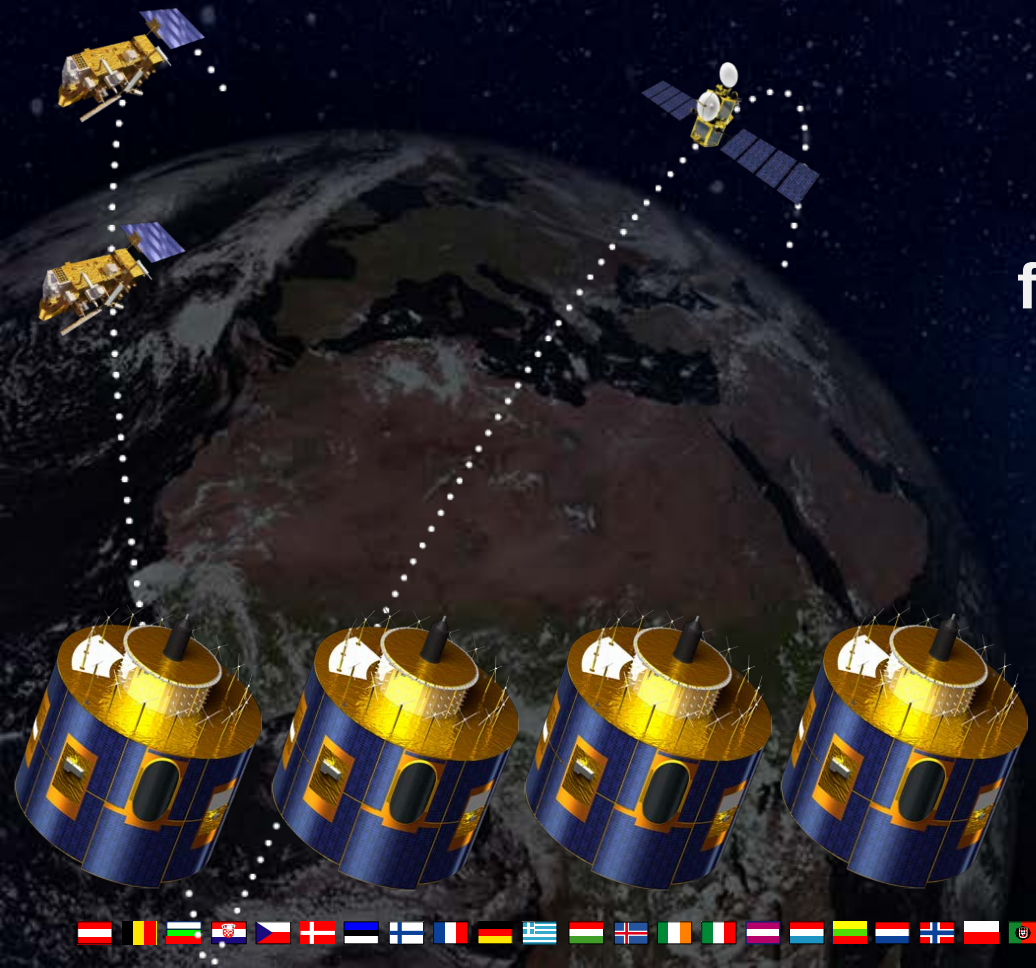
INTO THE FUTURE
AN OVERVIEW OF THE EUMETSAT SATELLITE PROGRAMMES

EUMETSAT

Kenneth Holmlund
EUMETSAT
And many other contributors
from EUMETSAT and its partners



Current EUMETSAT satellite fleet

METOP -A and -B
(LOW-EARTH, SUN – SYNCHRONOUS ORBIT)

EUMETSAT POLAR SYSTEM/INITIAL JOINT POLAR SYSTEM

JASON-2
(LOW-EARTH, 63° INCL. NON SYNCHRONOUS ORBIT)

OCEAN SURFACE TOPOGRAPHY MISSION



METEOSAT SECOND GENERATION -8.-9.-10, MSG-4 (-11)
(GEOSTATIONARY ORBIT)

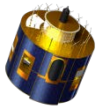
TWO-SATELLITE SYSTEM:
- MSG-4 (METEOSAT-11) under commissioning

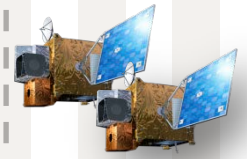
- METEOSAT-10: FULL DISK IMAGERY MISSION AT 0° (15 MN)
- METEOSAT-9: RAPID SCAN SERVICE OVER EUROPE AT 9.5°E (5 MN)
- METEOSAT- 8: BACK UP AT 3.5°E

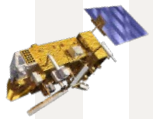
METEOSAT – 7 (1st GENERATION)
(GEOSTATIONARY ORBIT)

INDIAN OCEAN DATA COVERAGE MISSION
AT 57°5 E (UNTIL END 2016)

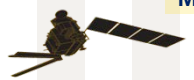
EUMETSAT programmes overview















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

METEOSAT FIRST GENERATION

METEOSAT-7

METEOSAT SECOND GENERATION

METEOSAT-8 …Extended lifetime .....

METEOSAT-9 …Extended lifetime .....

METEOSAT-10 …Extended lifetime ...

MSG-4/METEOSAT-11 ……..

METEOSAT THIRD GENERATION

MTG-I-1 : IMAGERY

MTG-S-1: SOUNDING

MTG-I-2: IMAGERY

MTG-I-3: IMAGERY

MTG-S-2: SOUNDING

MTG-I-4: IMAGERY

Mandatory Programmes

EUMETSAT POLAR SYSTEM (EPS)

METOP-A …Extended lifetime .....

METOP-B …Extended lifetime .....

METOP-C …Extended lifetime .....

METOP SECOND GENERATION

METOP-SG-A1

METOP-SG-B1

METOP-SG-A2

METOP-SG-B2

METOP-SG-A3

METOP-SG-B3

Operational Development

JASON

JASON-2

JASON-3

JASON CONTINUITY OF SERVICE (JASON-CS)

Optional and Third Party Programmes

COPERNICUS

SENTINEL-3

SENTINEL-4 ON MTG-S

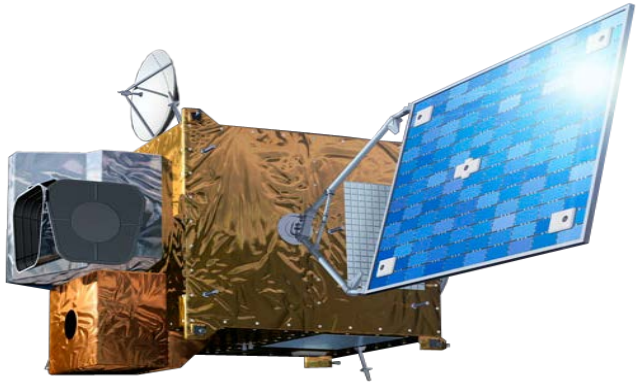
SENTINEL-5 ON EPS-SG

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

EUMETSAT

Future programmes shape the 2018 – 2040 timeframe





MTG: Approved, under development
Sentinel-4 approved (funded by Copernicus)



Jason-CS/Sentinel-6:
Approval process ongoing





EPS-SG: Approved, under development
Sentinel-5 approved (funded by Copernicus)

Process for user requirements elaboration

User Needs

Should drive



User Requirements

Process for user requirements elaboration



Users

Can't always formulate

User Needs

Should drive

User Requirements

Are not always aware of

Process for user requirements elaboration



Users

Can't always formulate

User Needs

Should drive

User Requirements

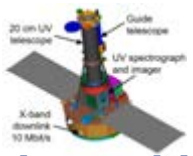
Trigger / justify evolution

Open possibilities

Constrain the fulfilment

Are not always aware of





Technological Capabilities

Process for user requirements elaboration



Users

Can't always formulate

User Needs

Know / translate

Should drive



Formulate

Experts

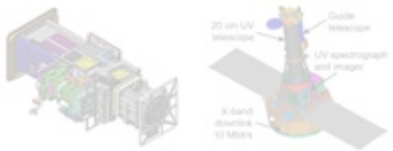
User Requirements

Trigger / justify evolution

Open possibilities

Constrain the fulfilment

Are not always aware of



Technological Capabilities

Consider

EUMETSAT

Process for user requirements elaboration



Users

Can't always formulate

User Needs

Know / translate

Should drive



Guide

Discuss / endorse

User Workshop

Formulate



Experts

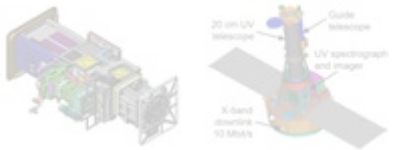
User Requirements

Trigger / justify evolution

Open possibilities

Constrain the fulfilment

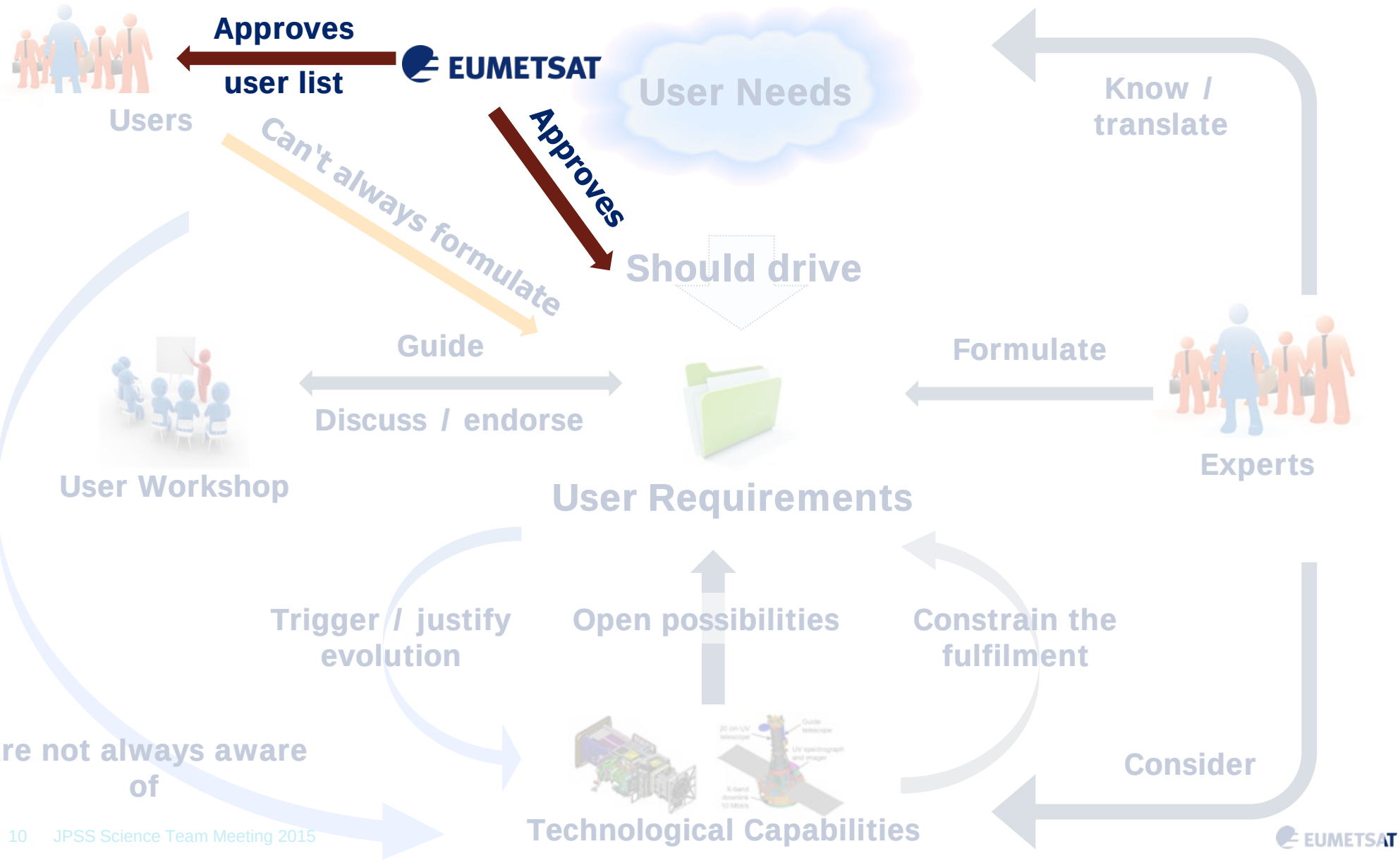
Are not always aware of



Technological Capabilities

Consider

Process for user requirements elaboration



Process for user requirements elaboration



Users

Approves user list

EUMETSAT

User Needs

Know / translate

Can't always formulate

Approves

Should drive

Guide

Discuss / endorse



User Workshop



User Requirements

Formulate



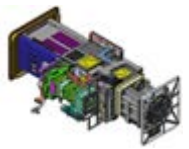
Experts

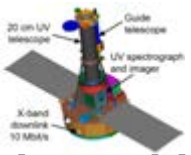
Trigger / justify evolution

Open possibilities

Constrain the fulfilment

Are not always aware of

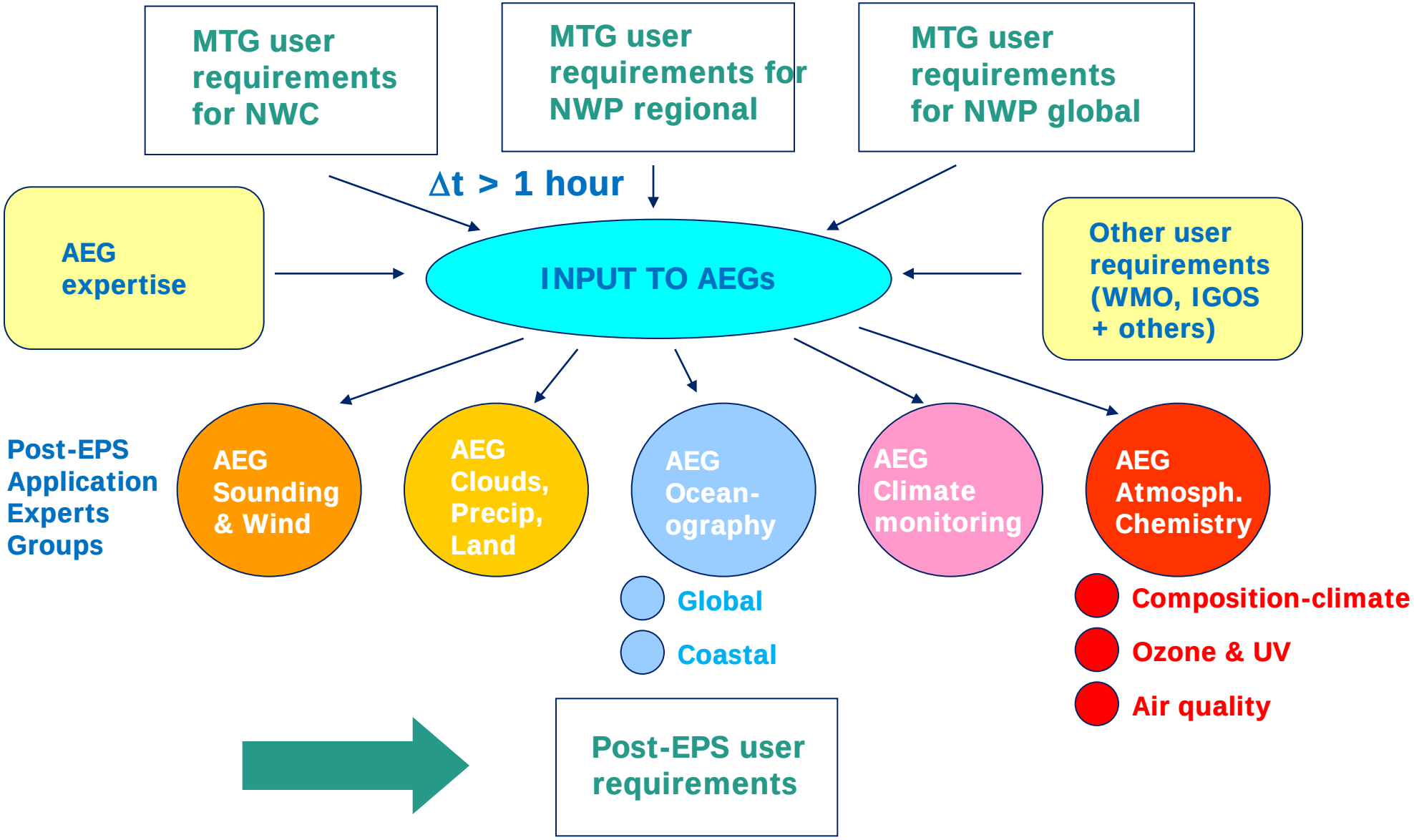




Technological Capabilities

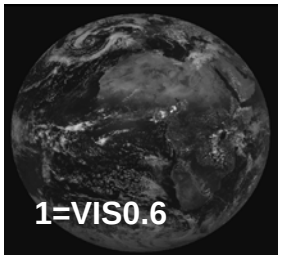
Consider

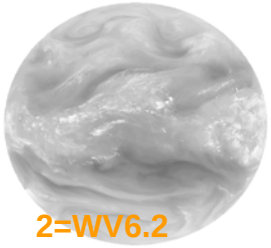
EUMETSAT

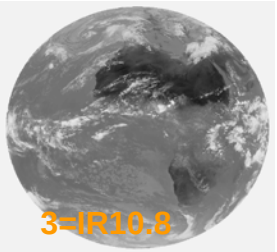

MTG user requirements for NWC
MTG user requirements for NWP regional
MTG user requirements for NWP global
Δt > 1 hour
AEG expertise
INPUT TO AEGs
Other user requirements (WMO, IGOS + others)
Post-EPS Application Experts Groups
AEG Sounding & Wind
AEG Clouds, Precip, Land
AEG Ocean-ography
AEG Climate monitoring
AEG Atmosph. Chemistry
Global
Coastal
Composition-climate
Ozone & UV
Air quality
Post-EPS user requirements

From MVIRI on MTP...

Meteosat-7 is the last
Located over
- Indian Ocean
Operational
- until end of 2016







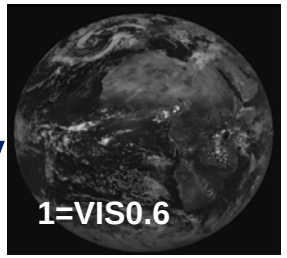
EUMETSAT

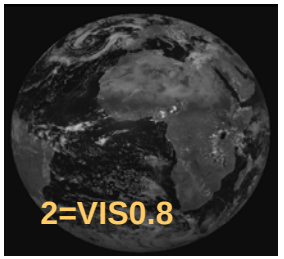
From MVIRI on MTP to SEVIRI on MSG...

MSG-4 (Meteosat-11)
- is the last
- in-orbit storage 2.5 y

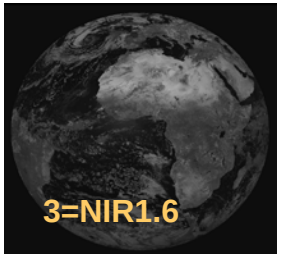
Indian Ocean Data
- coverage is considered using Meteosat-8

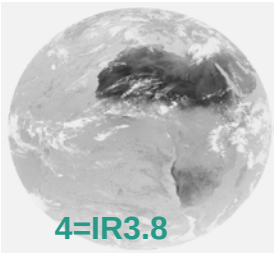
Operational programme
- until 2025 (TBC)

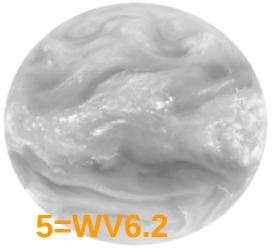


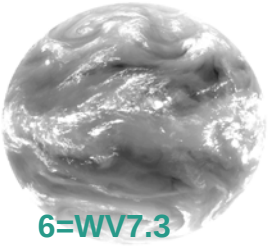


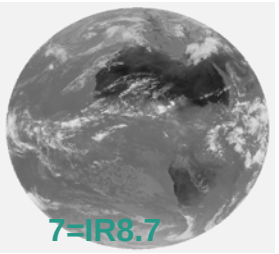


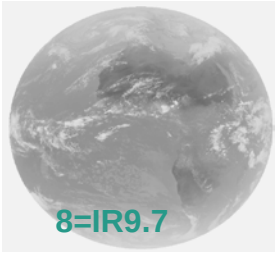


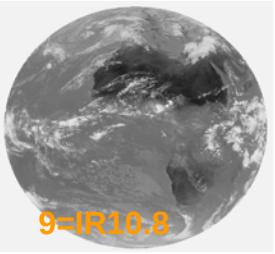


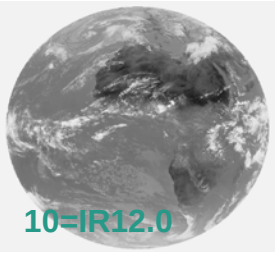


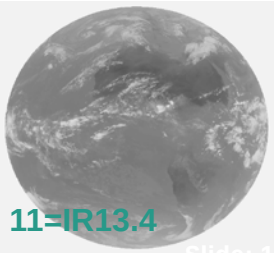






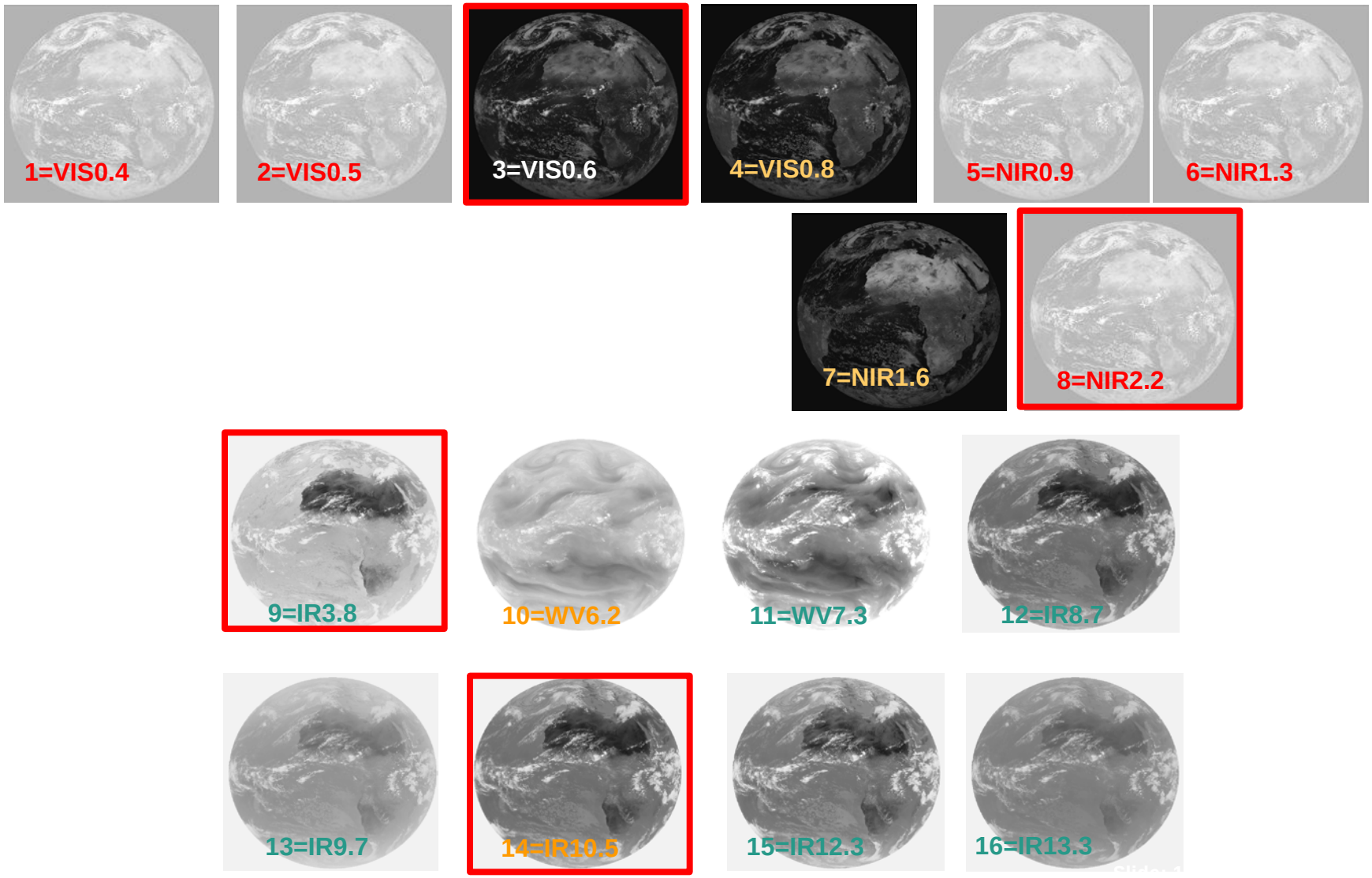






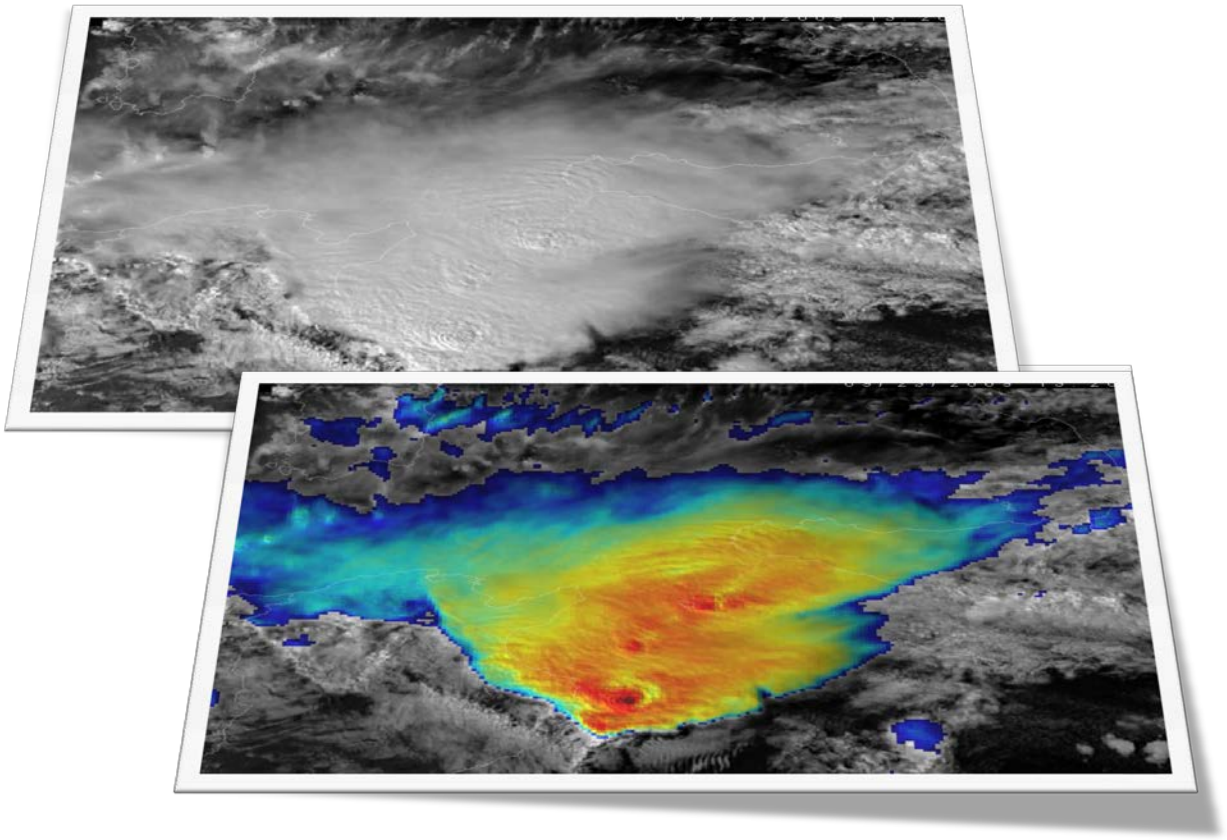
EUMETSAT

From MVIRI through SEVIRI to FCI on MTG

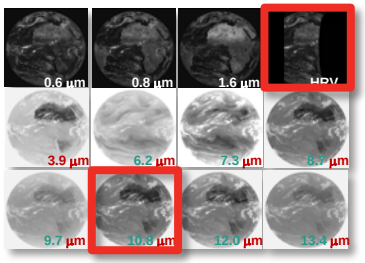


EUMETSAT

Visual Analysis: Monitoring Stages of Convection

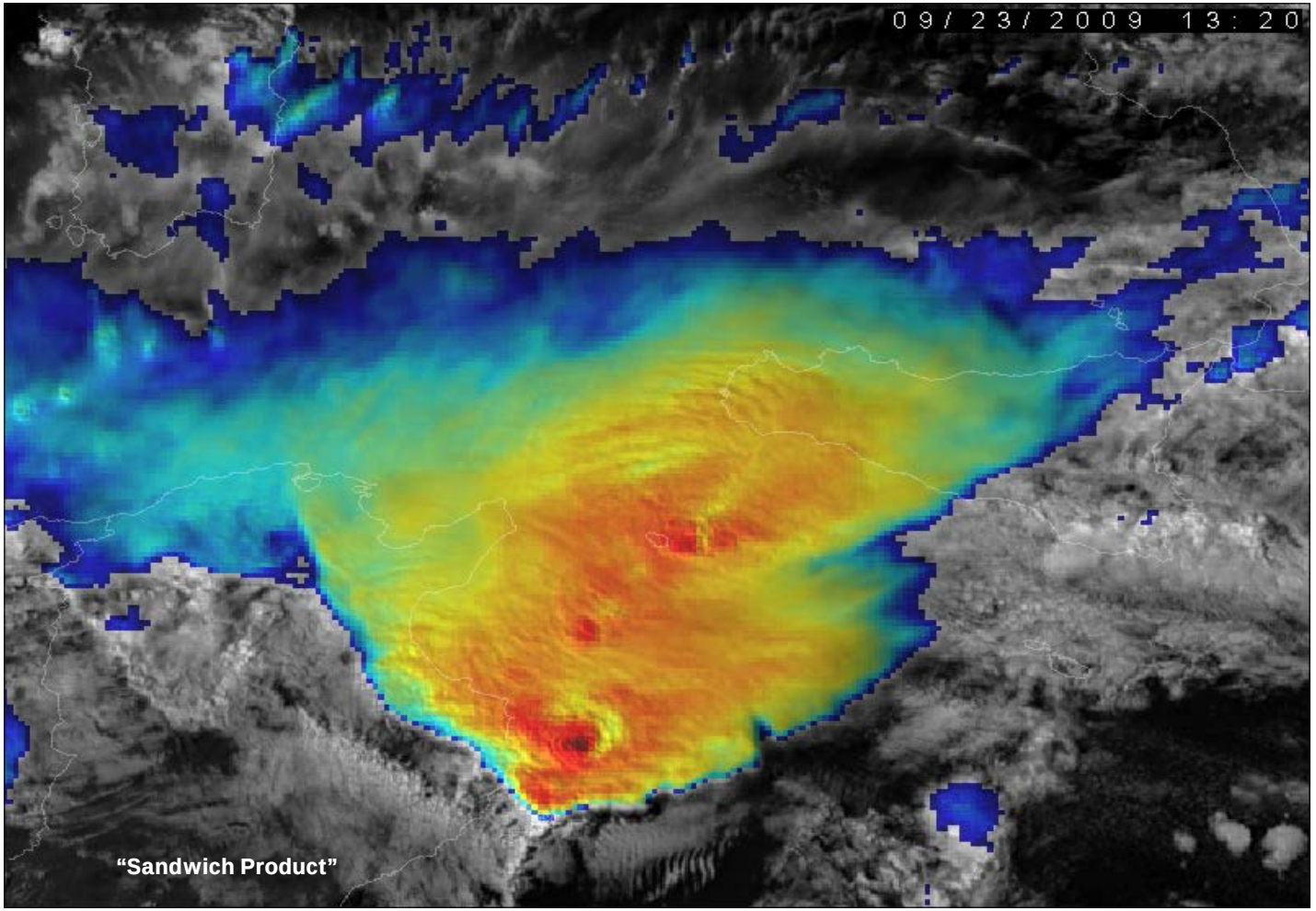


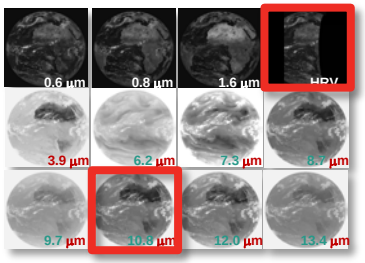
23. September 2009
Mediterranean Sea



EUMETSAT

Visual Analysis: Monitoring Stages of Convection



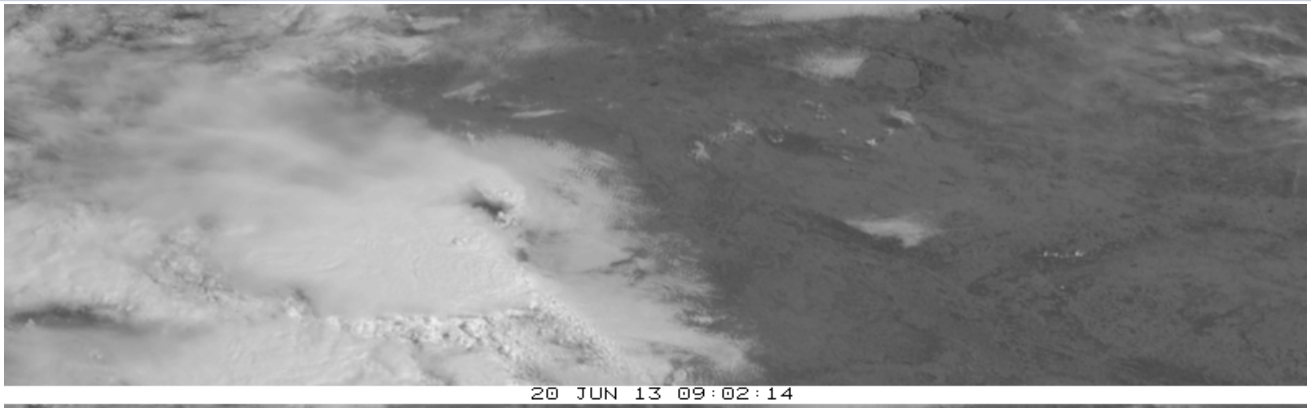




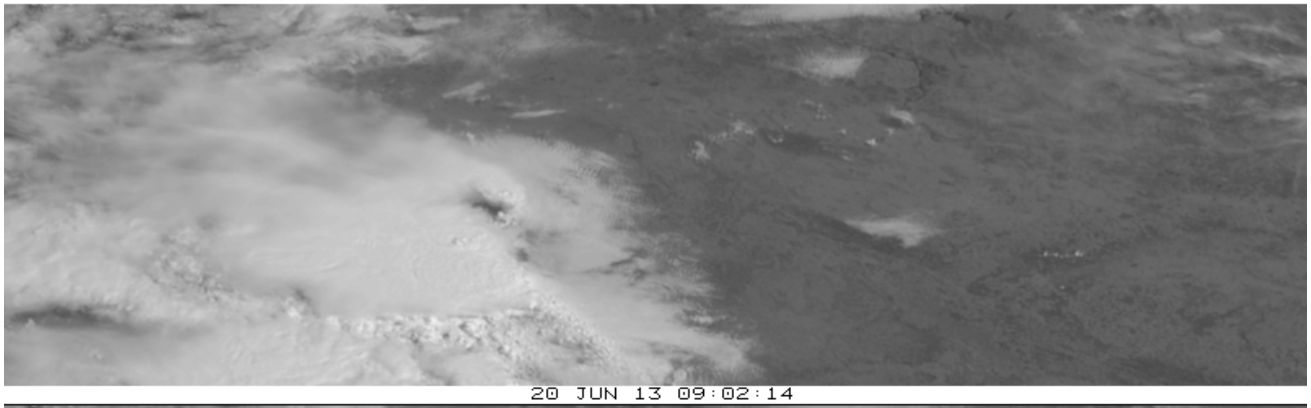
EUMETSAT

Met-8 super-rapid scans 2.5 min experiment

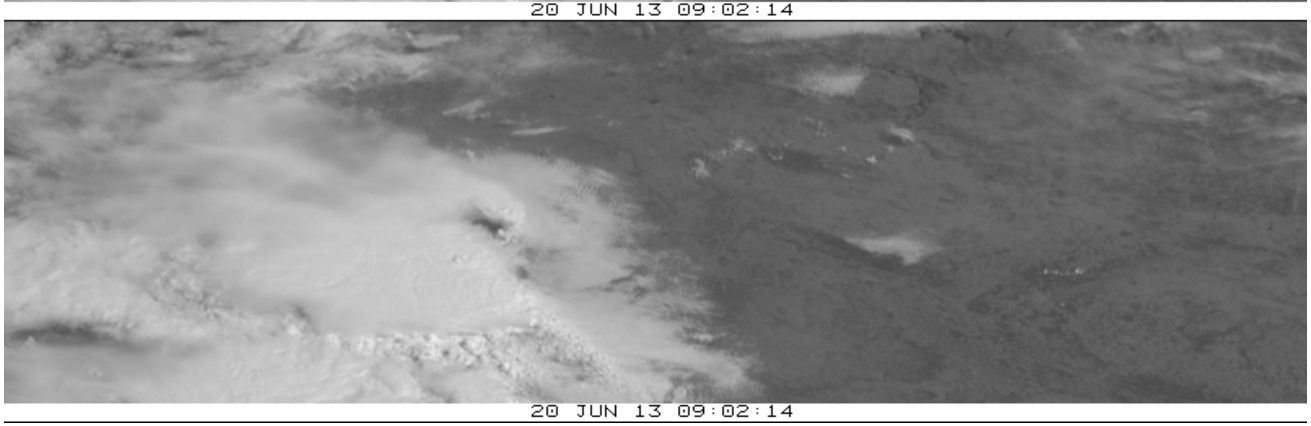
2.5 minutes Repeat Cycle



5 minutes Repeat Cycle



15 minutes Repeat Cycle



EUMETSAT

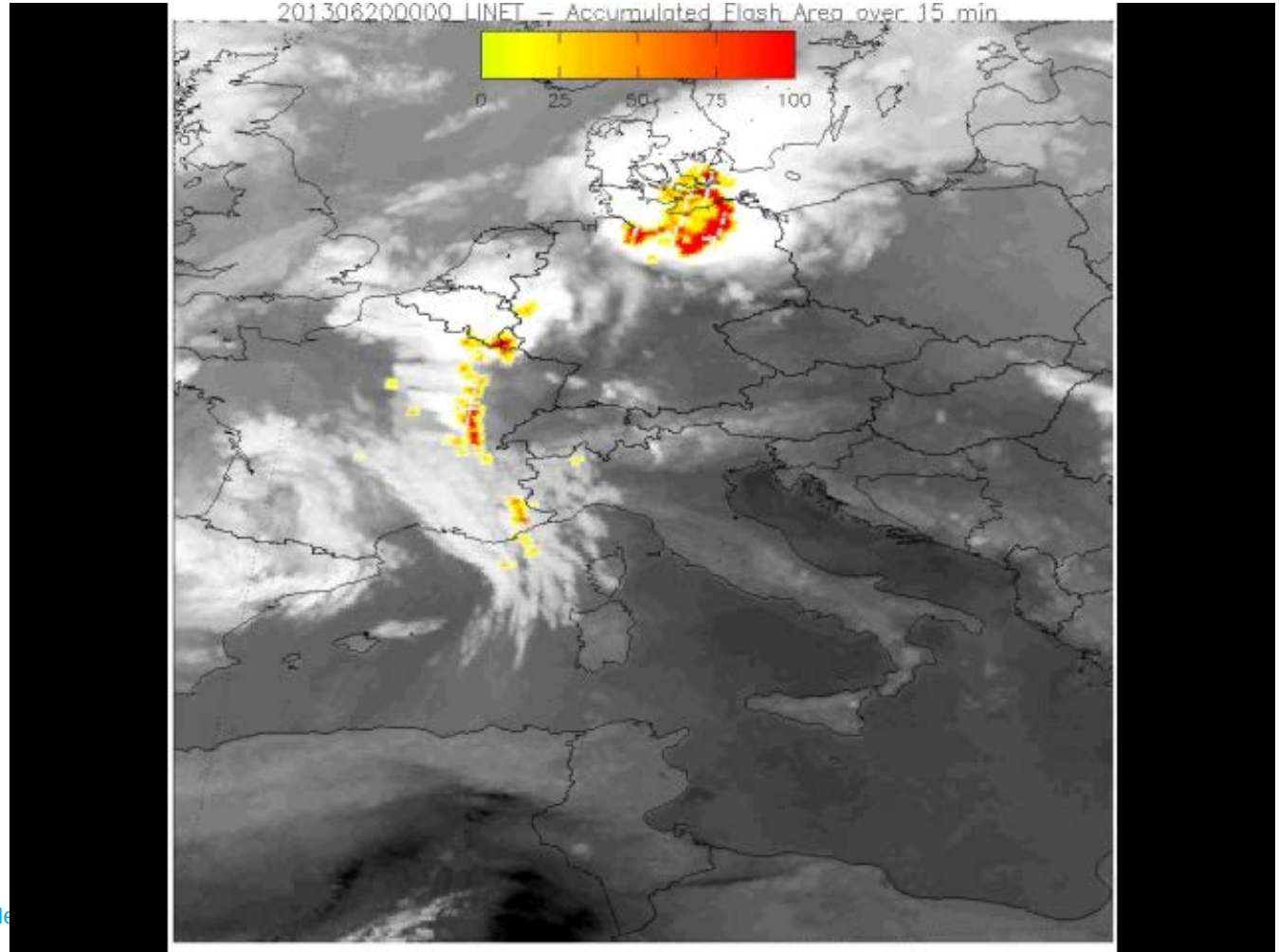
Meteosat Third Generation: Mission overview



- Imagery mission implemented by a two-satellite MTG-I system:
  1. Full disk imagery every 10 minutes in 16 spectral bands
  2. Fast imaging of European weather every 2.5 minutes
  3. Lightning Imager (LI)
- Hyperspectral Infrared (IRS) Sounding mission:
  4. 3D mapping of water vapour, temperature, O3 every 1 hour
  5. Air quality monitoring and atmospheric chemistry in synergy with Sentinel-4 Ultraviolet Visible
- start of operations in 2019 and 2021
- operational exploitation: 2019– 2040

LI reference processor development – product example

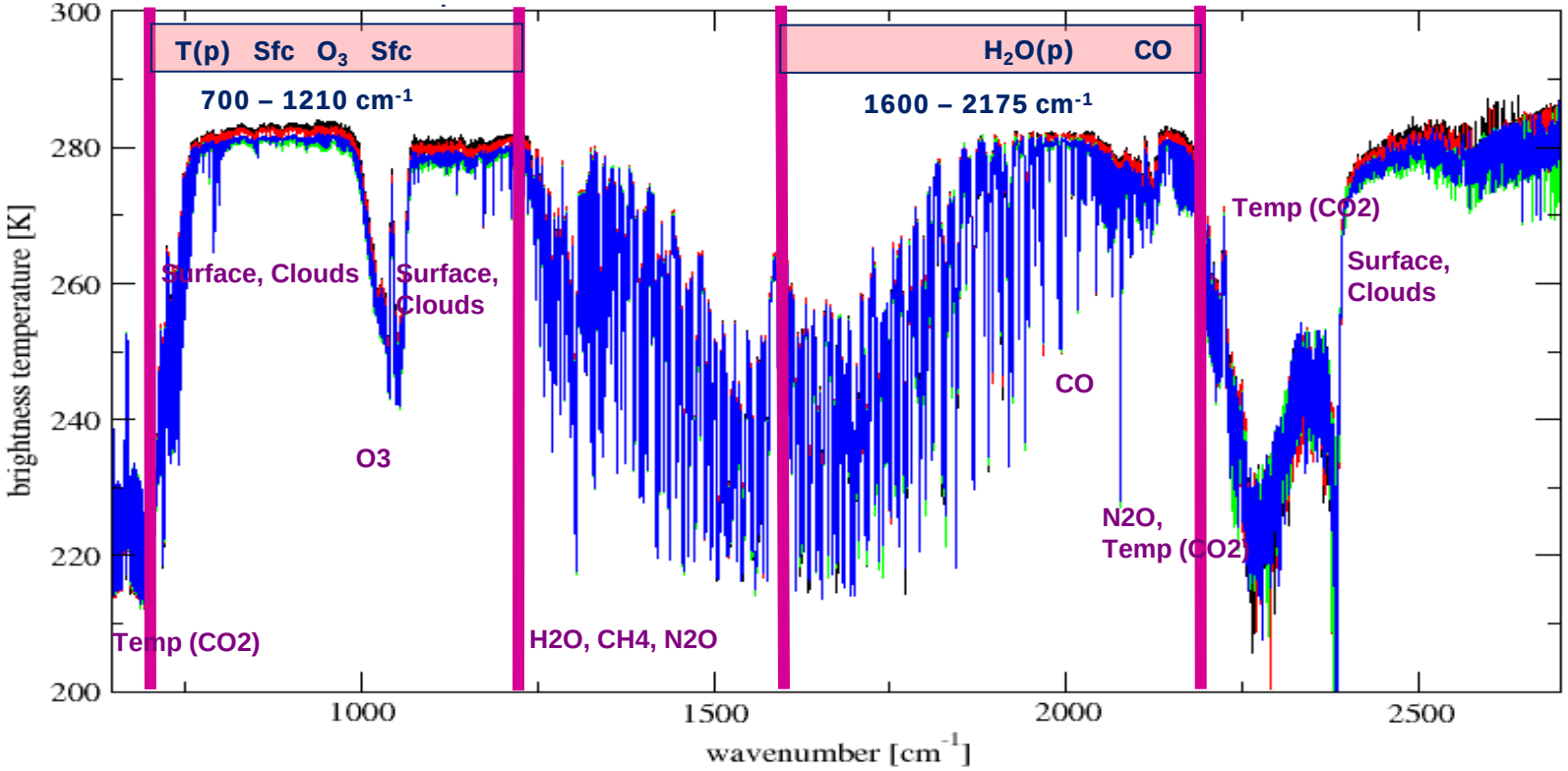
“Accumulated flash area” product, integrated over 15 minutes and updated every 30 seconds
Date: 20 June 2013.



EUMETSAT

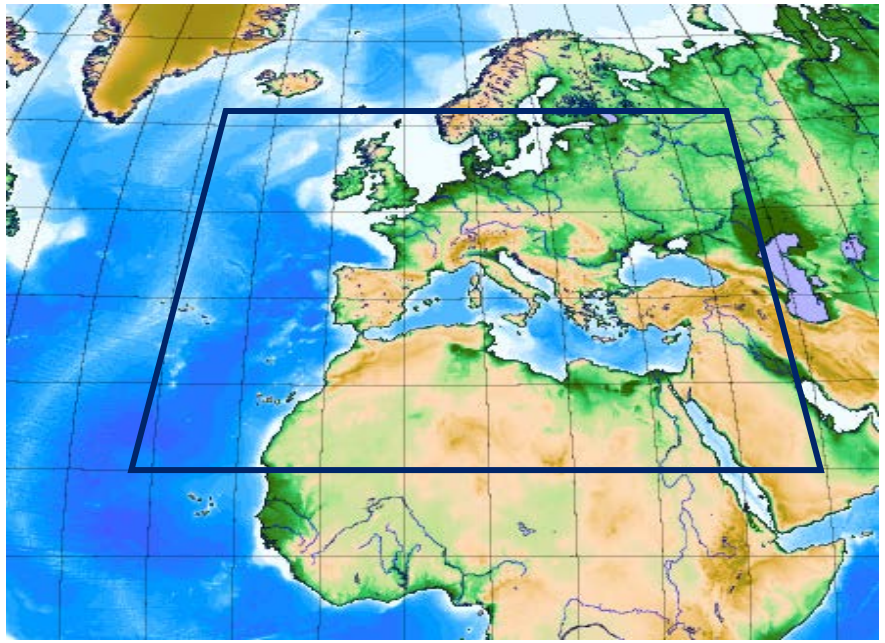
MTG Mission: InfraRed Sounder (IRS)

- MTG-IRS will deliver unprecedented information on horizontal and vertical gradients of moisture, wind and temperature from the geostationary orbit:
  - Full Disk Sounding;
  - Repeat Cycle = 60 min;
  - spatial resolution of 4 km,
  - hyperspectral soundings at 0.625 cm-1 spectral sampling in two bands:
    - Long-Wave-IR (LWIR: 700 – 1210 cm-1 ~820 spectral samples)
    - Mid-Wave-IR (MWIR: 1600 – 2175 cm-1 ~920 spectral samples)

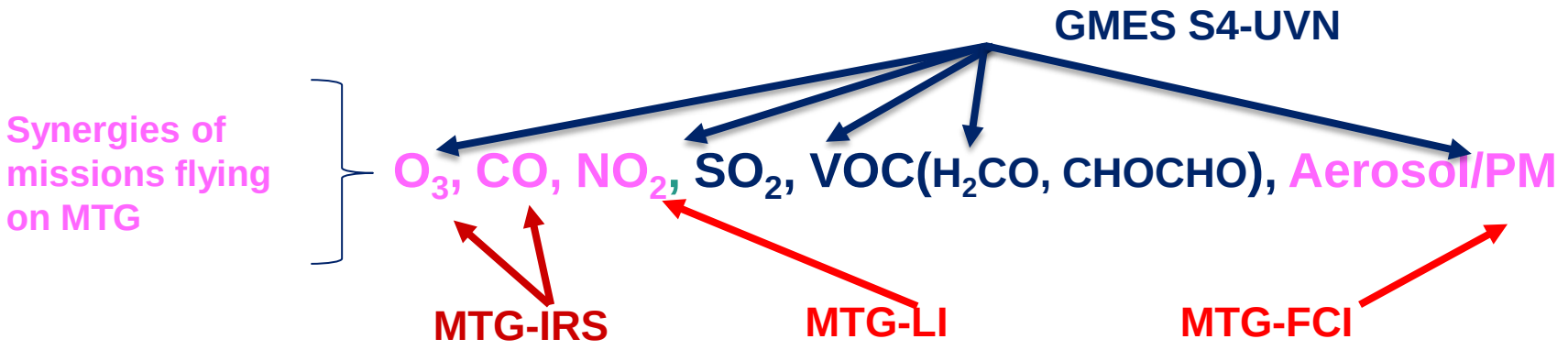


EUMETSAT

MTG Mission: hosting GMES Sentinel-4



- The GMES Sentinel-4 sounding mission is achieved through the Ultraviolet, Visible & Near-infrared (UVN) Instrument accommodated on the MTG-S satellites
  - covering Europe every hour
  - taking measurements in three spectral bands (UV: 305 - 400 nm; VIS: 400 - 500 nm, NIR: 750 - 775 nm)
  - with a resolution around 8km.
- The primary data products are O3, NO2, SO2, HCHO and aerosol optical depth.



EUMETSAT

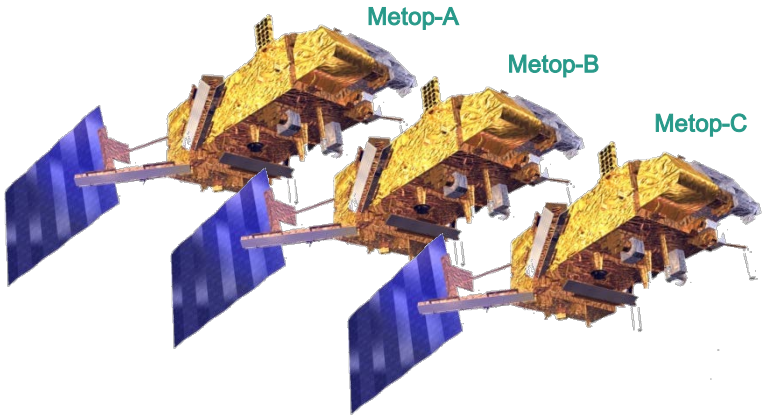
EUMETSAT Polar System Programme



Polar Stations
Svalbard, 78 deg North



Launcher Service
(Soyuz, Baikonur)





LEOP Service
(ESOC)



EUMETSAT
Mission Control Centre

Satellite Application
Facilities (SAF)
8 Meteorological Themes

- Metop-A launched in 2006
- Metop-B launched in 2012
- Metop-C launch scheduled for 2019
- Sun Synchronous orbit
- 820 km, 9h30 LST,100 min
- Sole source of mid-morning orbit data
- 11 Instruments
- Soyuz Launcher Service (Baikonur/Kourou)
- ESOC LEOP Service (Darmstadt)
- Central & distributed Ground Segment components
- 14+ years of operations

EUMETSAT

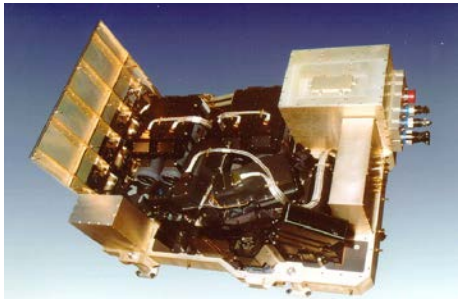
The EUMETSAT polar system as part of the initial joint polar system shared with the US





- Coordinated programmes
- Exchange of instruments
- Coordinated operations, data and services
- Only Metop provides mid-morning service
- And now China has committed to the early morning orbit

Current Capabilities - EUMETSAT Polar System



AVHRR
Advanced Very High Resolution Radiometer

HIRS/4
High-resolution Infrared Radiation Sounder

IASI
Infrared Atmospheric Sounding Interferometer

AMSU-A1
Advanced Microwave Sounding Unit-A1

MHS
Microwave Humidity Sounder

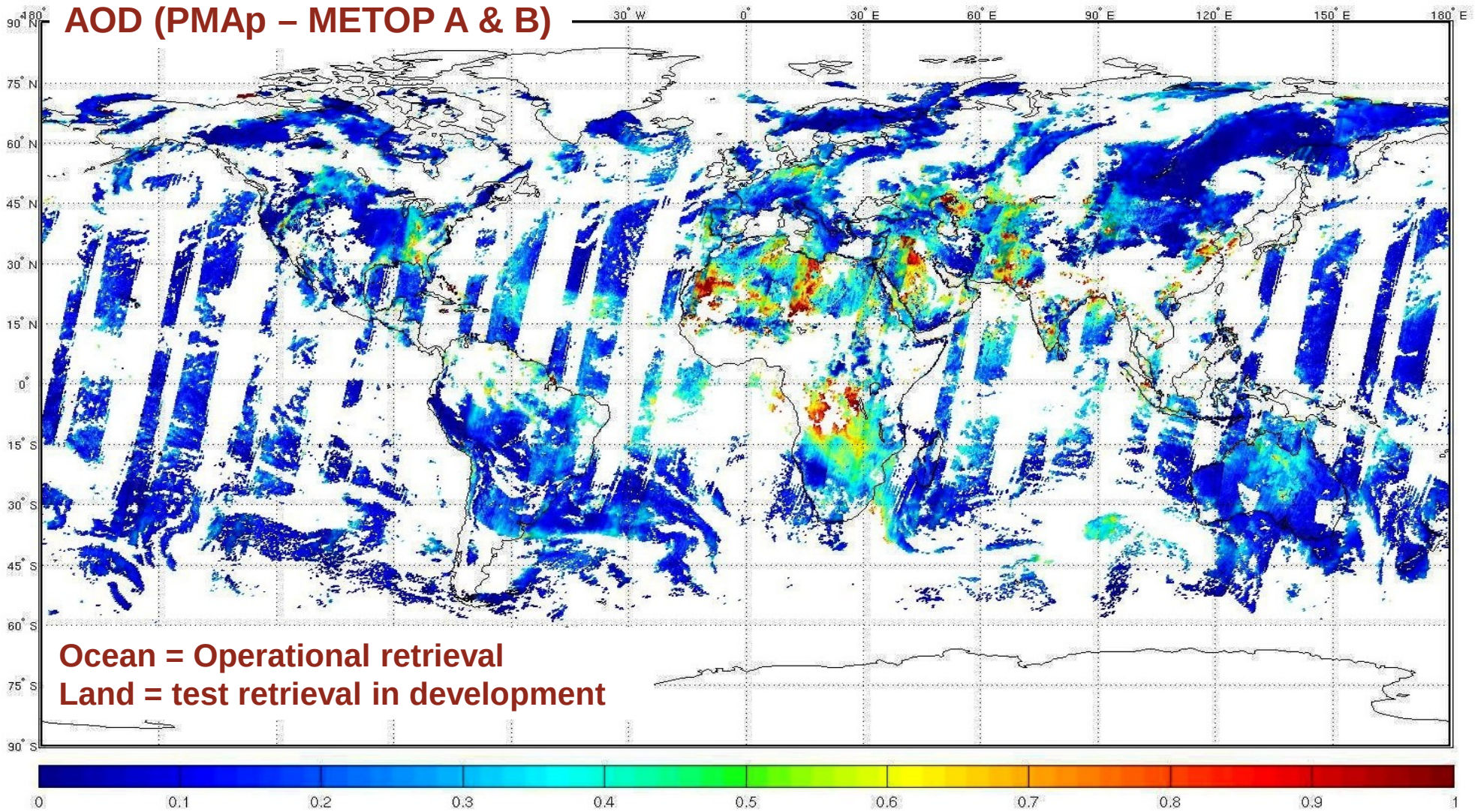
GRAS
GPS Receiver for Atmospheric Sounding

GOME-2
Global Ozone Monitoring Experiment

AMSU-A2
Advanced Microwave Sounding Unit-A2

ASCAT
Advanced SCATterometer

Aerosol: PMAp (GOME-2 + AVHRR) Metop A & B combined



EUMETSAT

Metop-B is in the same orbital plane as Metop-A

Morning Orbit

Equator crossing time: 09:30 LST
Orbit phasing: 48.93 min.

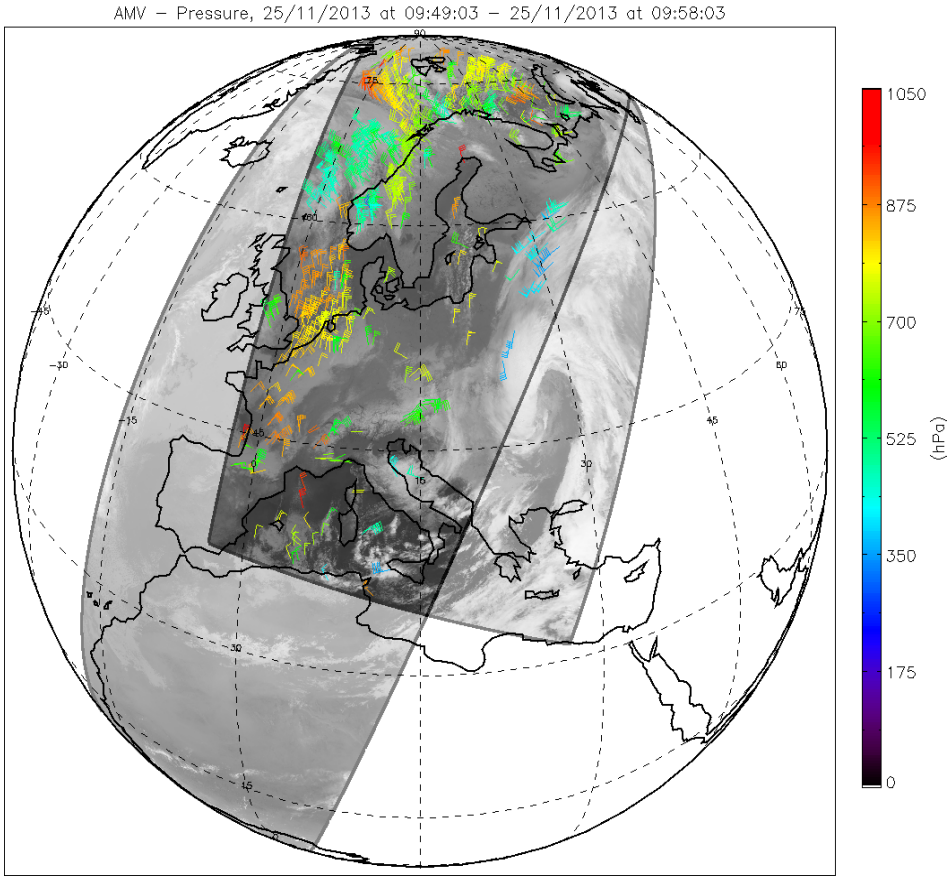


Metop-C in 2018

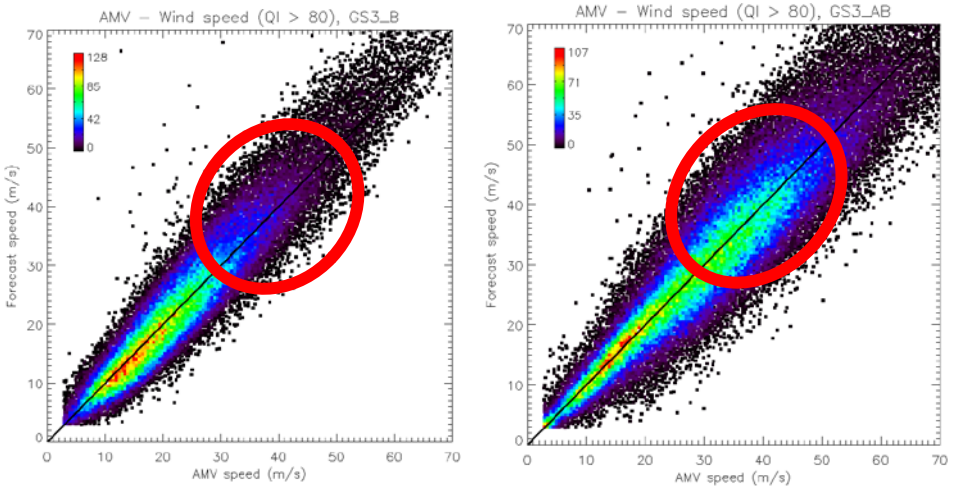
EUMETSAT

Dual Metop winds:
Global coverage and quality improvement in polar regions

Global dual Metop winds



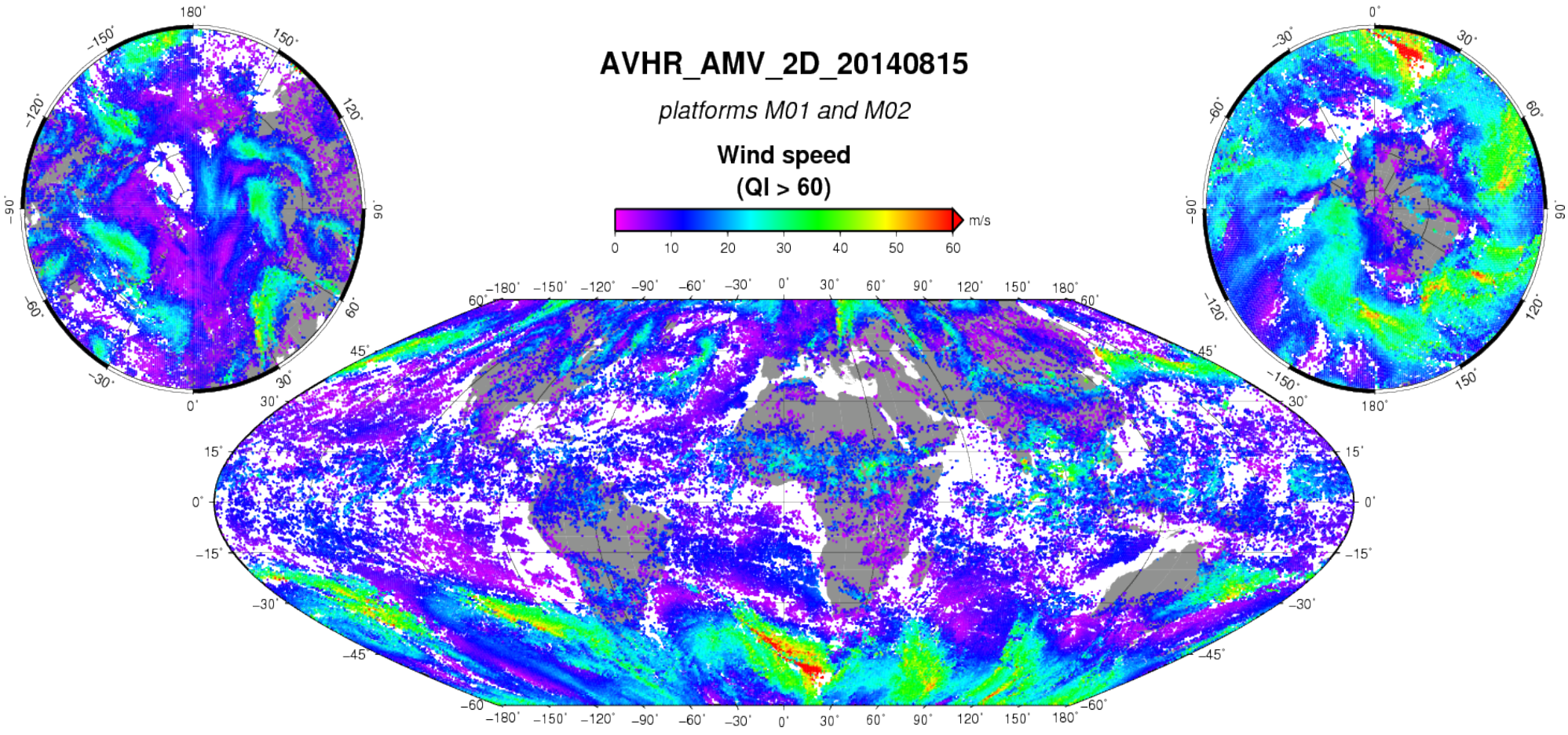
Metop winds over South Pole (QI>80)



One Metop **Dual Metop**

EUMETSAT

EUMETSAT dual Metop winds: Global coverage



Bin size = 80x80 km²

EUMETSAT

EPS Second Generation

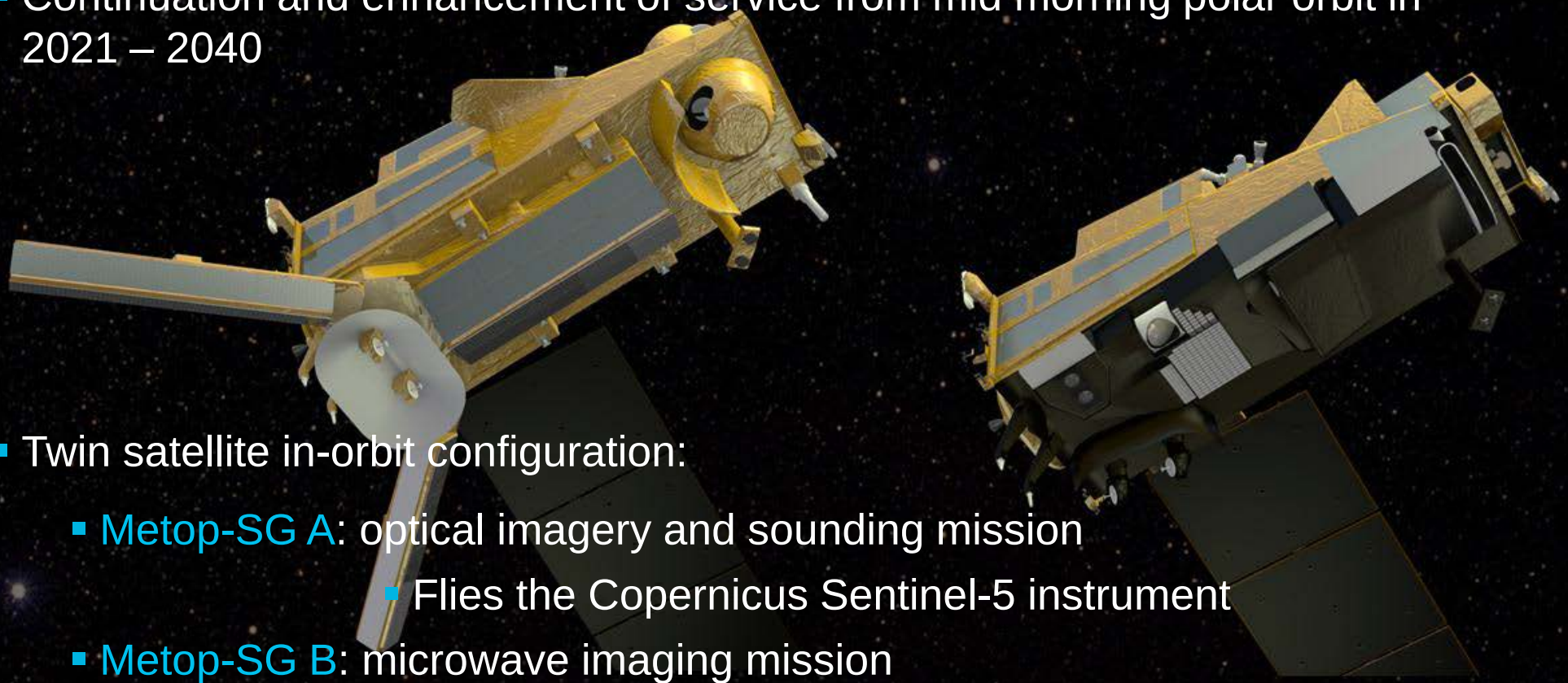
- Primary mission: further improve observational inputs to Numerical Weather Prediction models

- Significant contributions to other real time applications:
  - Nowcasting at high latitudes
  - Marine meteorology and operational oceanography
  - Operational hydrology
  - Air quality monitoring

- Climate monitoring: expand by 20+ years the climate data records initiated in 2006 with EPS

EPS Second Generation

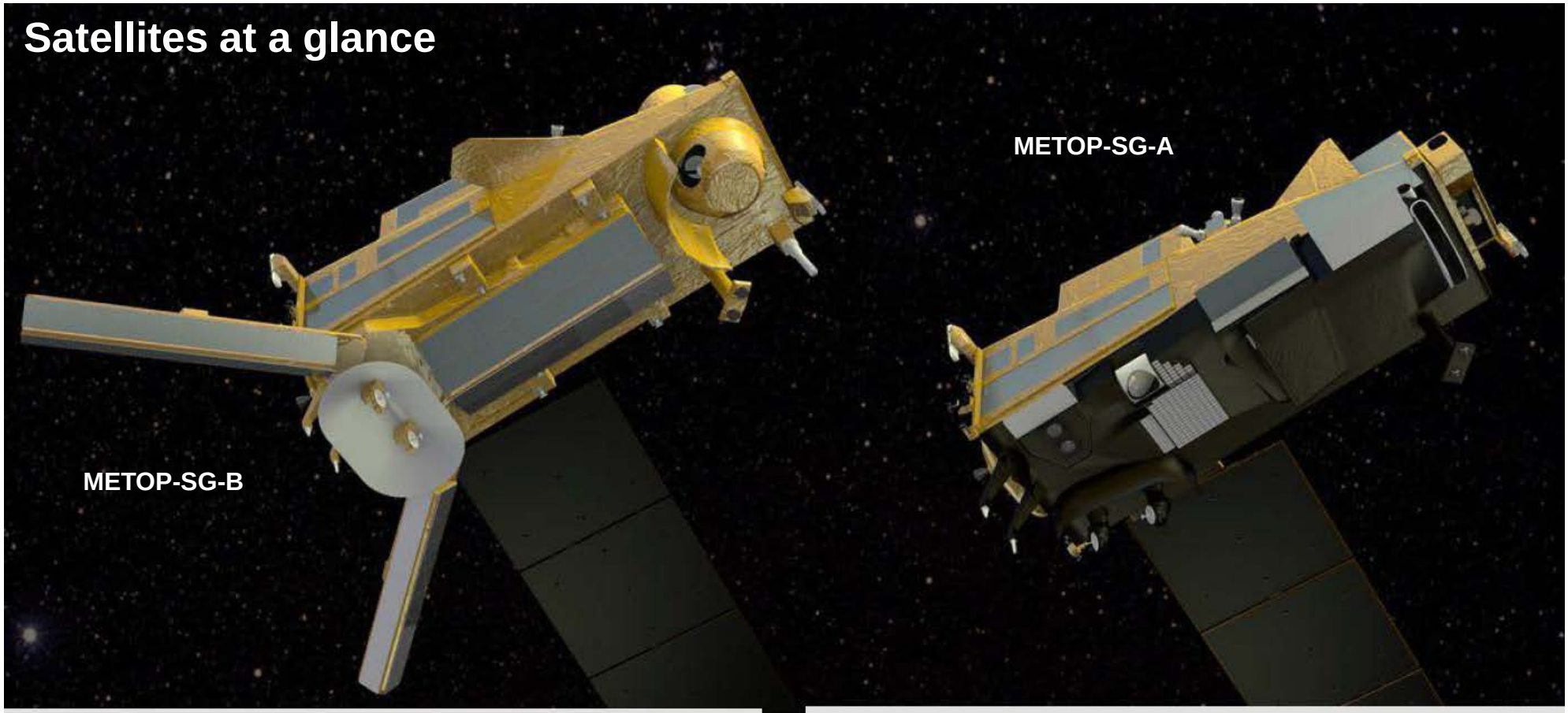
- Continuation and enhancement of service from mid morning polar orbit in 2021 – 2040



- Twin satellite in-orbit configuration:
  - Metop-SG A: optical imagery and sounding mission
    - Flies the Copernicus Sentinel-5 instrument
  - Metop-SG B: microwave imaging mission
- Two series of 3 successive satellites for 21 years of operations
- European contribution to the Joint Polar System (JPS) shared with the US/NOAA

EPS Second Generation

Satellites at a glance



METOP-SG-B

- Launch mass = 3.79 tons
- Mean power consumption = 2.7 kW
- Data rate = day / night / peak
  14 / 14 / 17 Mbps

METOP-SG-A

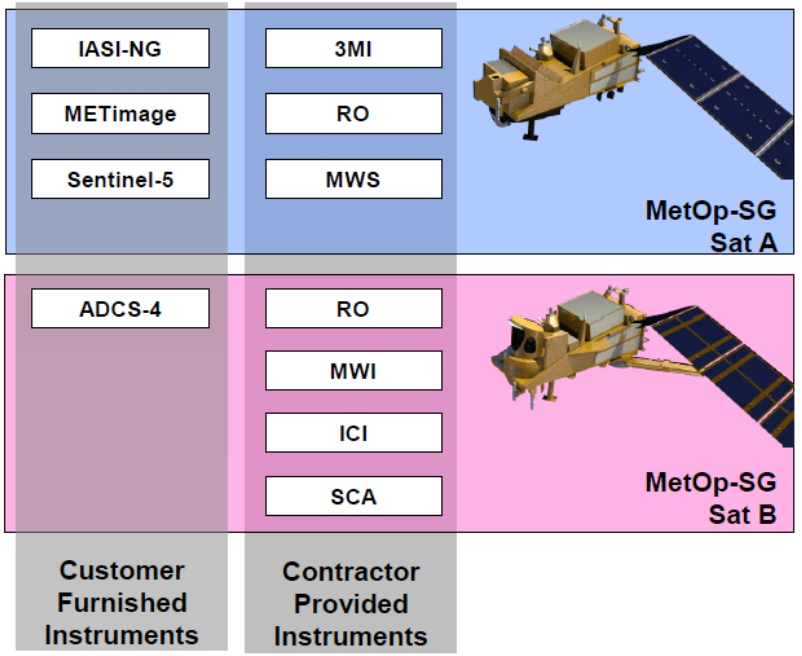
- Launch mass = 4,08 tons
- Mean power consumption = 3.4 kW
- Data rate = day / night / peak
  60 / 22 / 77 Mbps

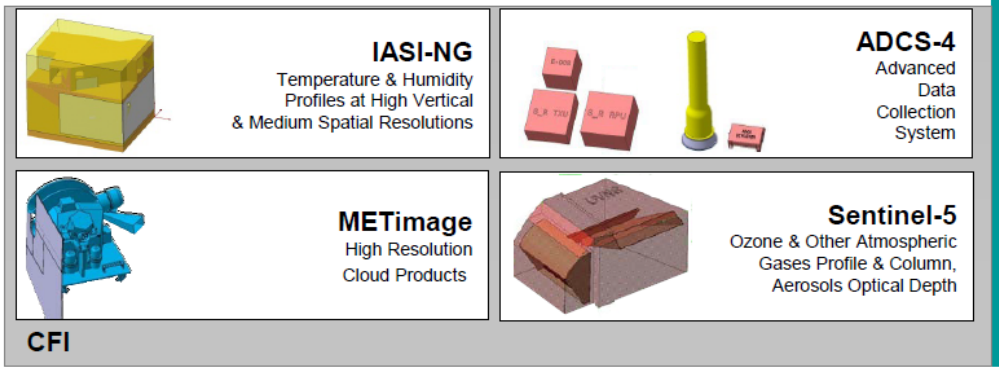
- Launcher: Soyuz in Kourou / Falcon 9 / Ariane 5
- Orbit: MetOp Sun Synchronous Orbit 817 km, 9h30 Local Time at Descending Node
- Controlled re-entry into the South Pacific Ocean Uninhabited Area

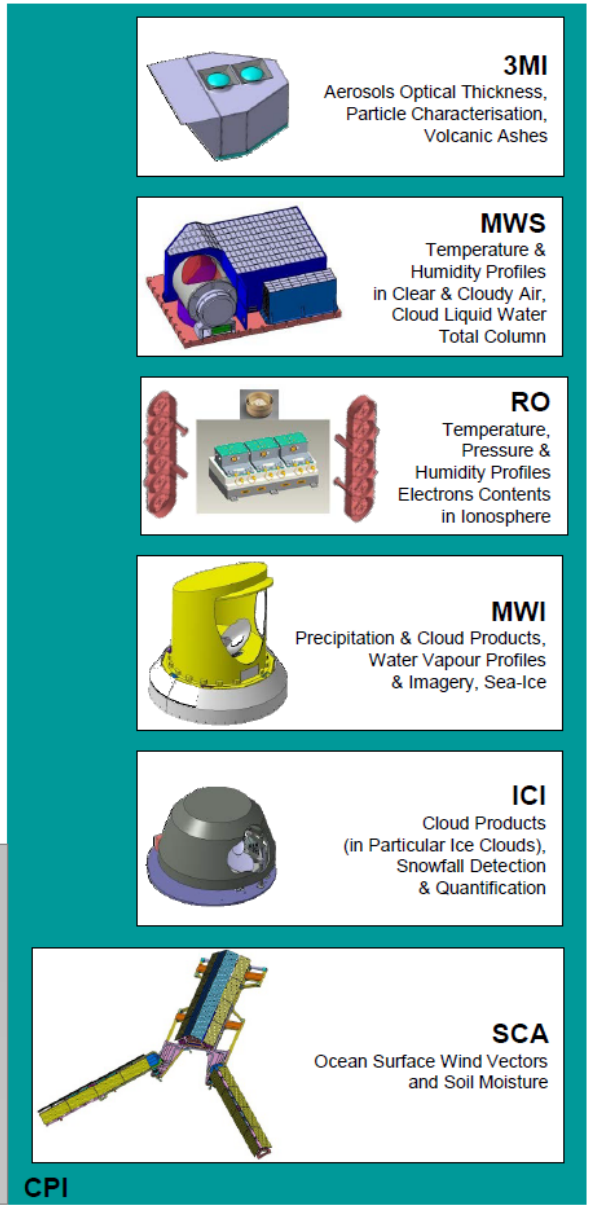
EUMETSAT

EPS Second Generation Instruments' Overview

Distribution of Instruments per Satellite







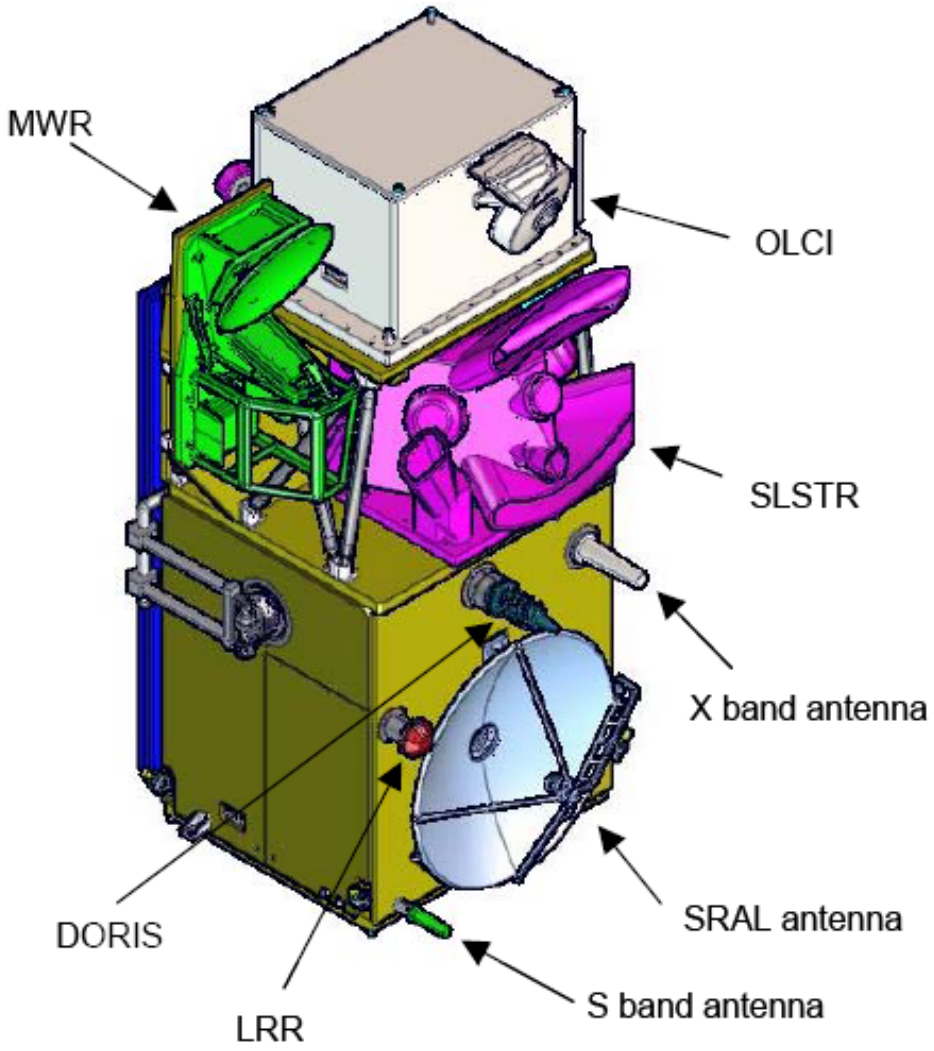
EPS-SG Current Status

- Achieved approval of the scope and contents of the EPS-SG Programme Proposal which includes the draft cooperation agreements with ESA, CNES, DLR and NOAA
- Achieved in June 2015 approval of full EPS-SG programme from January 2016 onwards
- System Preliminary Design Review (PDR) successfully completed in June 2015
- ESA: Prime contractors for the Metop-SG A and B satellites selected and Phase B2 kicked off in June 2014, PDR planned for September 2015
- CNES: IASI-NG PDR successfully completed in May 2015
- CNES: The first flight model of A-DCS4 for EPS-SG is under assembly
- DLR: METimage instrument PDR successfully completed in July 2015
- EUM: Overall Ground Segment PDR planned for September 2015

MONITORING THE OCEAN IN SUPPORT OF COPERNICUS



Sentinel-3 Satellite and Payload

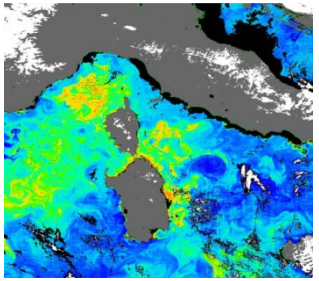


- SLSTR: Sea and Land Surface Temperature Radiometer
- SRAL: Synthetic Aperture Radar Altimeter
- OLCI: Ocean and Land Colour Instrument
- MWR: Micro-Wave Radiometer
- LRR: Laser Retro-Reflector
- DORIS: Doppler Orbitography and Radiopositionning Integrated by Satellite
- STM: Surface Topography Mission = SRAL + MWR

Sentinel-3 Marine product contents

Level 1B: SLTSR (radiance, BT at TOA) and OLCI (radiance at TOA) and SRAL(waveforms)

(ESA and EUMETSAT)



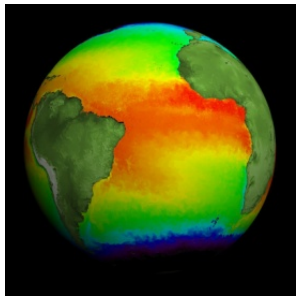
Level 2 OLCI:

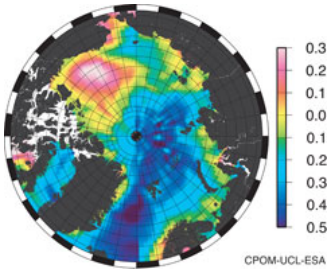
- Normalised water surface reflectance
- Algal pigment concentration for open and for coastal waters
- Total suspended matter concentration
- Diffuse attenuation coefficient
- Coloured dissolved matter absorption
- Photosynthetically active radiation
- Integrated water vapour
- Aerosol optical depth
- Aerosol Angström exponent

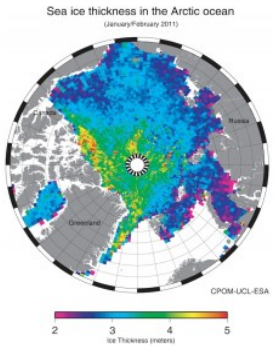
Level 2 SLTSR:

- Sea surface temperature

(L2P GHRSST standard)







Level 2 SRAL:

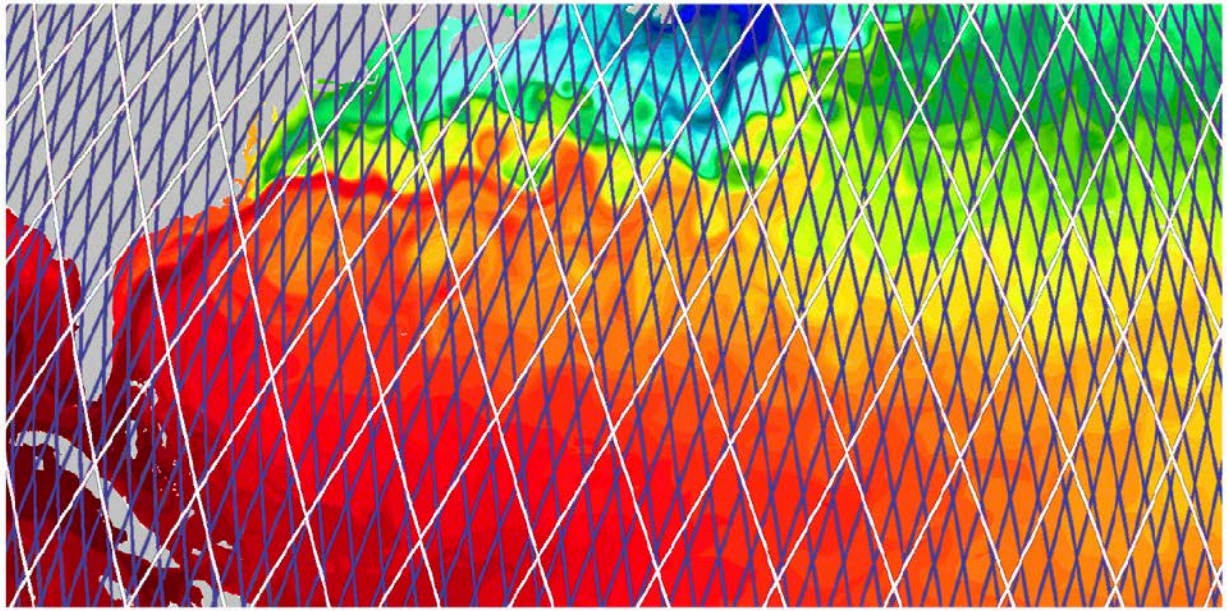
- Sea/coastal zone surface height
- Significant wave height
- Wind speed
- Backscatter coefficient σ_0
- Sea ice height, freeboard
- Total water, liquid water (from MWR)

EUMETSAT

Combining Sentinel-3 & Jason altimetry for operational oceanography and climate change monitoring





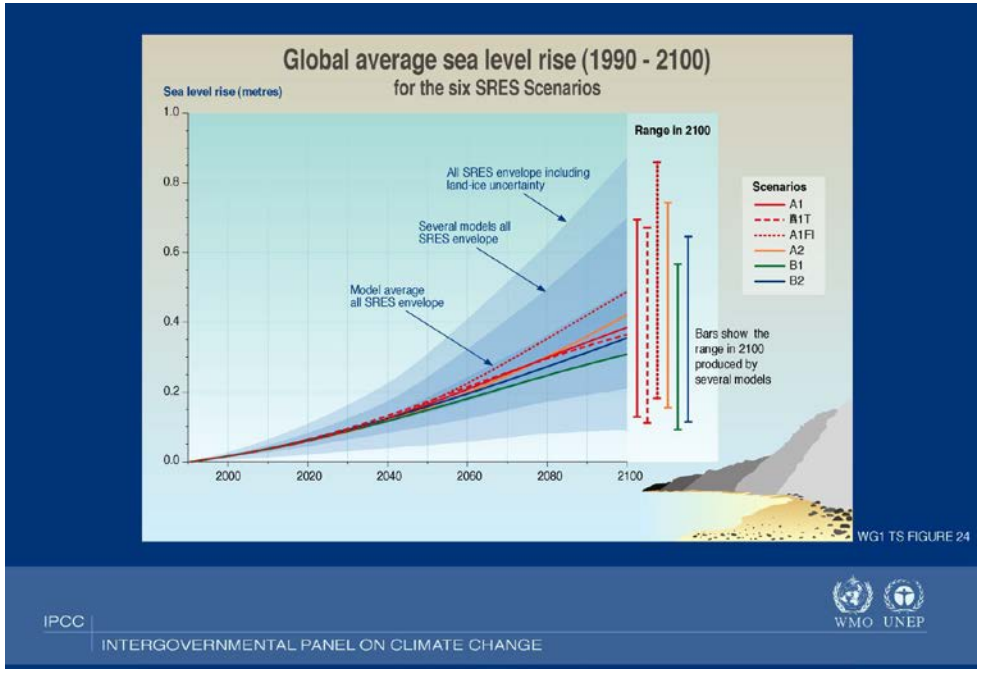


(Courtesy CNES/CLS/ESA)

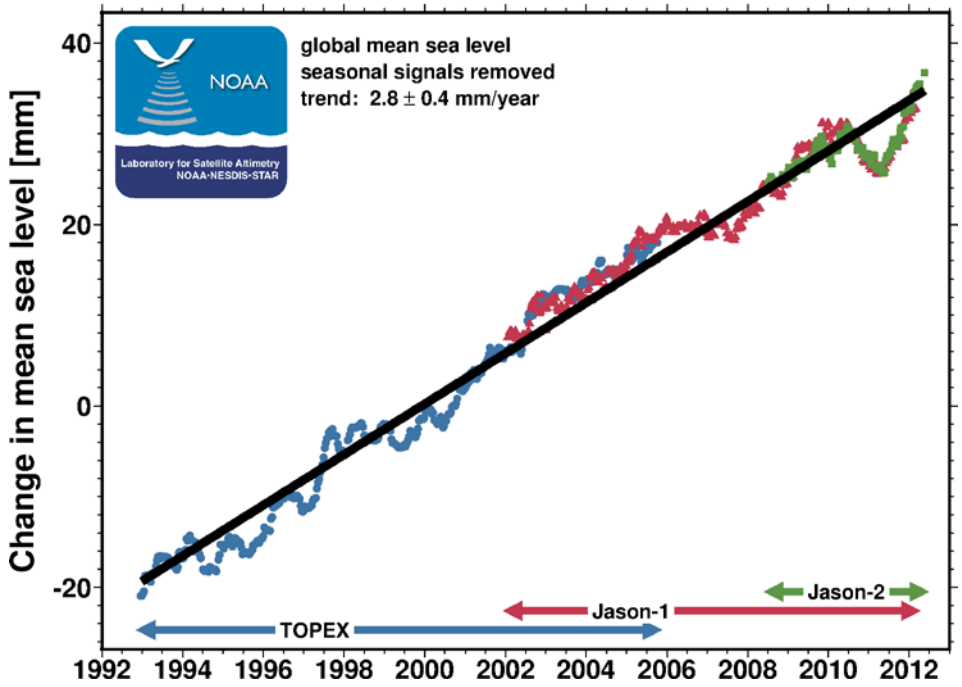
EUMETSAT

From Jason-2 to Jason- 3, Jason-CS: Global sea level rise

IPCC projections: Uncertainties



Observational evidence: Unique Climate Data Record

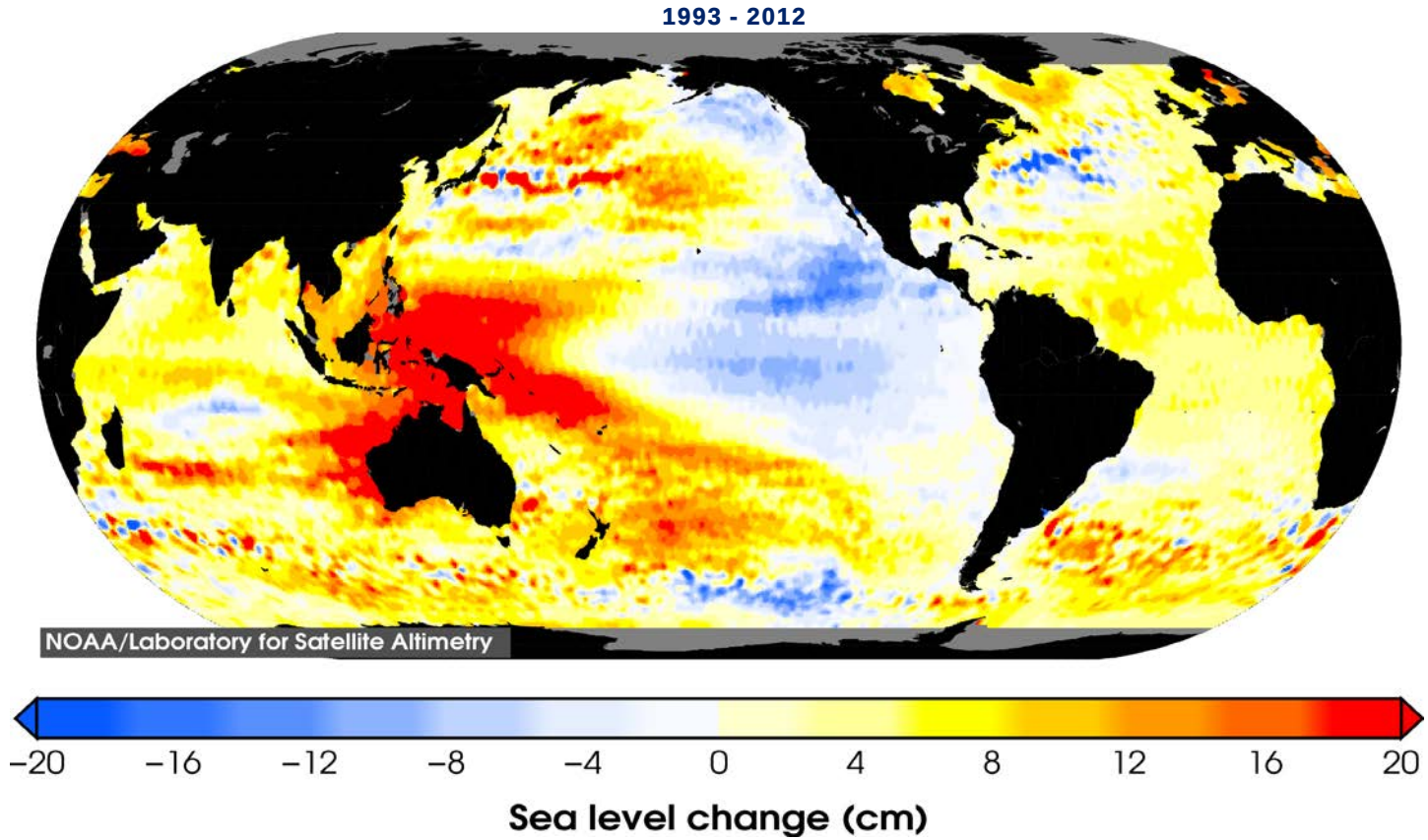


Global mean sea level during the altimetry era has risen at a nearly constant rate since 1993 (+- 3 mm/year) .

Relatively consistent despite large regional interannual variations and accelerations in the melting of land ice.

EUMETSAT

Mean sea level trends : regional differences



- Why has the western Pacific risen 3 times faster?
- Why has sea level dropped near the U.S. West Coast?
- How will regional sea level change in the future?

PRODUCT STATUS AND SCIENCE MATURITY



Product Status

STATUS	DEMONSTRATIONAL	PRE-OPERATIONAL	OPERATIONAL
PRODUCT QUALITY	**First version of the Product**	**Quality approaching to expected levels**	**Expected Quality (as per Requirements)**
STATUS OF VALIDATION PROCESS	Limited Validation performed	Validation almost completed (if not completed), with documented limitations	Validation performed and fully documented
PRODUCT LIMITATIONS	Potentially unknown or Major	Known & Not Major or None	None or Known limitations agreed with Users
PRODUCT DOCUMENTATION	Product Validation report & User manual Not Available	Product Validation report & User manual (mainly) completed	All completed, published and available
AUDIENCE	Internal Users + Investigators Usually not more than a very limited set of users	Varying from 'limited set of Users' to 'All Registered Users'	Usually 'All Registered Users' (unless exceptions)
ACCESS BY EXTERNAL USERS	No Access to the Documentation	Documentation on the WEB	Documentation on the WEB

CDR Maturity Matrix - Top Layer

			CDR Name Here			Maturity level as of mm/dd/yyyy
Maturity	**Software Readiness**	**Metadata**	**Documentation**	**Product Validation**	**Public Access**	**Utility**
1	Conceptual development	Little or none	Draft Climate Algorithm Theoretical Basis Document (C-ATBD); paper on algorithm submitted	Little or None	Restricted to a select few	Little or none
2	Significant code changes expected	Research grade	C-ATBD Version 1+ ; paper on algorithm reviewed	Minimal	Limited data availability to develop familiarity	Limited or ongoing
3	Moderate code changes expected	Research grade; Meets int'l standards: ISO or FGDC for collection; netCDF for file	Public C-ATBD; Peer-reviewed publication on algorithm	Uncertainty estimated for select locations/times	Data and source code archived and available; caveats required for use.	Assessments have demonstrated positive value.
4	Some code changes expected	Exists at file and collection level. Stable. Allows provenance tracking and reproducibility of dataset. Meets international standards for dataset	Public C-ATBD; Draft Operational Algorithm Description (OAD); Peer-reviewed publication on algorithm; paper on product submitted	Uncertainty estimated over widely distributed times/location by multiple investigators; Differences understood.	Data and source code archived and publicly available; uncertainty estimates provided; Known issues public	May be used in applications; assessments demonstrating positive value.
5	Minimal code changes expected; Stable, portable and reproducible	Complete at file and collection level. Stable. Allows provenance tracking and reproducibility of dataset. Meets international standards for dataset	Public C-ATBD, Review version of OAD, Peer-reviewed publications on algorithm and product	Consistent uncertainties estimated over most environmental conditions by multiple investigators	Record is archived and publicly available with associated uncertainty estimate; Known issues public. Periodically updated	May be used in applications by other investigators; assessments demonstrating positive value
6	No code changes expected; Stable and reproducible; portable and operationally efficient	Updated and complete at file and collection level. Stable. Allows provenance tracking and reproducibility of dataset. Meets current international standards for dataset	Public C-ATBD and OAD; Multiple peer-reviewed publications on algortihm and product	Observation strategy designed to reveal systematic errors through independent cross-checks, open inspection, and continuous interrogation; quantified errors	Record is publicly available from Long-Term archive; Regularly updated	Used in published applications; may be used by industry; assessments demonstrating positive value

Maturity Matrix – Validation Layer Guideline

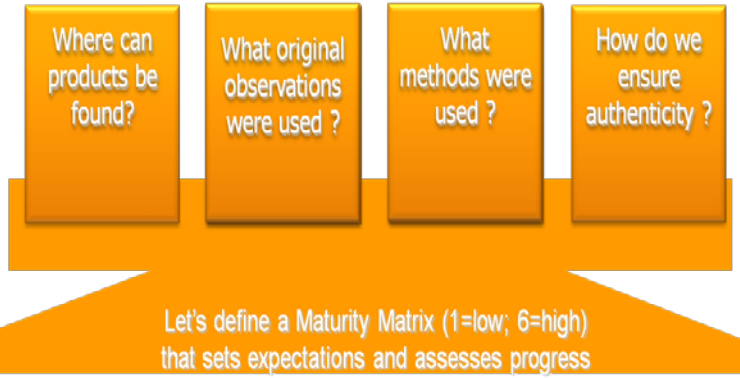
Maturity	PRODUCT VALIDATION	Independent validation	Uncertainty (for TCDRs)	Quality flag	Operational monitoring
1	Little or None	Incomplete	Little or no information on biases and errors	None	Incomplete
2	Minimal	Comparison to training set, test dataset, or previous product	Limited information on biases and errors	Data gaps identified or flagged as appropriate	Incomplete
3	Uncertainty estimated for select locations/times	At least 1 comparison to models, in-situ data, or other indpendent products as available and appropriate to particular CDR	Biases and errors identified and documented	Data gaps identified or flagged as appropriate; Masks applied as appropriate (e.g., land masks, cloud masks)	Incomplete
4	Uncertainty estimated over widely distributed times/location by multiple investigators; Differences understood.	At least 2 comparisons to models, in-situ data, or other indpendent products as available and appropriate to particular CDR; differences in results understood	Biases and errors quantified	Masks applied as appropriate (e.g., land masks, cloud masks); algorithm failures identified	Method for operational monitoring being developed
5	Consistent uncertainties estimated over most environmental conditions by multiple investigators	At least 5 comparisons to models, in-situ data, or other indpendent products as available and appropriate to particular CDR; differences in results understood	Biases and errors minimized	Masks applied as appropriate (e.g., land masks, cloud masks); algorithm failures identified; instrument degradation flags applied	Operational monitoring in place
6	Observation strategy designed to reveal systematic errors through independent cross-checks, open inspection, and continuous interrogation; quantified errors	At least 10 comparisons to models, in-situ data, or other indpendent products as available and appropriate to particular CDR; observation strategy designed to reveal systematic errors through independent cross checks, open inspection, and continuous interrogation	Biases and errors minimized	Masks applied as appropriate (e.g., land masks, cloud masks); algorithm failures identified; instrument degradation flags applied. Additional flags or modification of flag algorithms as a result of additional validation and user feedback	Operational monitoring in place with results fed back to quality flags

As an example ERA-Interim

Maturity	Software Readiness	Metadata	Documentation	Product Validation	Public Access	Utility
1	Conceptual development	Little or none	Draft Climate Algorithm Theoretical Basis Document (C-ATBD); paper on algorithm submitted	Little or None	Restricted to a select few	Little or none
2	Significant code changes expected	Research grade	C-ATBD Version 1+ ; paper on algorithm reviewed	Minimal	Limited data availability to develop familiarity	Limited or ongoing
3	Moderate code changes expected	Research grade; Meets int'l standards: ISO or FGDC for collection; netCDF for file	Public C-ATBD; Peer-reviewed publication on algorithm	Uncertainty estimated for select locations/times	Data and source code archived and available; caveats required for use.	Assessments have demonstrated positive value.
4	Some code changes expected	Exists at file and collection level. Stable. Allows provenance tracking and reproducibility of dataset. Meets international standards for dataset	Public C-ATBD; Draft Operational Algorithm Description (OAD); Peer-reviewed publication on algorithm; paper on product submitted	Uncertainty estimated over widely distributed times/location by multiple investigators; Differences understood.	Data and source code archived and publicly available; uncertainty estimates provided; Known issues public	May be used in applications; assessments demonstrating positive value.
5	Minimal code changes expected; Stable, portable and reproducible	Complete at file and collection level. Stable. Allows provenance tracking and reproducibility of dataset. Meets international standards for dataset	Public C-ATBD, Review version of OAD, Peer-reviewed publications on algorithm and product	Consistent uncertainties estimated over most environmental conditions by multiple investigators	Record is archived and publicly available with associated uncertainty estimate; Known issues public. Periodically updated	May be used in applications by other investigators; assessments demonstrating positive value
6	No code changes expected; Stable and reproducible; portable and operationally efficient	Updated and complete at file and collection level. Stable. Allows provenance tracking and reproducibility of dataset. Meets current international standards for dataset	Public C-ATBD and OAD; Multiple peer-reviewed publications on algorithm and product	Observation strategy designed to reveal systematic errors through independent cross-checks, open inspection, and continuous interrogation; quantified errors	Record is publicly available from Long-Term archive; Regularly updated	Used in published applications; may be used by industry; assessments demonstrating positive value
5.083333 	4.5	2	6 C-ATBD too restrictive	6 Global reanalysis has more comparisons to observations than anyone else before using them (short forecast). Plus some datasets are withheld completely, yet compared with.	6	6

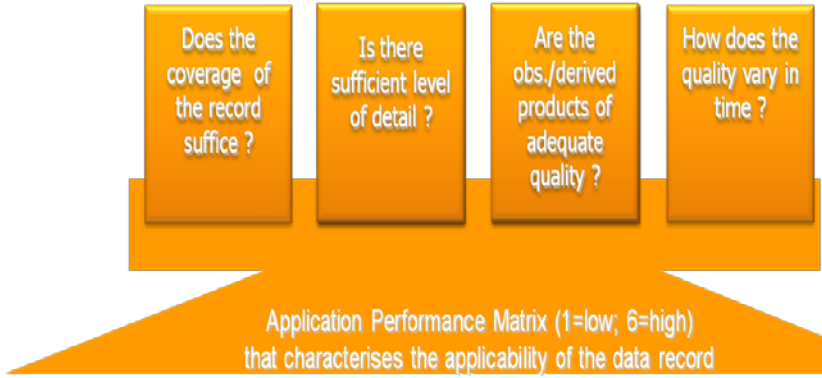
FP7 CORE-CLIMAX
Establishing Common Practices for Climate Observations

System Maturity Matrix



Software	Metadata	Documents	Uncertainties	Access	Utility
Are to codes compliant with standards, stable, portable and reproducible?	Do the metadata meets int. standards, and allow provenance tracking?	Are the formal documents and peer-reviewed papers up-to-date and public?	Are the uncertainties assessed systematically in a standard manner?	Are the data, source code, and documents publicly available?	Are the data wildly used in the scientific, decision and policy making communities?

Application Performance Matrix



Coverage	Sampling	Uncertainty	Stability
Are the record length and spatial coverage meeting the application's requirements?	Does the spatial and temporal sampling meet the applications requirements?	Does the random and systematic uncertainties meet the requirements?	Does the temporal stability meet the requirements?

Courtesy: John Bates (NOAA)

NASA Data Maturity Levels

- Beta level
  - Products intended to enable users to gain familiarity with the parameters and the data formats
- Provisional
  - Product was defined to facilitate data exploration and process studies that do not require rigorous validation. These data are partially validated and improvements are continuing
- Validated
  - Stage 1-4 validated

NASA Validation Stages

- **Stage 1 Validation:** Product accuracy is estimated using a small number of independent measurements obtained from selected locations and time periods and ground-truth/field program efforts.
- **Stage 2 Validation:** Product accuracy is estimated over a significant set of locations and time periods by comparison with reference in situ or other suitable reference data. Spatial and temporal consistency of the product and with similar products has been evaluated over globally representative locations and time periods. Results are published in the peer-reviewed literature.
- **Stage 3 Validation:** Product accuracy has been assessed. Uncertainties in the product and its associated structure are well quantified from comparison with reference in situ or other suitable reference data. Uncertainties are characterized in a statistically robust way over multiple locations and time periods representing global conditions. Spatial and temporal consistency of the product and with similar products has been evaluated over globally representative locations and periods. Results are published in the peer-reviewed literature.
- **Stage 4 Validation:** Validation results for stage 3 are systematically updated when new product versions are released and as the time-series expands.

Science Maturity Index (1/2)

- Initiated by concepts developed for Climate data record Generation
  - (see e.g. Bates and Privette 2012)
- However, there are also significant technical aspects in the CDR maturity model, whereas here we are trying to assess the scientific maturity of the centrally derived products
- The proposed index is based on four major maturity categories:
  - Scientific Understanding
  - Modelling of the physical principals
  - Instrument capability and characterisation
  - Validation
- All categories receive an estimate:
- 3= Highest achievable status, 2 = medium maturity and 1 = initial/immature
- The Scientific Maturity Index =
- Sum of the estimates per category (Max = 12, Min = 4)

Science Maturity Index (2/2)

- The purpose of the Index is to provide guidance on where efforts should be invested for future development.
- It is considered a useful complementary dimension based on an agreed assessment methodology.
- However, it is only one aspect that has to be considered.
- In addition the utility of the product for scientific application and exploitation has to be considered.
- Should also aid setting the overall priorities wrt to available resources..

An example for Metop Level-1 data

Product Processing Facility (PPF)	*Metop-A Status*	*Metop-B Status*	*Maturity Total (SU, M, ICC, VAL)*	*Remarks*
AVHRR Level 1	Operational	Operational	12 (3,3,3,3)	
AMSU-A Level 1	Operational	Operational	11 (3,3,2,3)	Some channel out of spec / failed
HIRS/4 Level 1	Operational	Operational	11 (3,3,2,3)	Some channels on Metop-B are at times out of specification
MHS Level 1	Operational	Operational	12 (3,3,3,3)	
IASI Level 1	Operational	Operational	12 (3,3,3,3)	
IASI L1 PCC	Operational	Operational	9 (3,2,2,2)	
ASCAT Level 1	Operational	Operational	10 (3,2,2,3)	
GOME-2 Level 1	Operational	Operational	11 (3,3,2,3)	Metop-A operating in 960km and Metop-B in 1920km swath mode.
GRAS Level 1	Operational	Operational	9 (3,2,2,2)	GO

Metop Level-2 Products (Derived at EUMETSAT HQ)

PPF	*Product Status*	*Maturity Total (SU, M, ICC, VAL)*	*Remarks*
IASI temperature and humidity retrieval	Operational	11 (3,2,3,3)	
IASI Ozone total column	Operational	11 (3,3,3,2)	
IASI CO profiles	Operational	10 (3,2,3,2)	Validation on-going with O3M SAF
IASI trace gases (ozone profiles, N_2O, CH_4, CO_2)	Demonstrational	7 (2,2,2,1)	Development started for CH_4
IASI surface emissivity	Pre-operational	7 (2,2,2,1)	
IASI Cloud Parameters	Operational	11 (3,3,2,3)	
IASI SST L2Pcore	Operational	11 (3,3,3,2)	
ATOVS Level 2	Operational	12 (3,3,2,3)	Some degradation for Metop-A due to noisy or missing AMSU-A channels
ASCAT Soil Moisture	Operational	8 (2,2,2,2)	H-SAF product operated
Polar Cap Winds from AVHRR	Operational	9 (3,2,2,2)	
Global AVHRR Winds	Operational	7 (3,2,1,1)	
Triplet AVHRR Winds	Pre-operational	7 (3,2,1,1)	
Polar Multi-sensor Aerosol properties over sea	Operational	9 (3,2,2,2)	
Polar Multi-sensor Aerosol (v2) including land	Pre-operational	8 (3,2,2,1)	Validation on-going

Science Readiness Level - Another matrix approach
Initial attempt (in coop with SAFs, DBs, ESA)– to be refined

SRL	Name	Associated documents	Theory / Model	Observation	Validation / Verification	User
1	Scientific Idea		Scientific idea	Non	non	define Application Area Interest from Users
2	Conceptual Technique		Conceptual model, physical principal is clearly defined (no software is needed)	Gap analysis; complementary in observation system; uniqueness		Set high level draft EURD
3	Scientific / Observation Requirements	Mission proposal	Forward model is available (i.e. RTM simulation of measur.)		Initial capability assessment (Info content anal.)	Scientific requirements vs user requirements approved
4	Proof of concept	MRD	Consolidated approach 1st sim. obs are available	Simulated measurements		Consolidated EURD
5	End-to-end performance simulations	Stable MRD, E2E (End-to-end simulator)	Consolidated retrieval and draft ATBD (+ prototype) are available	Demonstrator (e.g. airborne instr) “real data”	Calibration and Validation Plan established	Final EURD Committed Beta-User (e.g. through AO call’s)
6	Consolidated science and products (end: launch of sat)	ATBD’s	Final ATBD and operational processor / implementation	Pre-launch	Test data and sampled data processing	User studies with simulated or pre-cursor data
7	Demonstrated science (commissioning phase)			In orbit characterisations; perf vs. spec (EURD)	CAL/VAL conducted,; Early release of data; beta /demo data ava.	User feedback (validation team)
8	Validated and matured science(sat declared op)	Science feedback			Full validation	Operational validation and quality assurance via network
9	Science Impact quantification	Advancement in scientific understanding				User impact

Thank You
Questions?