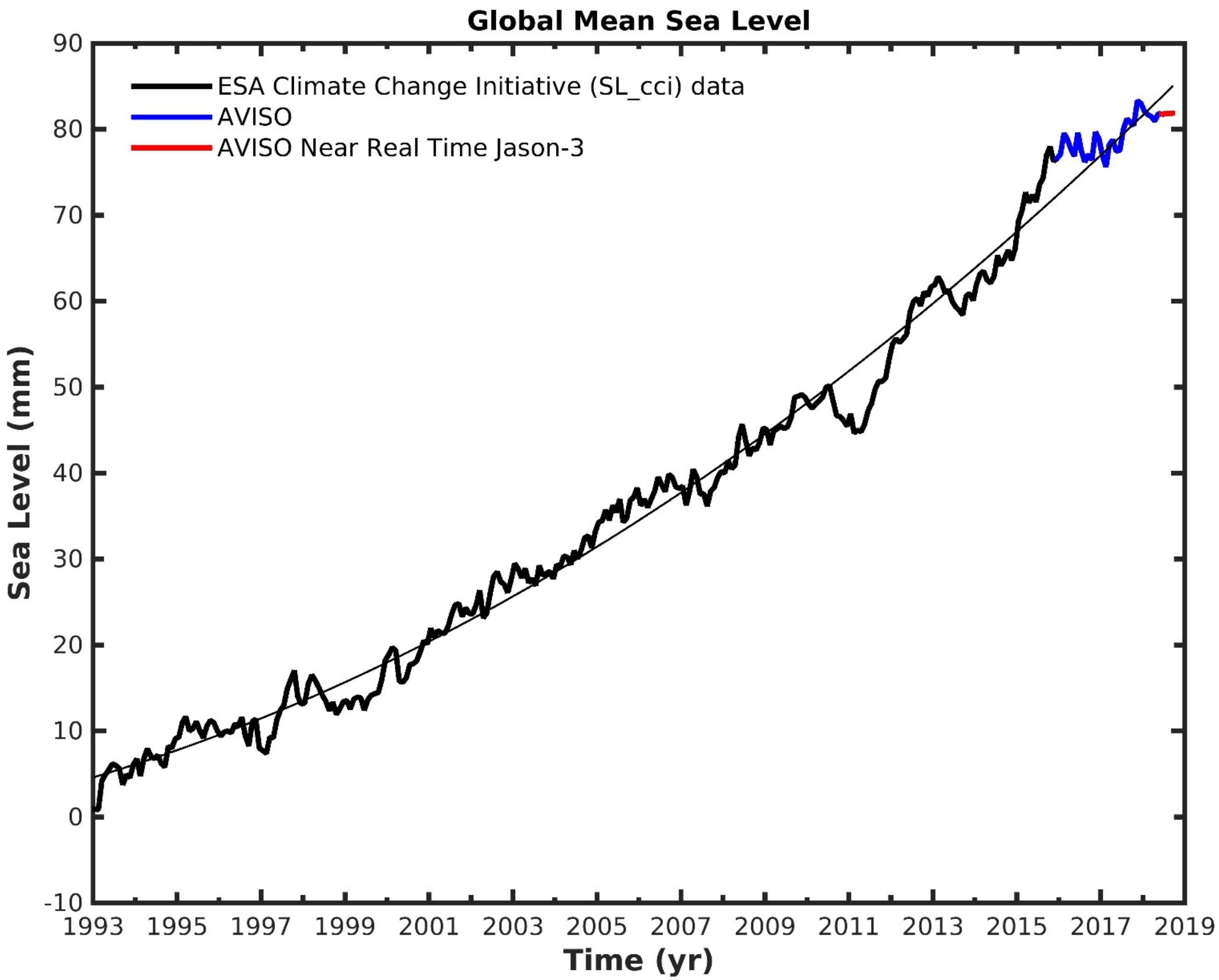
http://climatemonitoring.info/ecvinventory

Additional Capabilities

Altimetry missions – past, present and future



Jason contributing to mean sea level observations

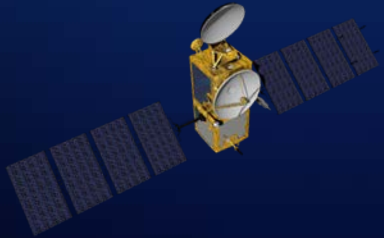


Cooperative Jason missions: EUMETSAT, NOAA, ESA, NASA, CNES, EU

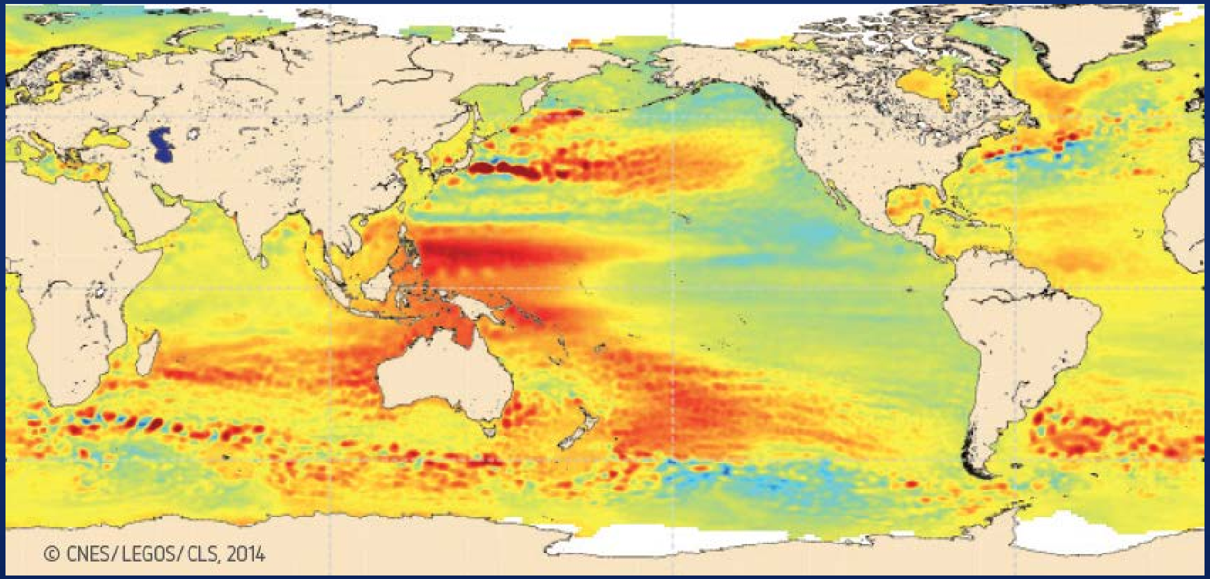
TOPEX-POSEIDON
1992-2006

JASON-1
2001

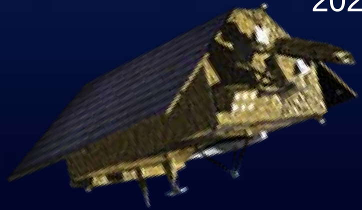
OSTM / JASON-2
2008



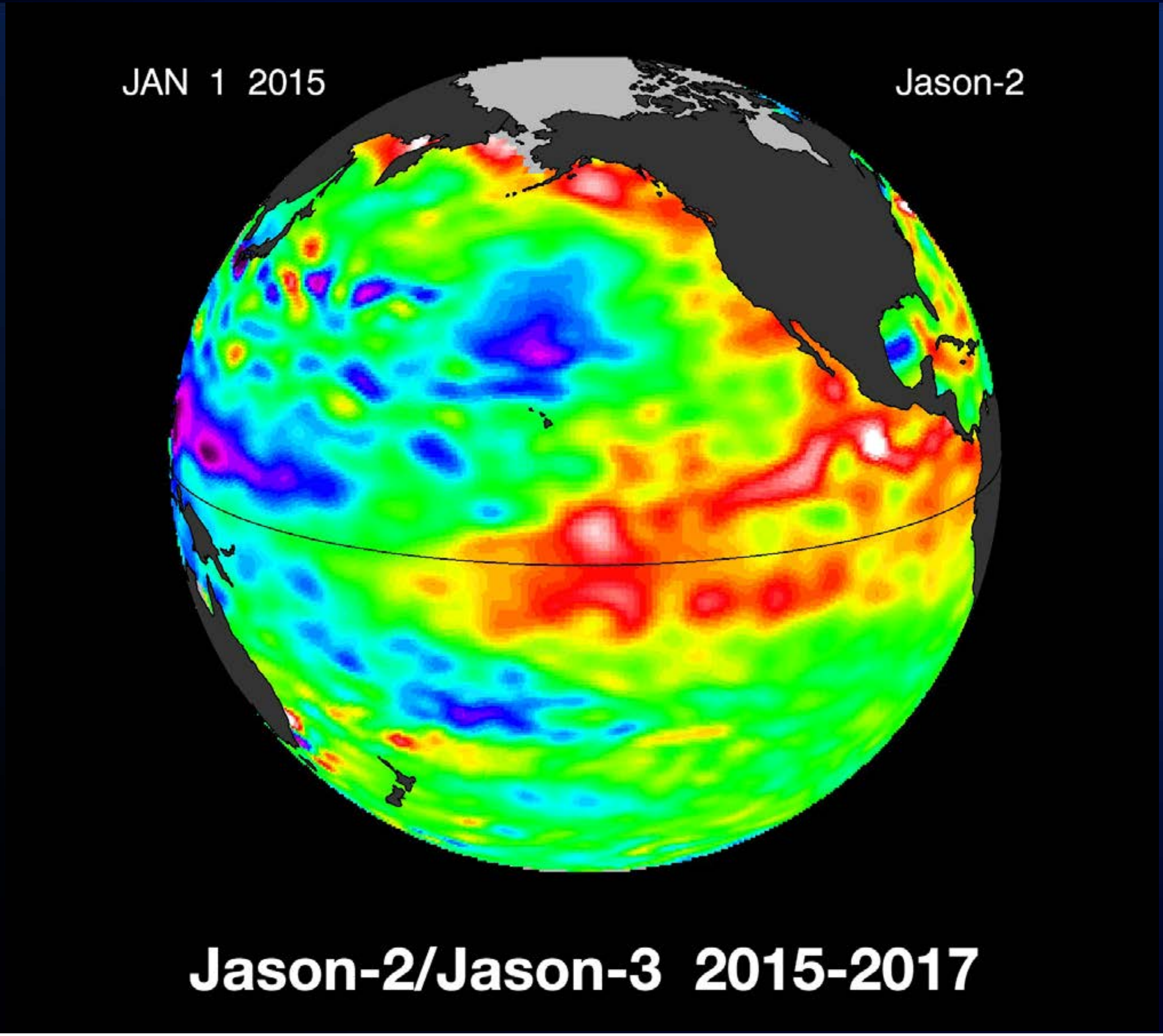
JASON-3
2016



SENTINEL-6 / JASON-CS
2020



Jason-3 contributing to El Nino observations

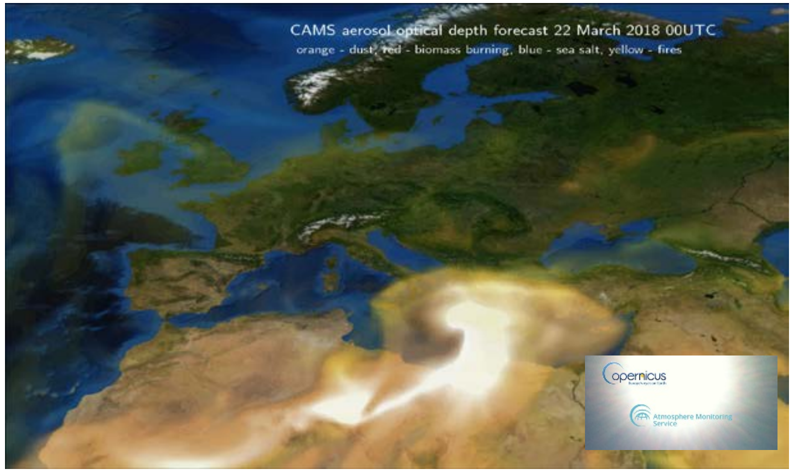


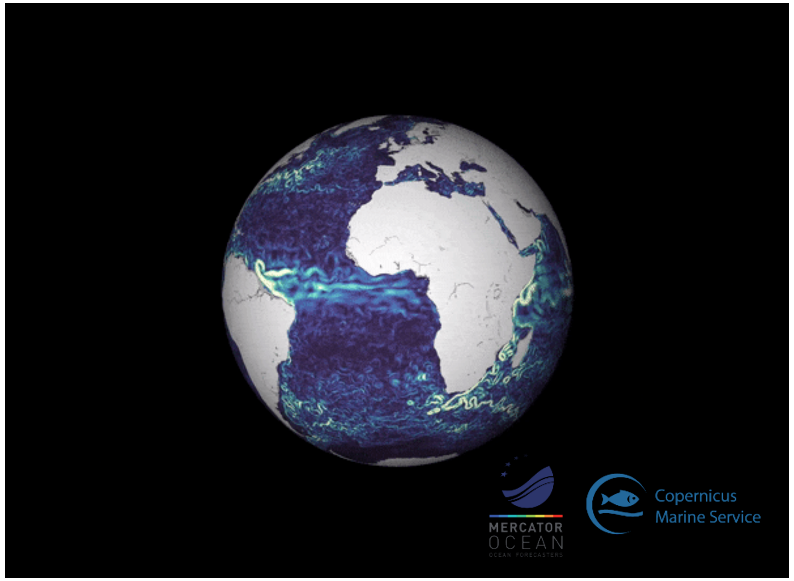
EUMETSAT

The Copernicus Missions

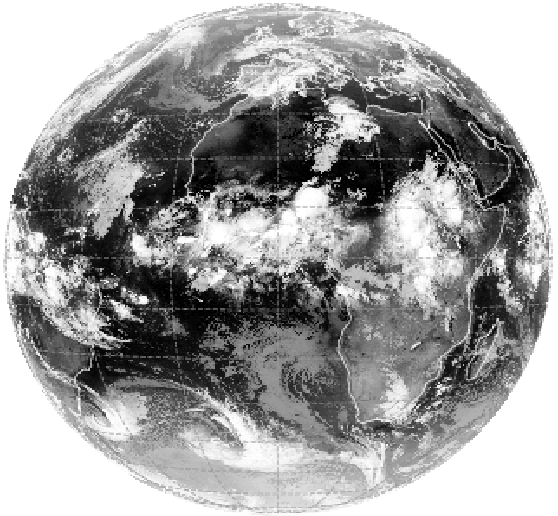
EUMETSAT

From weather to environmental forecasting

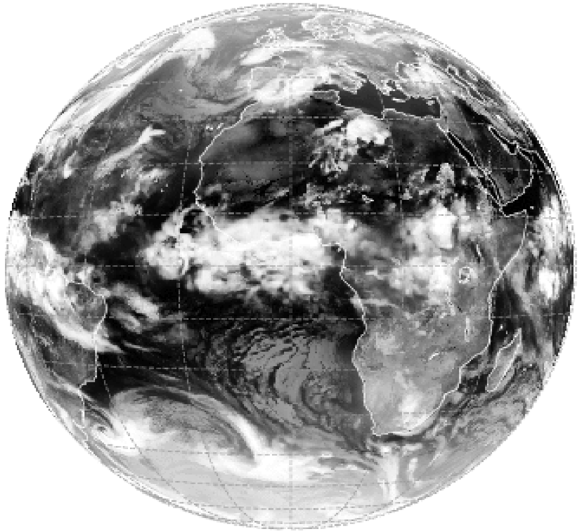




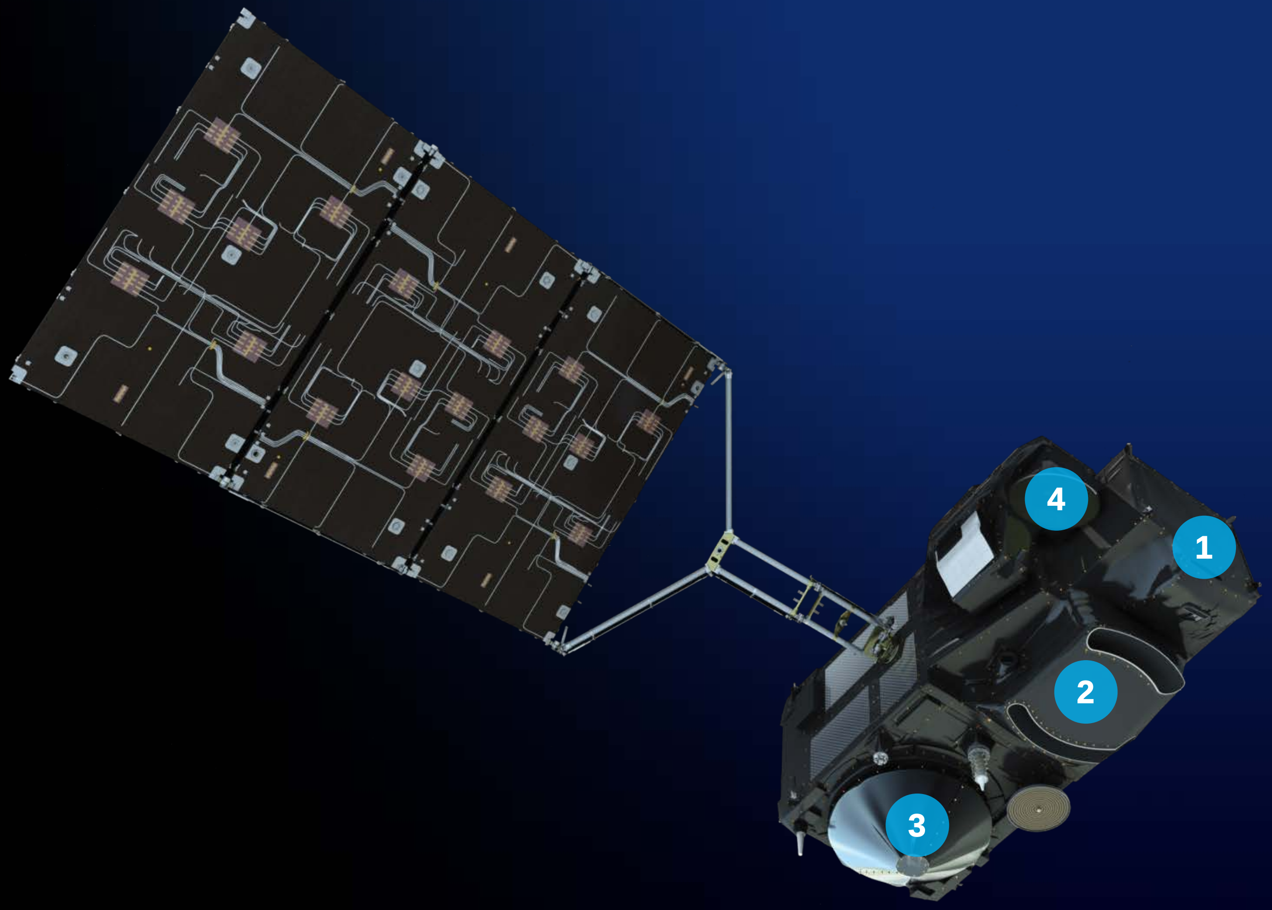
Meteosat 9 IR10.8 20080525 0 UTC



ECMWF Fc 20080525 00 UTC+0h:



Sentinel-3 a & b



1. **OLCI**
   Ocean and Land Colour Instrument
2. **SLSTR**
   Sea and Land Surface Temperature Radiometer
3. **SRAL**
   SAR Radar Altimeter
4. **MWR**
   Microwave Radiometer

Sentinel-4 and IRS - A synergetic approach with MTG
(UVN and hyperspectral IR sounders)

IRS on MTG-S

O_3

CO

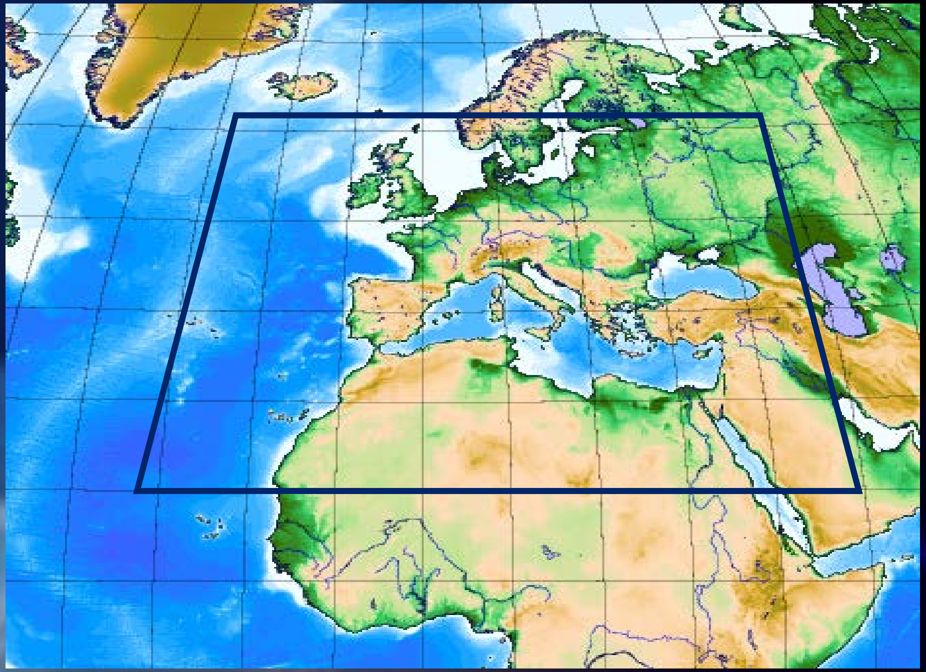
NO_2

S4-UVN on MTG-S

SO_2

VOC(H_2CO, CHOCHO)

Aerosol/PM



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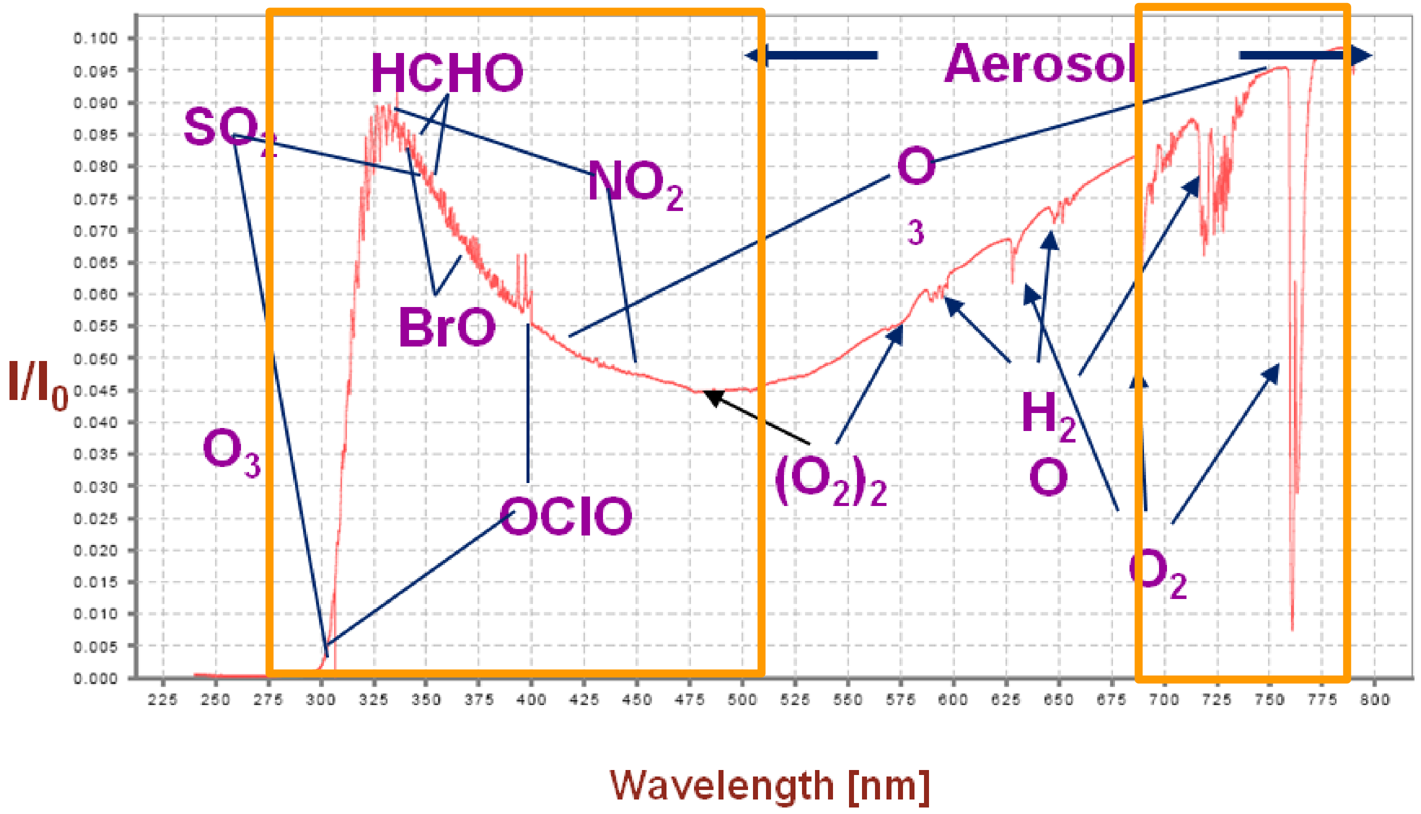
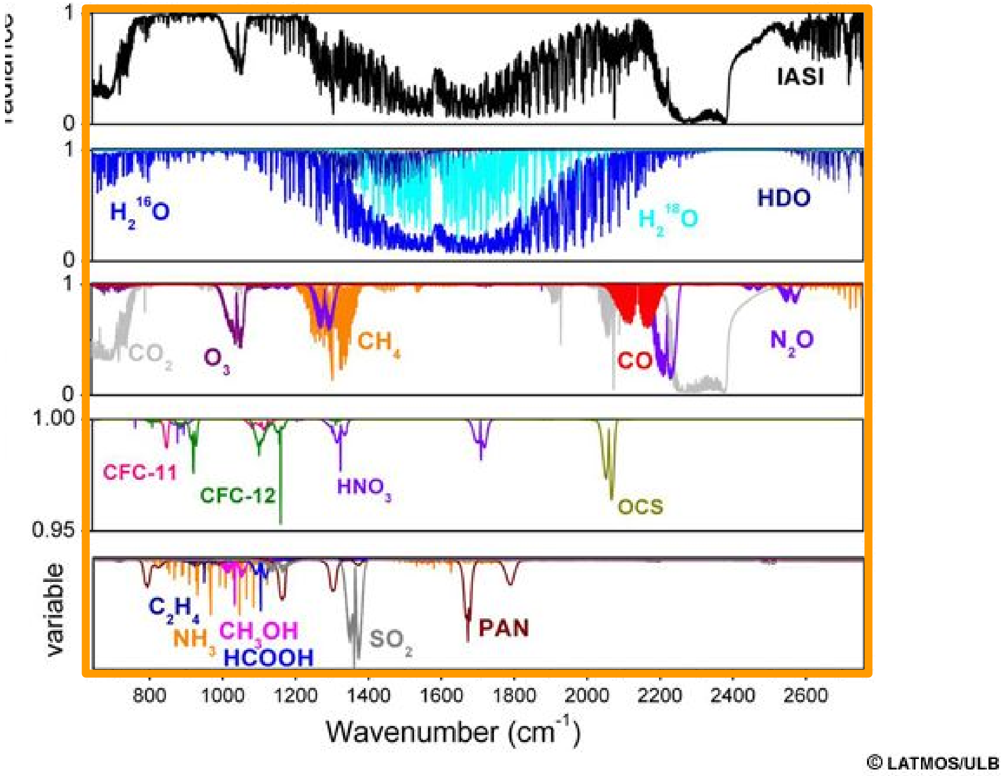
Sentinel-5 and IASI-NG on EPS-SG
(UVN/SWIR and hyperspectral IR sounding)





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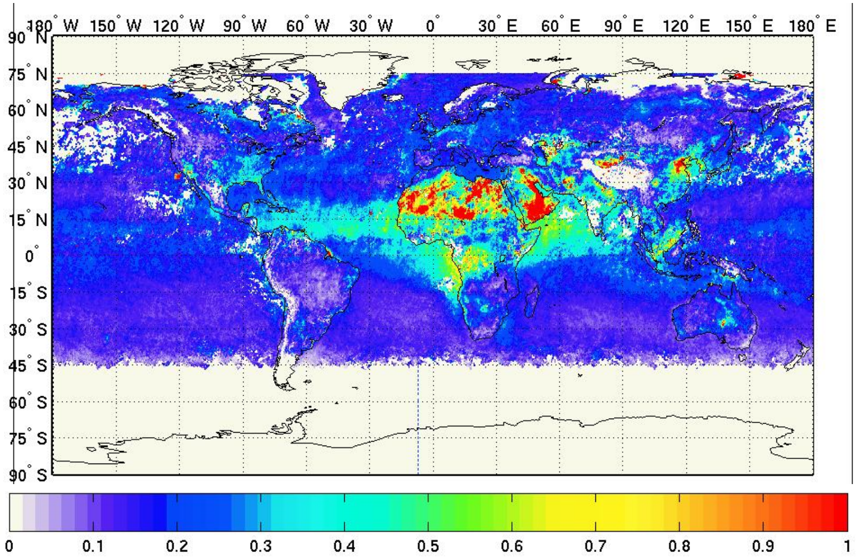
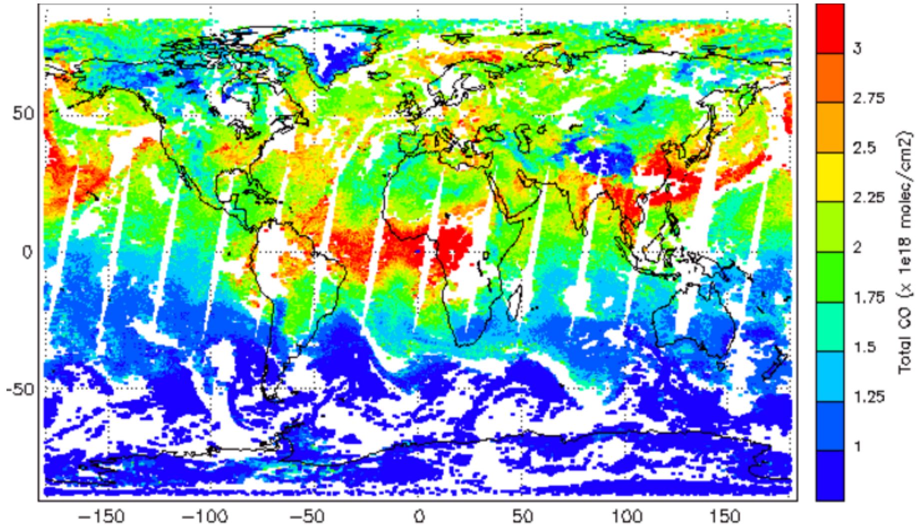
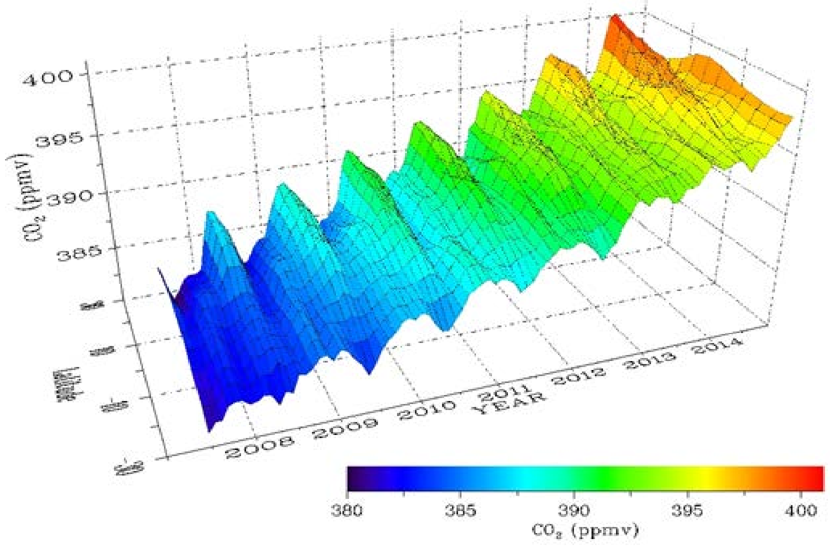
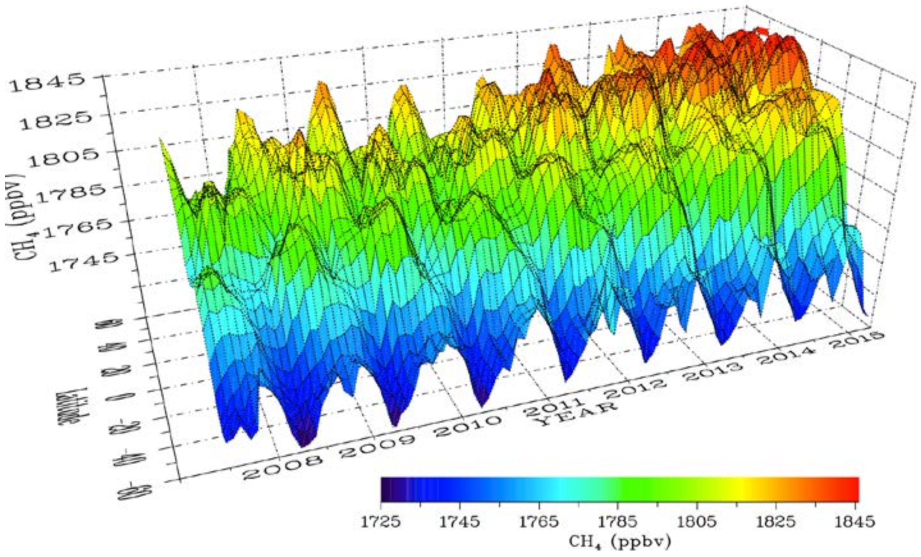
Greenhouse gases – preparing for Sentinel-7
A Carbon monitoring system





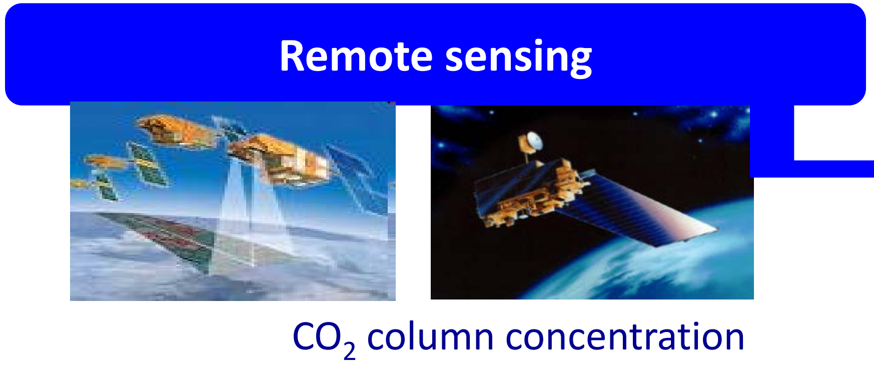


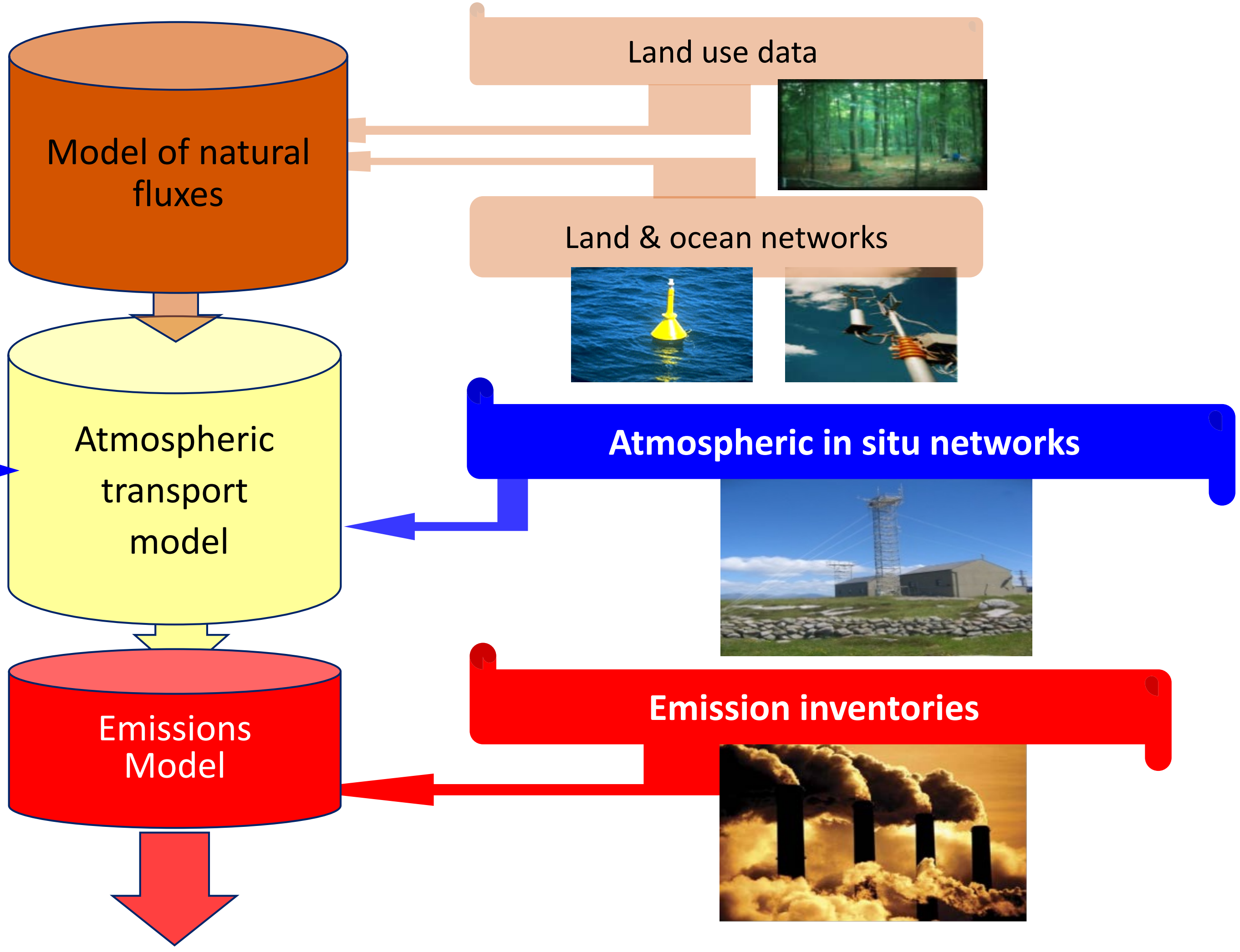


Monitoring CO2 and CH4 emissions
A scientific challenge involving observation and modelling

(Adapted from EU CO2 report)

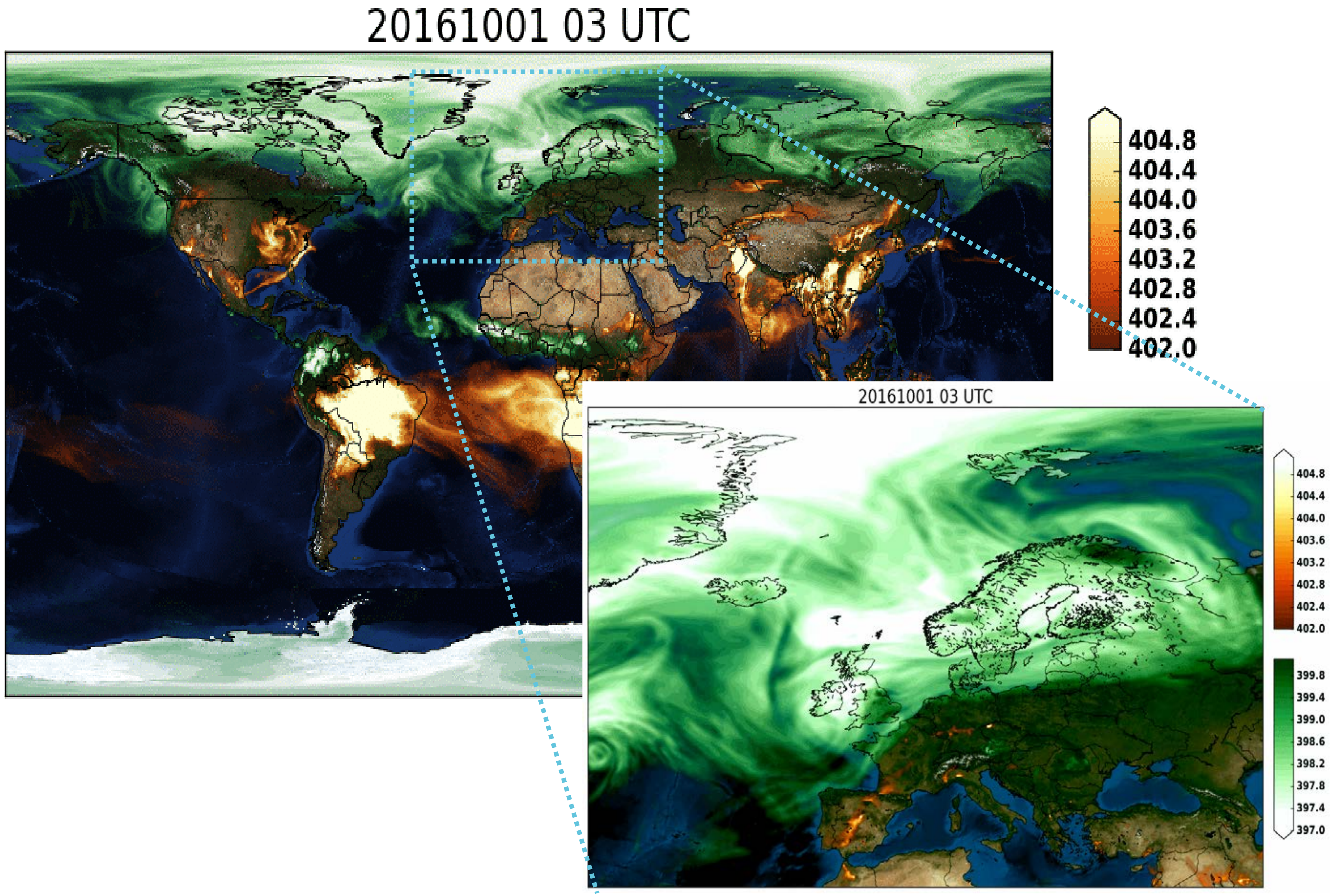
Notional components of a Fossil Fuel emission data assimilation system





Maps of CO2 anthropogenic emissions
Uncertainties & Trends

Copernicus Atmosphere Monitoring Service
Column-averaged dry-air mole fraction of CO_2 [ppm]



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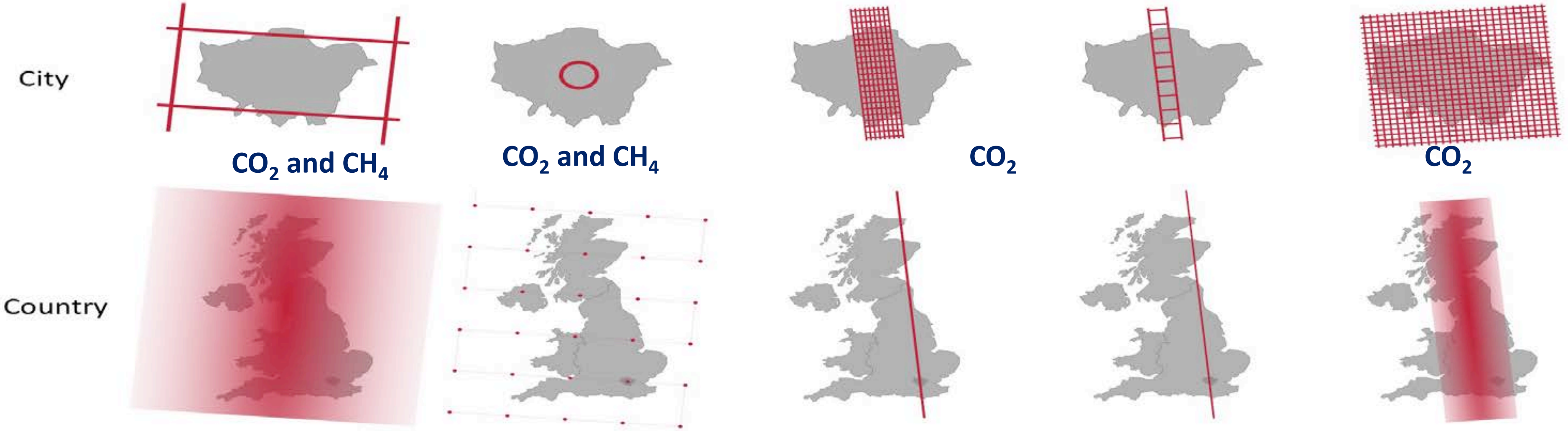
Space based measurements of atmospheric CO_2

Needed attributes of space observations of column CO_2 for emission monitoring

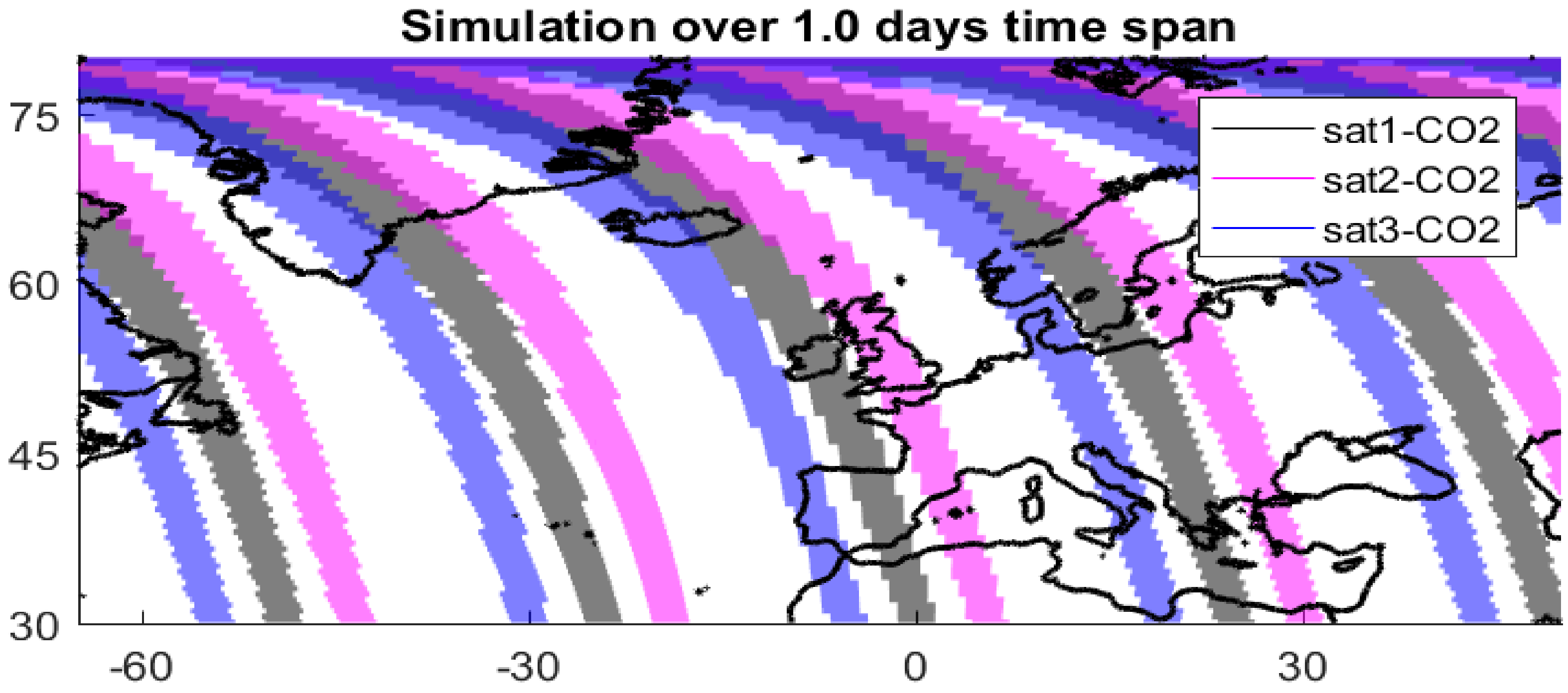
- ✓ Dense sampling (imagery) : images of CO_2 plumes produced by emitting areas
- ✓ High spatial resolution : capture emission hotspots and avoid clouds, pixel size < 3 km
- ✓ High accuracy : resolve the small atmospheric gradients, individual precision ≈ 1 ppm
- ✓ Global coverage

SCIAMACHY (stopped)	GOSAT (sounder)	OCO-2 (sounder)	Microcarb (sounder)	**European mission for monitoring CO_2 emissions (imager)**
30 x 60 km²	85 km²	2.3 x 1.3 km²	6 x 5 km²	

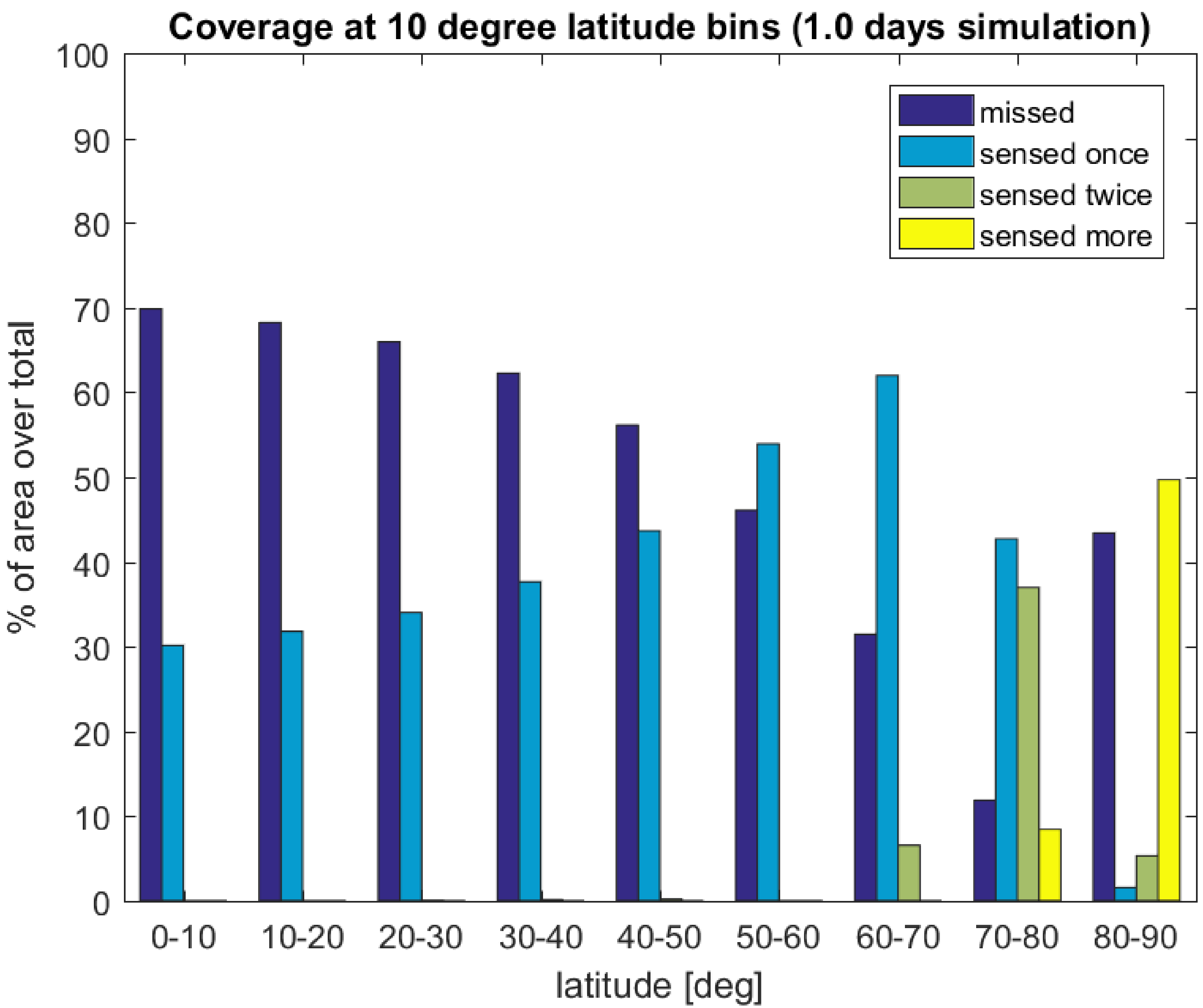


Resolution too low *Accuracy too low*	*Sampling too sparse* *Accuracy moderate*	*Sampling sparse* *Accuracy good*	***Imager : Sampling dense*** ***Accuracy good***

Zoom over Europe with daily coverage with three satellites



Three satellite daily revisit time is globally under 50% except for 60-70 deg latitude which is slightly better



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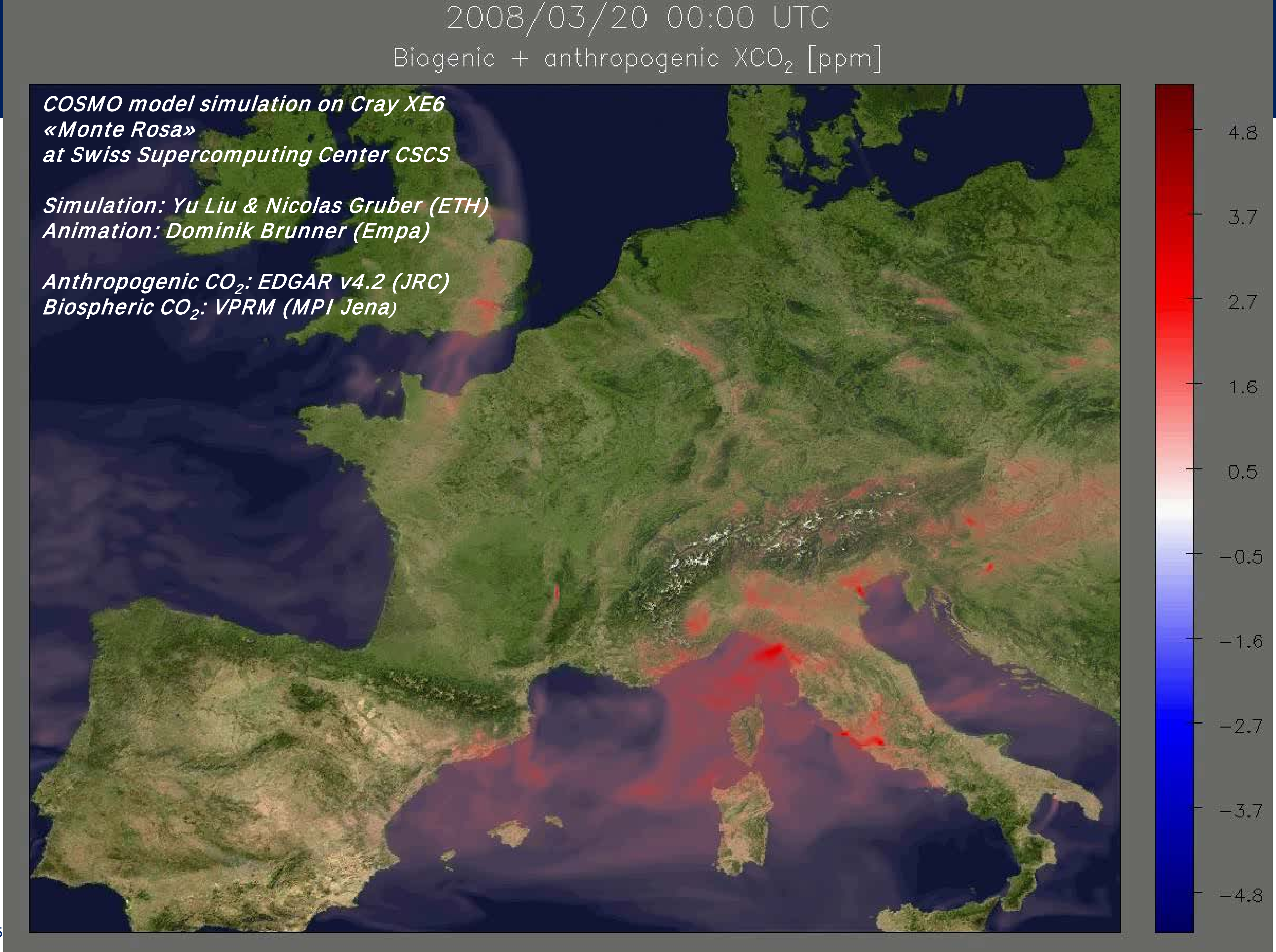
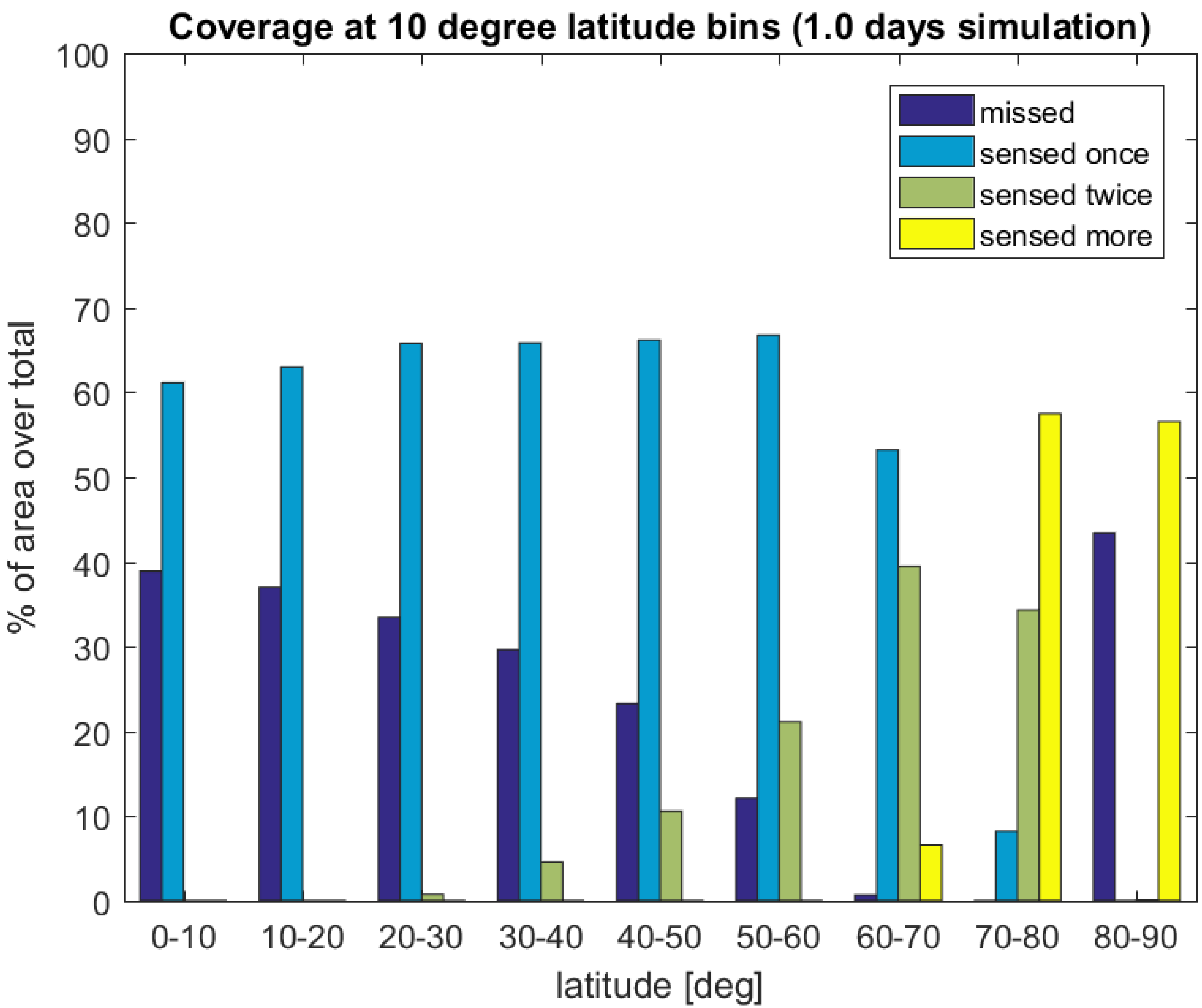

2008/03/20 00:00 UTC
Biogenic + anthropogenic XCO_2 [ppm]
COSMO model simulation on Cray XE6
«Monte Rosa»
at Swiss Supercomputing Center CSCS
Simulation: Yu Liu & Nicolas Gruber (ETH)
Animation: Dominik Brunner (Empa)
Anthropogenic CO_2: EDGAR v4.2 (JRC)
Biospheric CO_2: VPRM (MPI Jena)
4.8
3.7
2.7
1.6
0.5
−0.5
−1.6
−2.7
−3.7
−4.8

Coordination Matters: Daily coverage of best phasing 40 to 60 deg latitude band misses 15-25%



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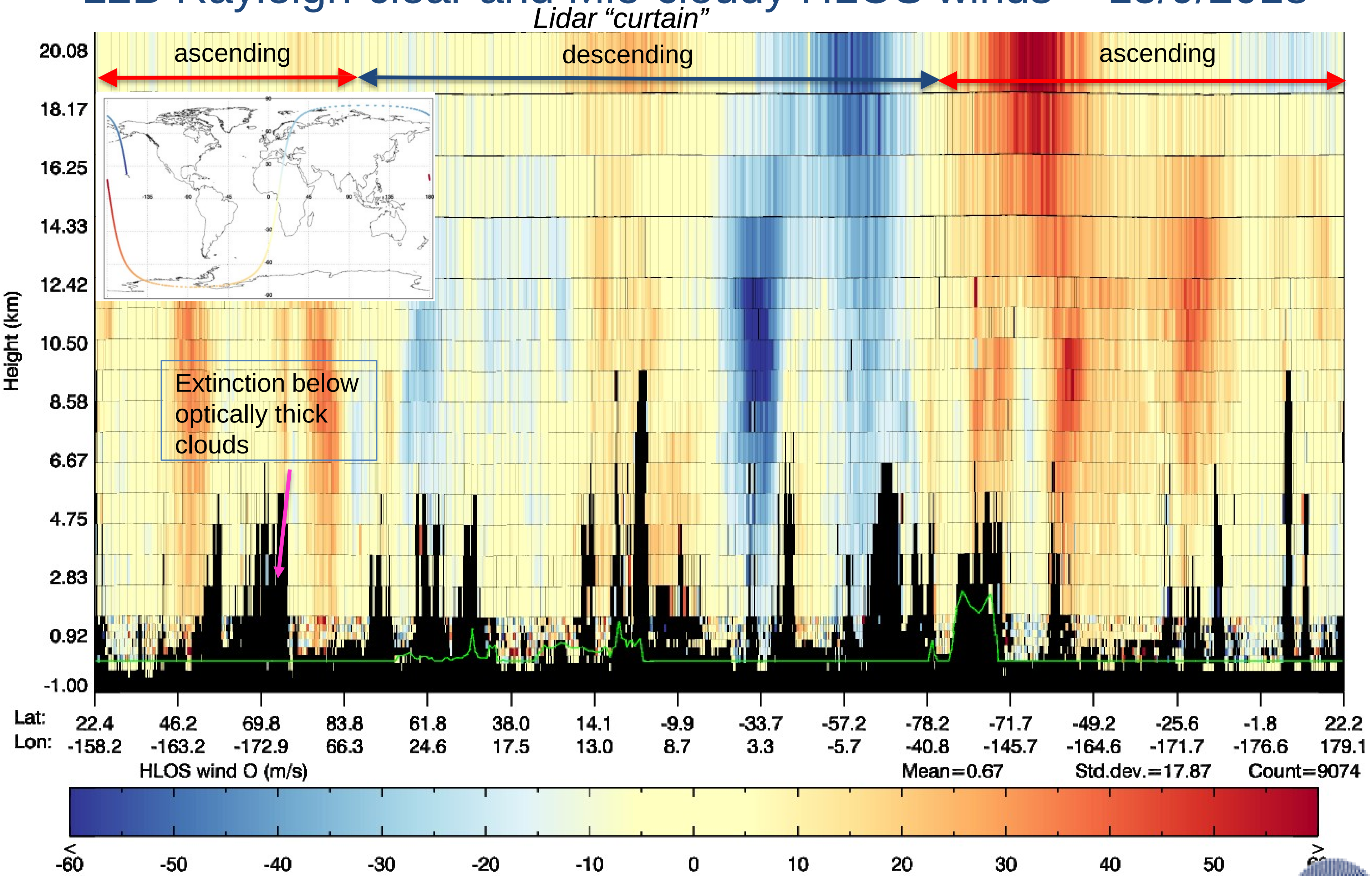
Moving Forward from “Science” to “Operational” GHG Missions

- With the exception of the Sentinels, all of the existing and planned GHG missions are “science” missions, designed to identify optimal methods for measuring CO_2 and CH_4, not “operational” missions designed to deliver policy relevant GHG products focused on anthropogenic emissions
- Following the model developed by the operational meteorological satellite constellation, future GHG constellation will also need to focus on orbit and mission coordination, data distribution, data exchange, and data format requirements
- To fully exploit the information collected by future GHG constellations, the missions will also have to invest in training and capacity building as well as public outreach
- CEOS should exploit the experience of CGMS and other organizations to foster the development of these capabilities

Further future opportunities

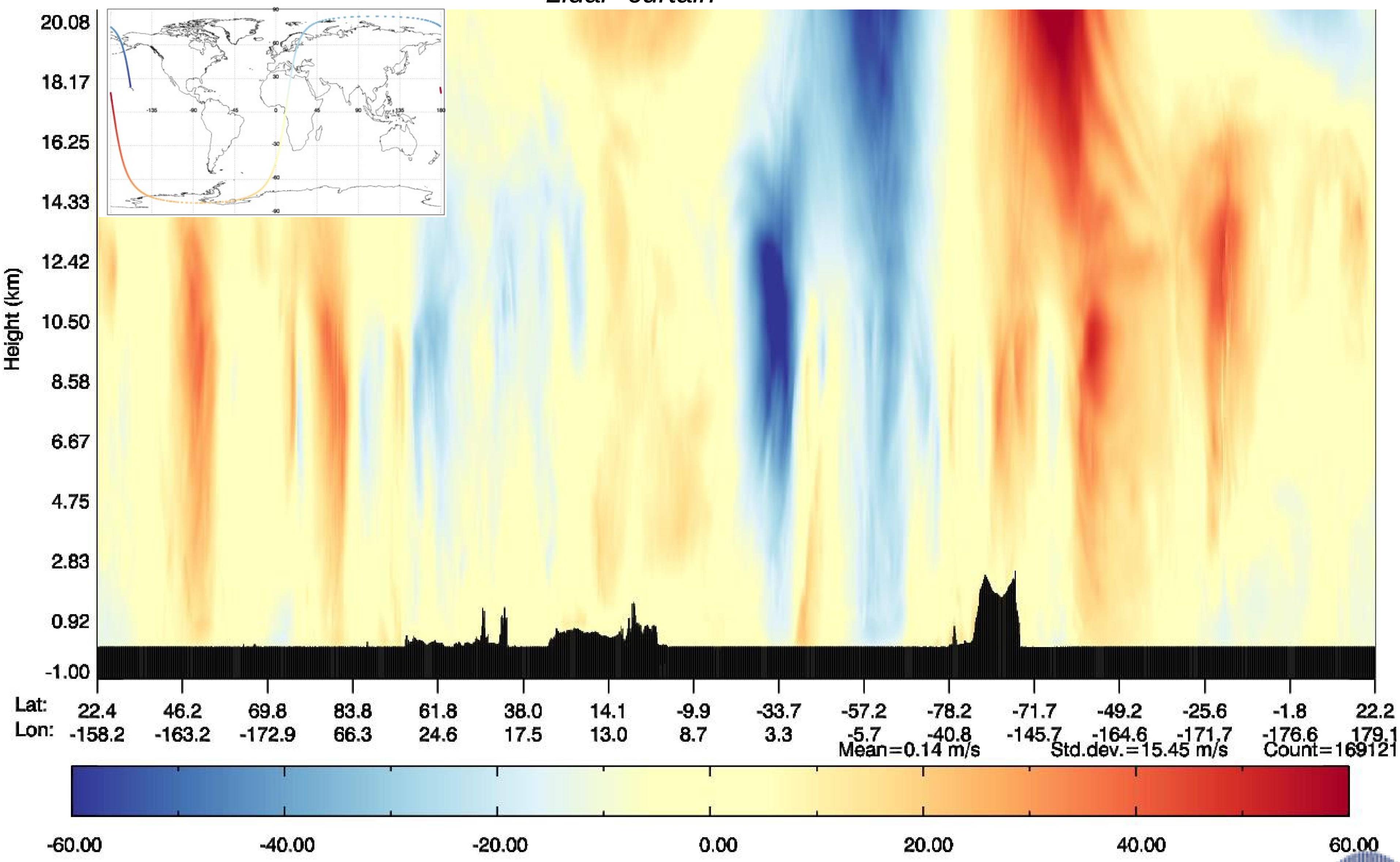
L2B Rayleigh-clear and Mie-cloudy HLOS winds – 15/9/2018



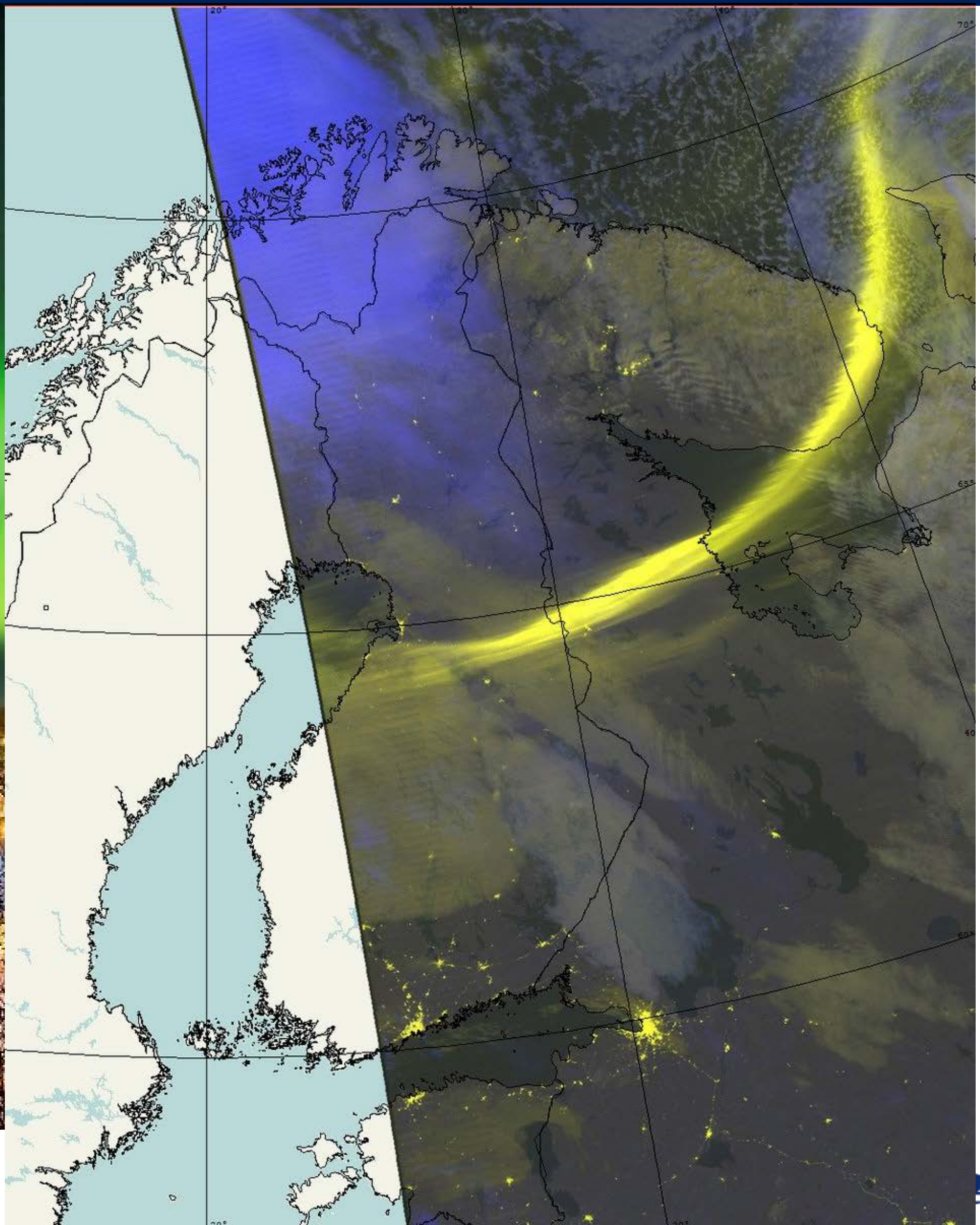
ESA Aeolus mission
Wind for the future?

ECMWF model HLOS winds - 15/9/2018

ESA Aeolus mission
Wind for the future?



Linking Suomi-NPP, Space Weather and Finland!



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International cooperation

International cooperation

- Cooperation in satellite meteorology, oceanography and climate monitoring

- Critical for meeting future challenges

- Focus on operational data exchange, data redistribution, production of climate-relevant datasets, scientific exchange, user training, coordination through multilateral partnerships (CGMS, CEOS, GEO)

EUMETSAT International Cooperation Partners

Country	Agency
Canada:	ECCC
China:	CMA, CNSA, NSOAS
India:	ISRO, IMD
Japan:	JAXA, JMA
Russian Federation:	Roshydromet
South Korea:	KMA
United States:	NASA, NOAA

NOAA Satellites

NOAA and International Partners

Conclusions

- EUMETSAT and NOAA provide critical satellite data world wide
- Future challenges include
  - Earth System Modelling
  - Huge Data Volumes
  - Efficient use of data
- Need for optimum design of the Global Observing System

Aeolus

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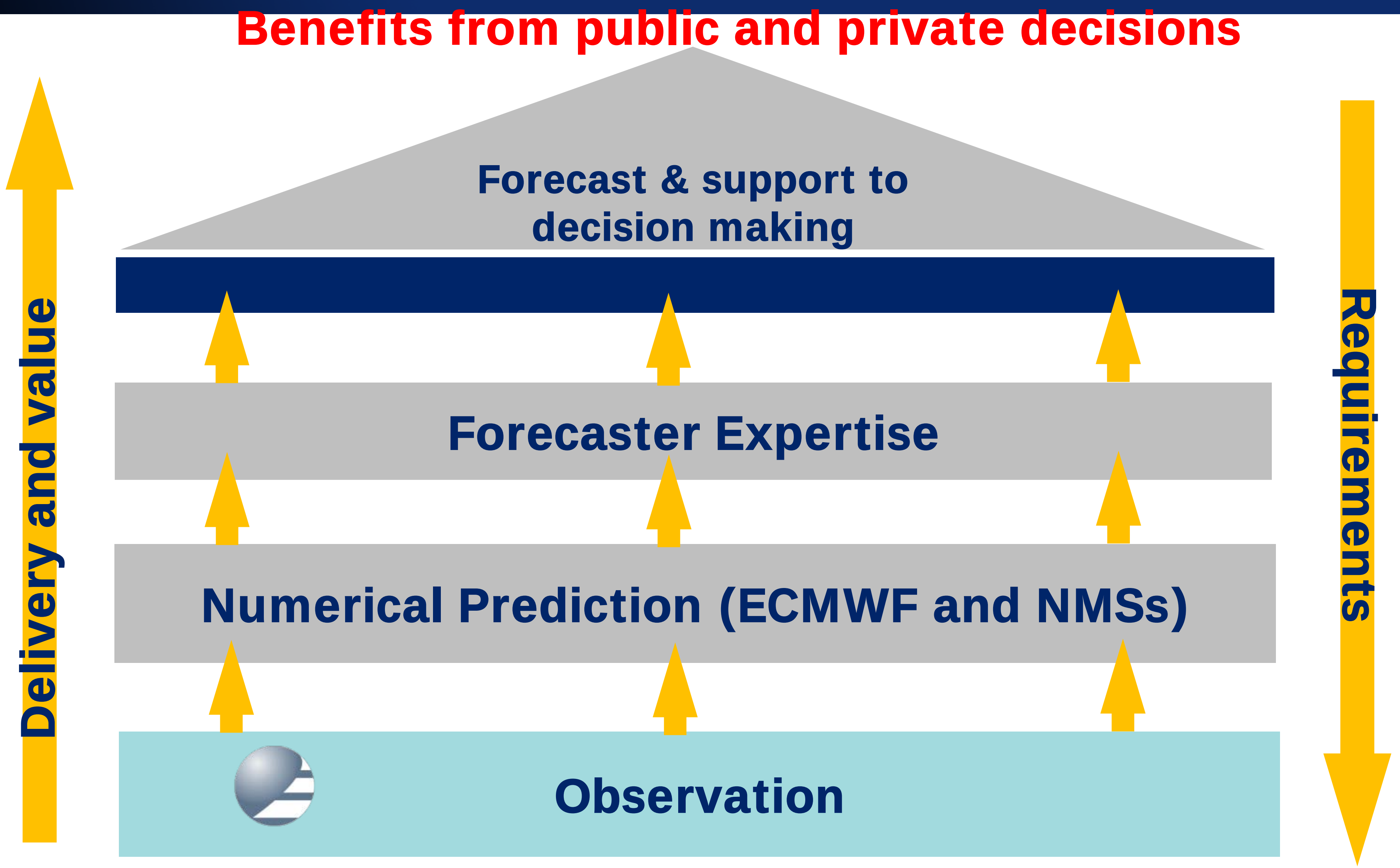
Socio-Economic Benefits

From observation to socio-economic benefits ?



Benefits areas of weather forecasting

Safety of life, property and infrastructure…

Transport …

....Energy, agriculture, tourism....

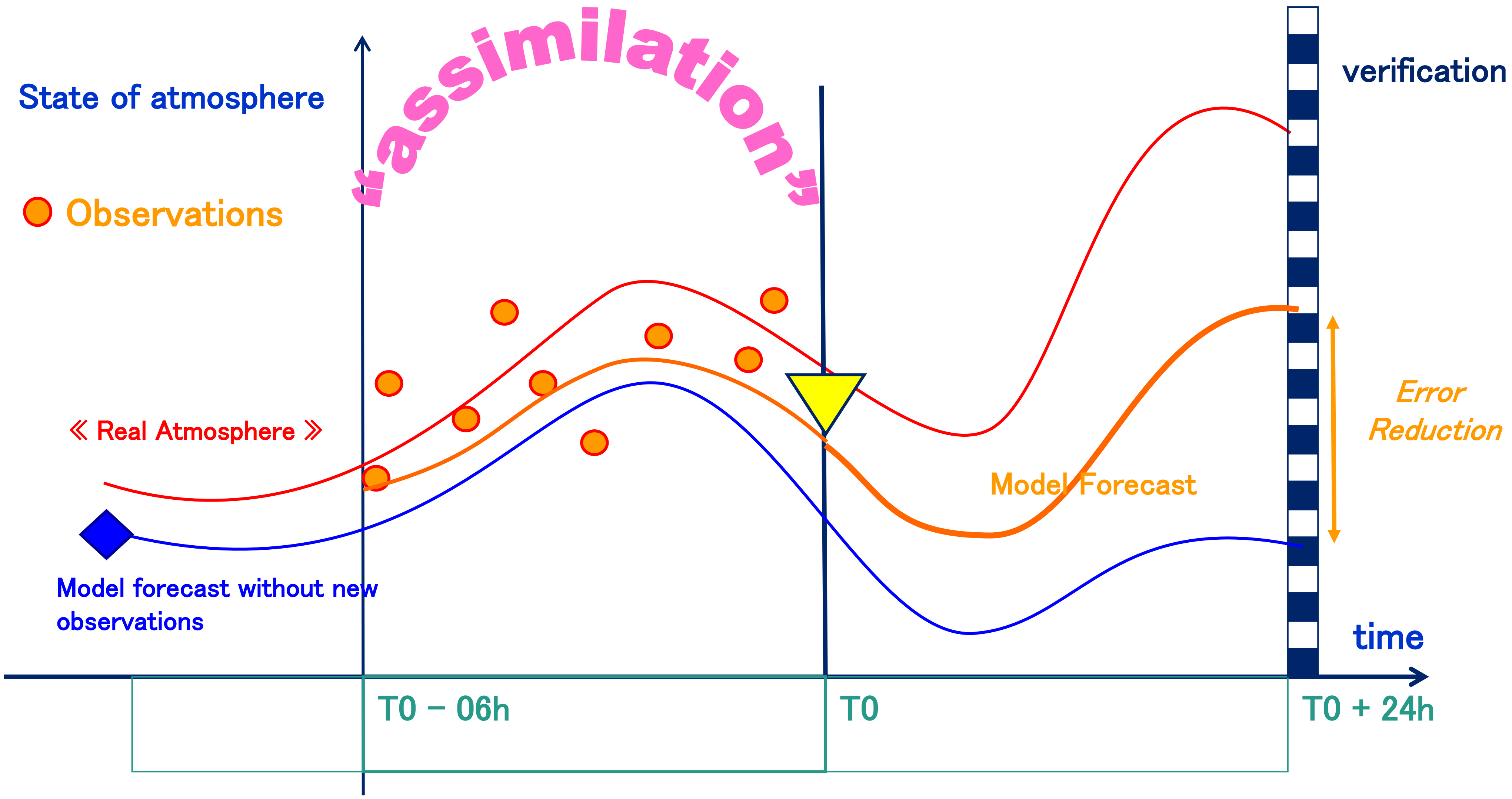
...Climate policy and environment protection

Estimated benefits of weather forecasts in EU 27

BENEFIT AREA	LIKELY BENEFIT
Protection of property and infrastructure	€5.4 billion/year
Added value to the European economy	€41.0 billion/year
Private use by European citizens	€15.0 billion/year
TOTAL	**€61.5 billion/year**

- The value of hundreds of lives saved each year is not captured, nor the benefits to defense and security
- Also ignored are additional benefits of weather forecasts on specialised forecasts of weather-dependent phenomena, i.e. air quality, marine forecasts, dispersion of pollution in the context of Copernicus

Ingestion of observations by models: « Assimilation »
Constraining the initial model « trajectory »



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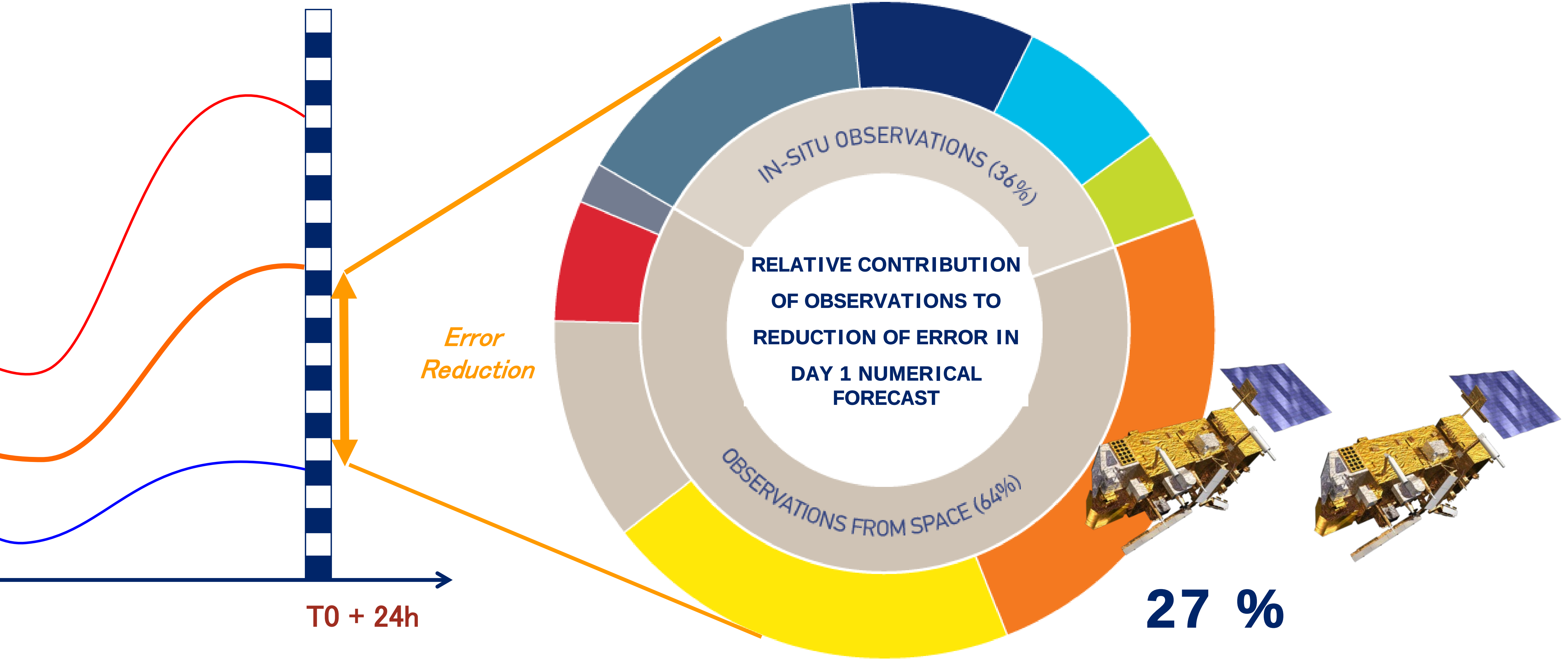
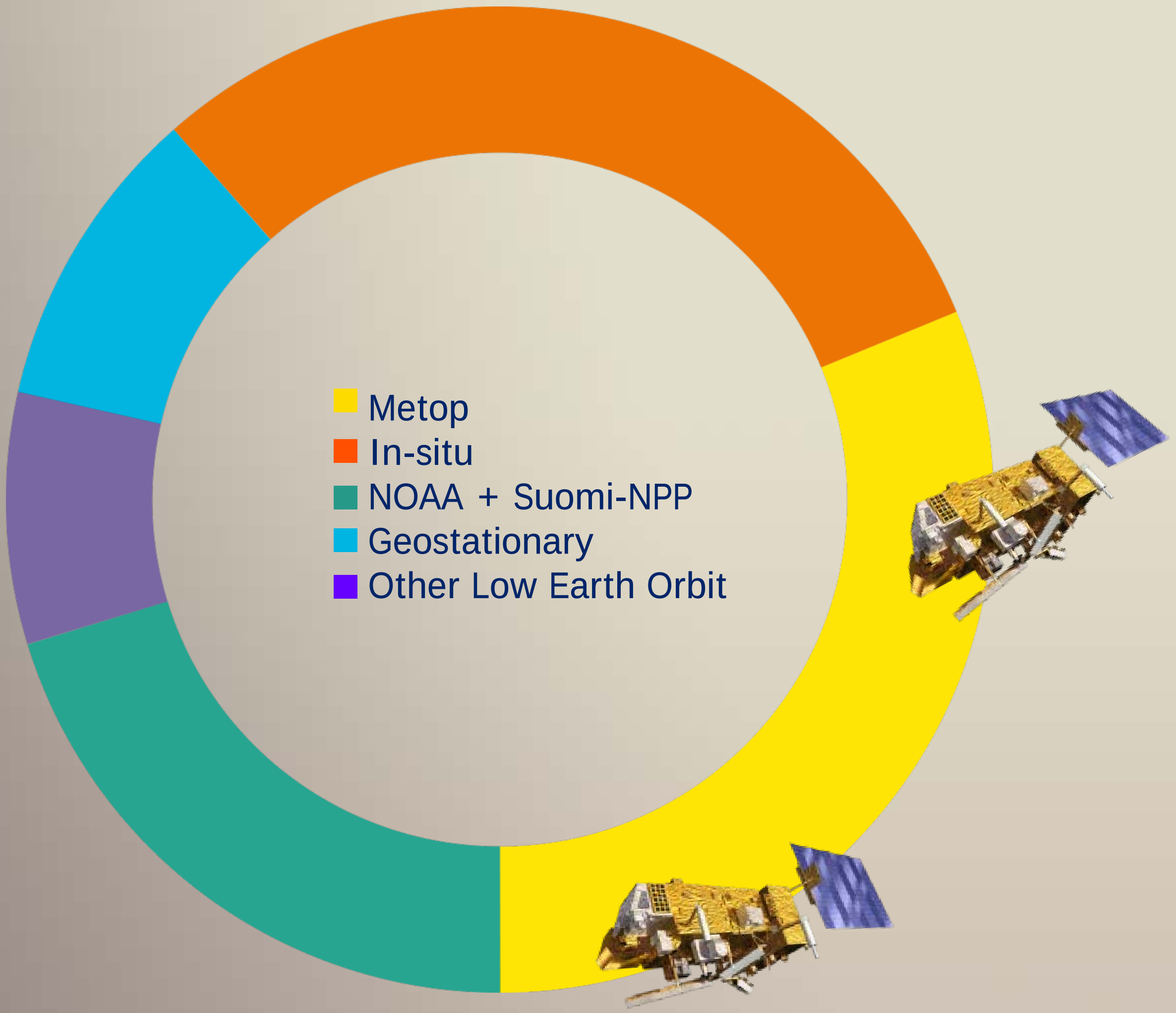
Major impact of Metop-A on Day 1 forecast



Contribution of IJPS satellites to reduction of day-1 forecasts



Metop satellites : 44.45%

SNPP and NOAA satellites : 29.36 %

IJPS satellites : 73.81 %

Source: Met Office, UK

Benefit/cost ratio of EPS-SG Programme

Most conservative forecast impact of 8% assumed, as for EPS/Metop
21 years of observation: 2020-2041

BENEFIT AREA	LIKELY
Protection of property and infrastructure	€ 6.0 billion
Added value to the European economy	€ 45.2billion
Private use by European citizens	€ 11.5 billion
TOTAL	**€ 63 billion**

(2010 values, using discount rate of 4% and assuming GDP growth rate of 2%)

Benefit to cost ratio of EPS-SG is in the order of 20