EUMETSAT science roadmaps and product development

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Member State visit to Croatia

Zagreb, 13 February 2020

Topics

- EUMETSAT product development in a nutshell
- Concept of Science Roadmaps – medium-term product evolution
- Highlights and some examples of product development in the Science Roadmap context
- EUMETSAT's next generation satellite programmes with expected improvements
    - Meteosat Third Generation (MTG), **2022 →**
    - EUMETSAT Polar System Second Generation (EPS-SG), **2023 →**
- Summary

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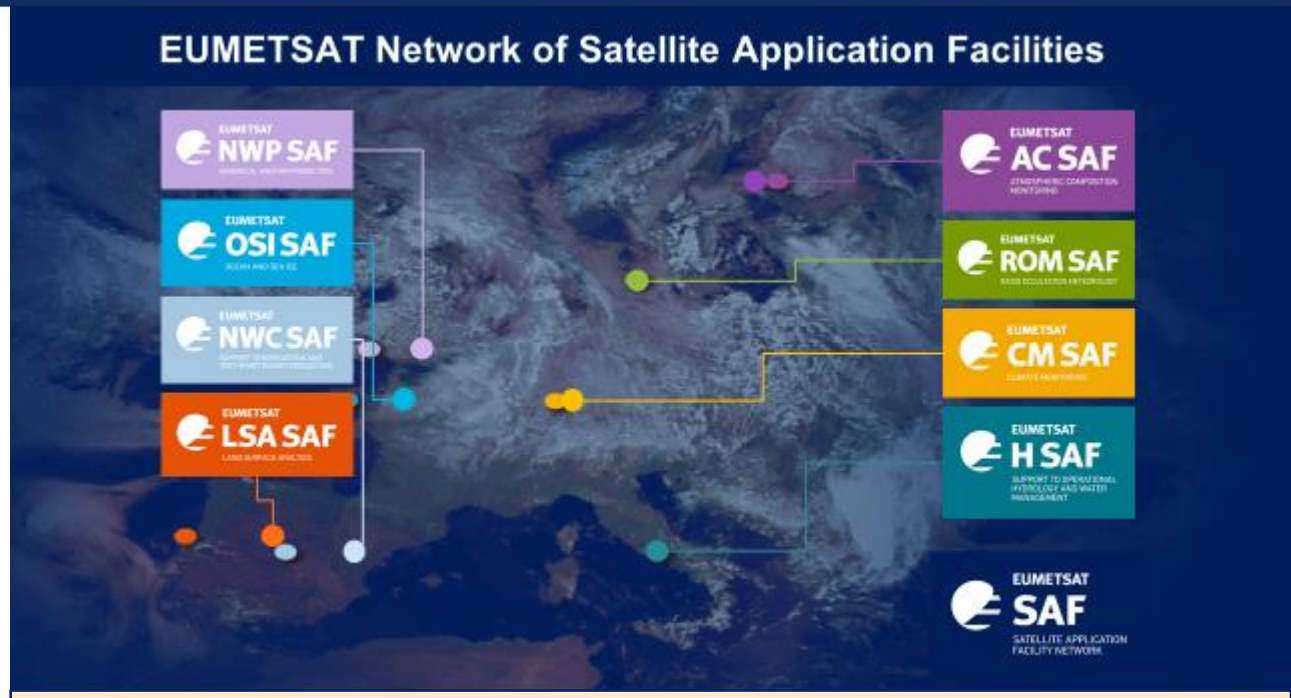
EUMETSAT product development in a nutshell

- EUMETSAT product development is shared between Satellite Application Facilities (SAF) and the Central Facility at EUMETSAT HQ
  - SAFs are an integral part of the EUMETSAT application ground segment
  - HQ development is required for L1 products and many Day-1 L2 products
- HQ product development is steered by the thematic **Science Roadmaps**, which are created in consultation with the SAFs



SAFs:

- Specialised on topics and themes, targeting specific communities and applications
- Located at Weather Services in EUMETSAT Member and Co-operating States
- Developed and operated by consortium of partners

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Science Roadmaps – *medium-term product evolution*

The scientific product development roadmaps are medium-term product/thematic plans that specifically address key issues of the product maintenance and evolution process:

1. ***The development of medium-term product/themed roadmaps with the objective:***
   - To maintain/improve the operational dataset quality;
   - To provide “scientifically relevant” and “up-to-date” datasets;
   - To ensure the provision of fully characterised, traceable, and ultimately interoperable datasets;
   - To address changing user and service needs and requirements, such as for coastal zones, the hydrology cycle, the Arctic, etc.;
   - To optimize efforts and resources within EUMETSAT and its Member States.

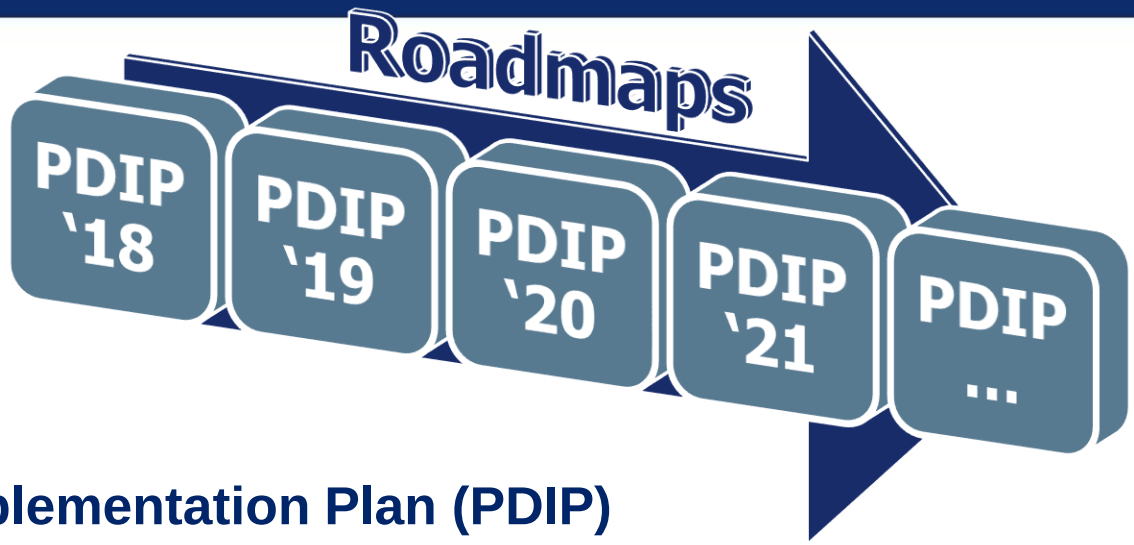
Roadmaps – *medium-term product evolution* (ii)

The Scientific Product Development Roadmaps are mid-term product/thematic plans that specifically address key issues of the product maintenance and evolution process:

2. The roadmaps process consists of:

- An internal assessment of the state of the field;
- Consultations with the SAFs, the Member States, Partner Agencies, and International Organisations;
- Providing a “white paper” covering the objectives and milestones of the roadmap to the EUMETSAT Delegate Bodies;
- A dedicated annual update on roadmap progress, to be presented to Delegate Bodies (with external review mechanisms when necessary, i.e. with the MAGs);
- Updating the roadmap schedule, comprising of a combination of evolutions, new developments and studies, annually, including a release plan for the products of following year in the **Product Development and Implementation Plan (PDIP).**

Roadmaps – *implementation through the PDIP*



The Scientific Roadmaps are implemented through the Product Development and Implementation Plan (PDIP)

The annual PDIP specifically addresses:

1. The release of Product Processing Facility (PPF) evolutions for EPS, MSG, Jason(s), and Sentinel-3 for the upcoming year
2. The planned studies for the upcoming years in support of the PPF evolutions, and are traceable to the roadmaps
3. The planned studies for the upcoming year in support of the future programmes

Roadmaps – *status* (1/2)

Aerosols (approved Autumn 2017)

- Implementation of simultaneous surface/aerosol/cloud retrievals for LEO and GEO instruments, while specifically addressing needs from the Copernicus Atmospheric Monitoring Service (CAMS), the WMO-SDS (sand and dust storms), and the VAACs (volcanic ash monitoring)

Atmospheric Motion Vectors - AMVs (approved Autumn 2017)

- Implementation of a modular LEO/GEO toolbox for AMVs with improved cloud heights and harmonised Quality Indicators (for inter-operability across agencies) and parallel developments of 3-D winds from hyperspectral IR sounders

Image Navigation, Registration and Calibration (approved Spring 2018)

- Working towards the operationalisation of multi-mission Image Quality (PICMICS) and Calibration (MICMICS) tools

Radio Occultation (approved Spring 2018)

- The RO roadmap **was developed with the ROM-SAF** and focuses on the evolution of the operational RO products (incl. uncertainty metrics), the development of Space Weather capabilities, and the mid-term implementation of a high accuracy POD (Precise Orbit Determination)

Roadmaps – *status* (2/2)

Hyperspectral Infrared (approved Autumn 2018)

- Working towards interoperability of IASI/IASI-NG/IRS, and directly support NWP, nowcasting, and end-user meteorological applications such as tools for forecasters

Atmospheric Chemistry (approved Spring 2019)

- Working towards the interoperability of GOME-2/Sentinel-5/Sentinel-4, and directly support the development of multi-sensor retrievals (e.g. IASI-NG and Sentinel-5) **in consultation with the AC-SAF**

To be followed by:

Fiducial Reference Measurements (2020)
Clouds (2020)
Marine (2020)
Passive Microwave (2020)
Meteorology and Marine Pathfinders (2021)

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…some highlights of the current Science Roadmaps

- Aerosols
- Atmospheric Motion Vectors (AMV)
- Radio Occultation (RO)
- Hyperspectral InfraRed (HSIR)
- Atmospheric Chemistry (ACh)

Aerosol Retrieval Approaches

Aerosol Roadmap Whitepaper EUM/TSS/PLN/17/910992 approved by STG/SWG → *Toward simultaneous surface/aerosol retrieval*

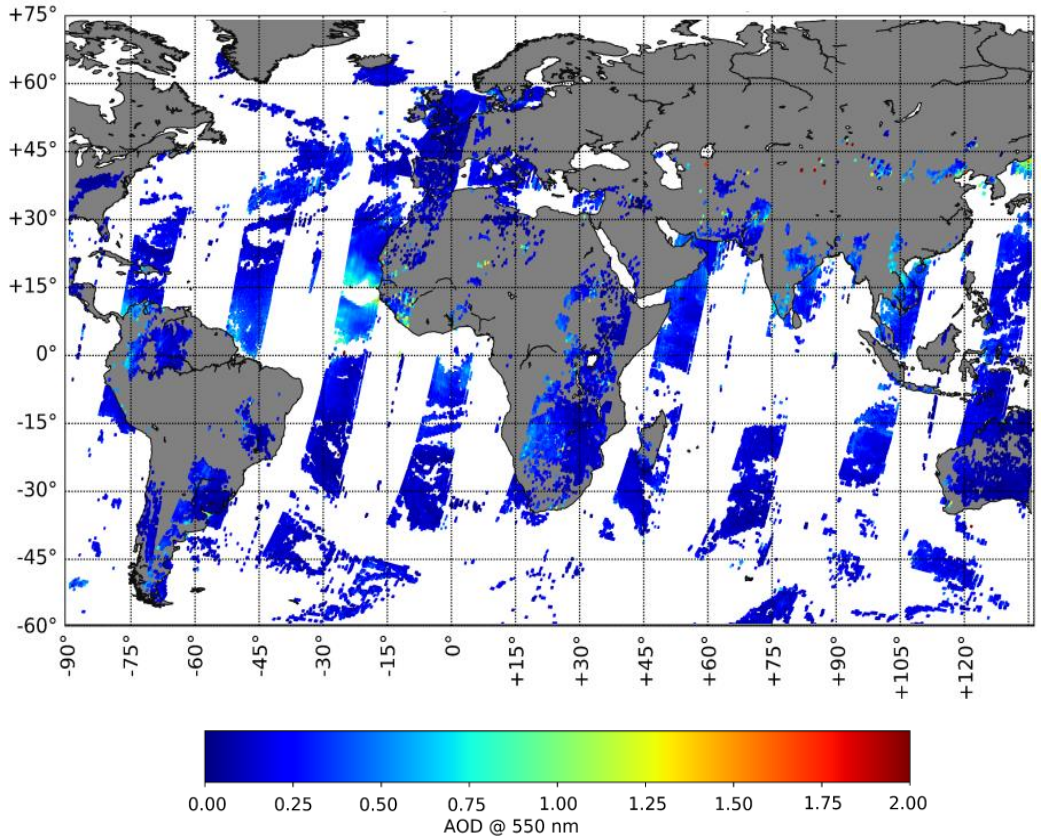
Algorithm and its performance (results as well as processing time for NRT) is strongly driven by the information content

- **EPS/PMAp** : Combination of instruments
  - LUT retrieval and spectral combination (Grzegorski et al. in prep)
- **S3/SLSTR** : Dual-view radiometer
  - Aerosol retrieval with a physical based surface model from U. Swansea (North. et al. 1999)
- **MSG/MTG** : Geostationary imagers
  - Simultaneous aerosol / surface retrieval with AERUS (Carrer et al. 2014)

Aerosol Product from EPS : PMAp

- Polar Multi-Sensor Aerosol product = AOD(550nm) + aerosol type classification
- Algorithm based on spectral and LUT approach (Grzegorski et al. in prep.)
- V2.1 operational – Activation of PMAp-C and progress on V2.2

V2.1 AOD(550) : MetopC 20190227



PMAp fact sheet:

V1:

- **AOD over ocean and under clear-sky, as well as partially cloudy conditions.**
- **Data from two Metop instruments, GOME-2 and AVHRR, are used.**

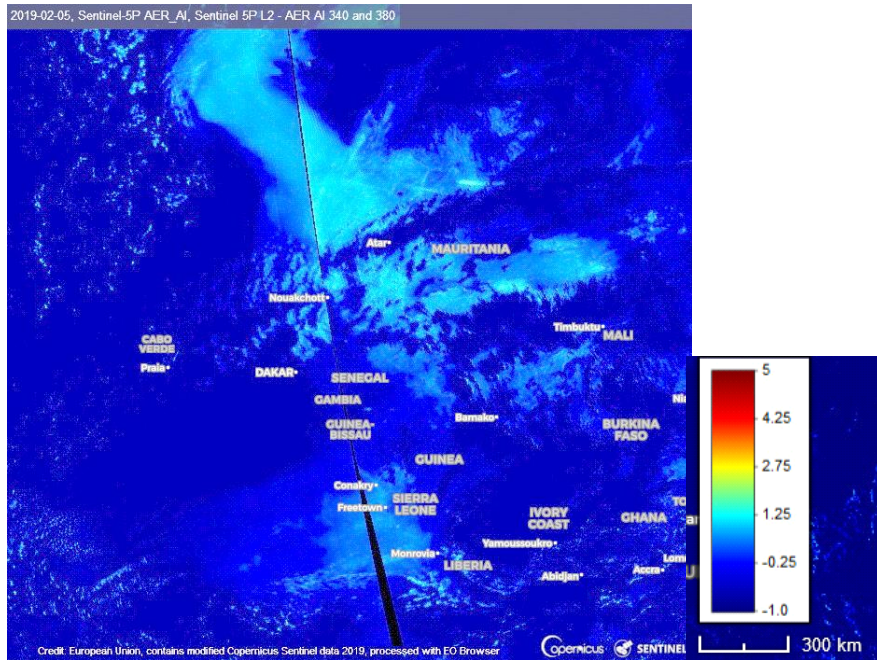
V2:

- **Extending the retrieval of AOD to land surfaces.**
- **Improved quality of the volcanic ash detection.**
- **Extended radiance range towards the blue and UV regions of the GOME-2 spectrum, and information from IASI thermal infrared measurements.**

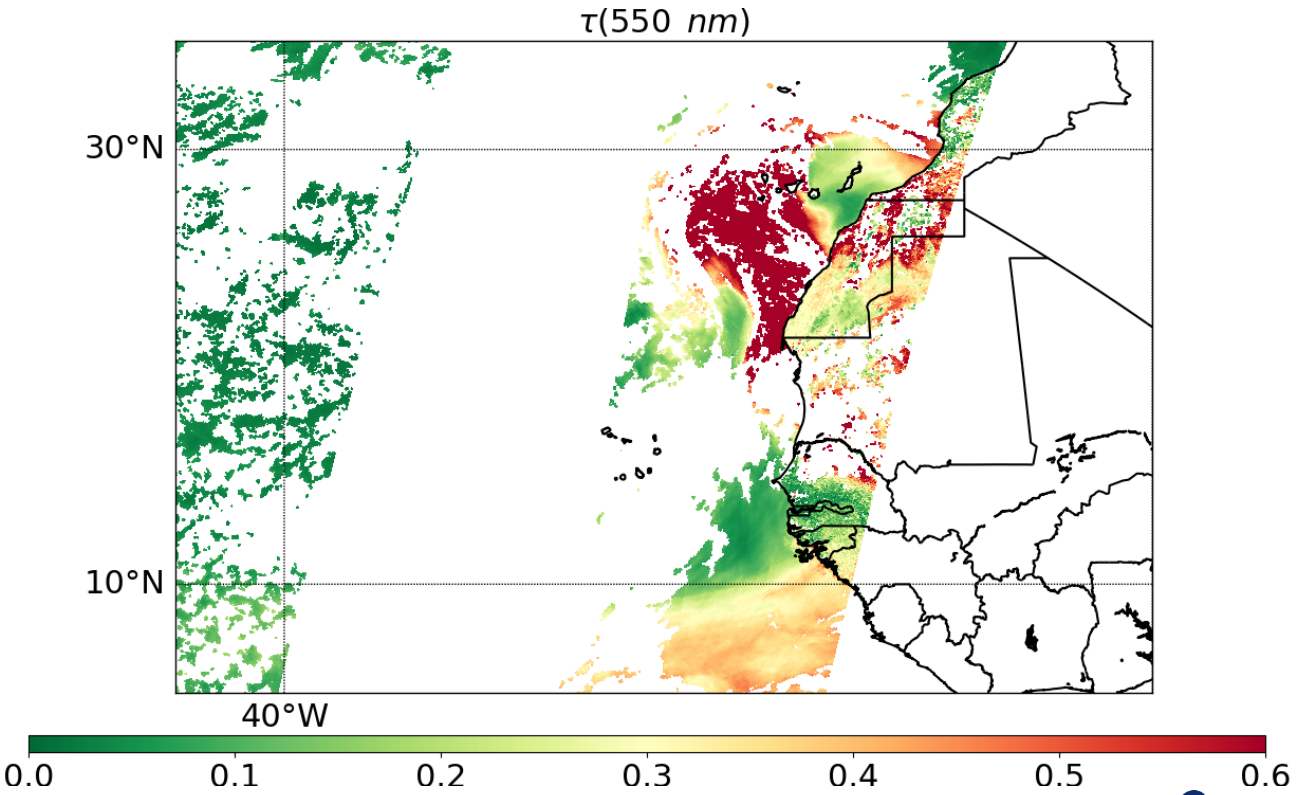
Aerosol Product from Sentinel-3 : SLSTR

- SLSTR (Sea and Land Surface Temperature Radiometer): aerosol retrieval with a physical based surface model from U. Swansea
  - Under development and validation (North. et al. 1999)

S5P-Tropomi over Middle Atlantic



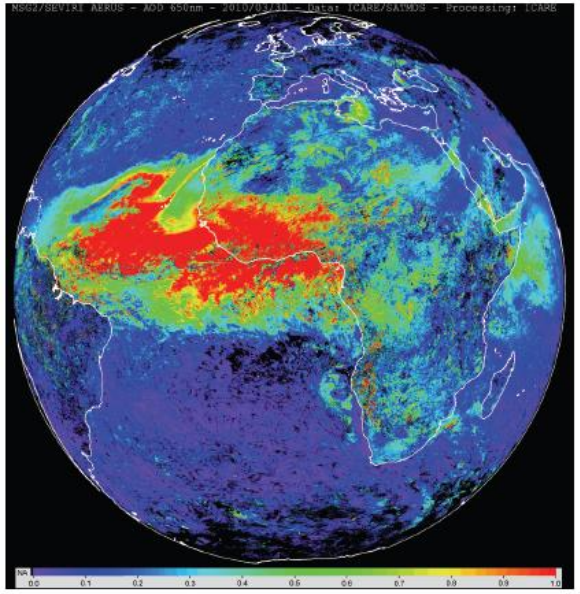
SLSTR retrieval over Middle Atlantic



EUMETSAT

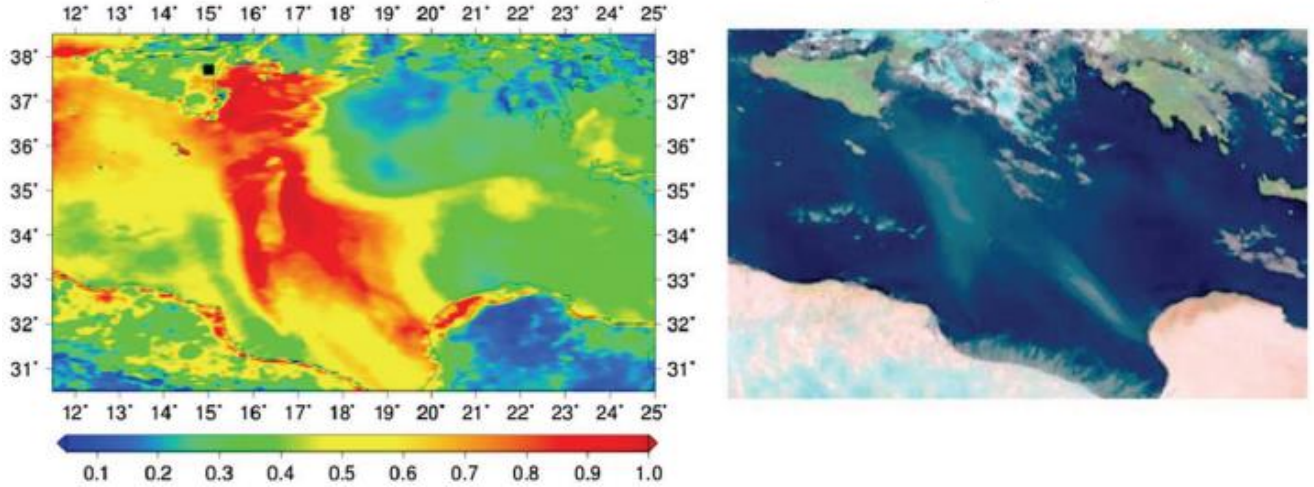
Aerosol Product from MSG: SEVIRI

- Simultaneous aerosol / surface retrieval with AERUS-GEO (Aerosol and surface albEdo Retrieval Using a directional Splitting method – application to GEOstationary data)
- Approach according Carrer et al., 2010; 2014
- Daily retrieval for MSG/SEVIRI available in ICARE (U. Lille)
- Instantaneous retrieval (up to 96/day) under development
- **Planned to be operationally implemented in EUMETSAT for MTG/FCI**



Daily AOD at 0.64µm on March 30th, 2010

Capture of aerosol plume from Etna volcano on April 15th, 2010



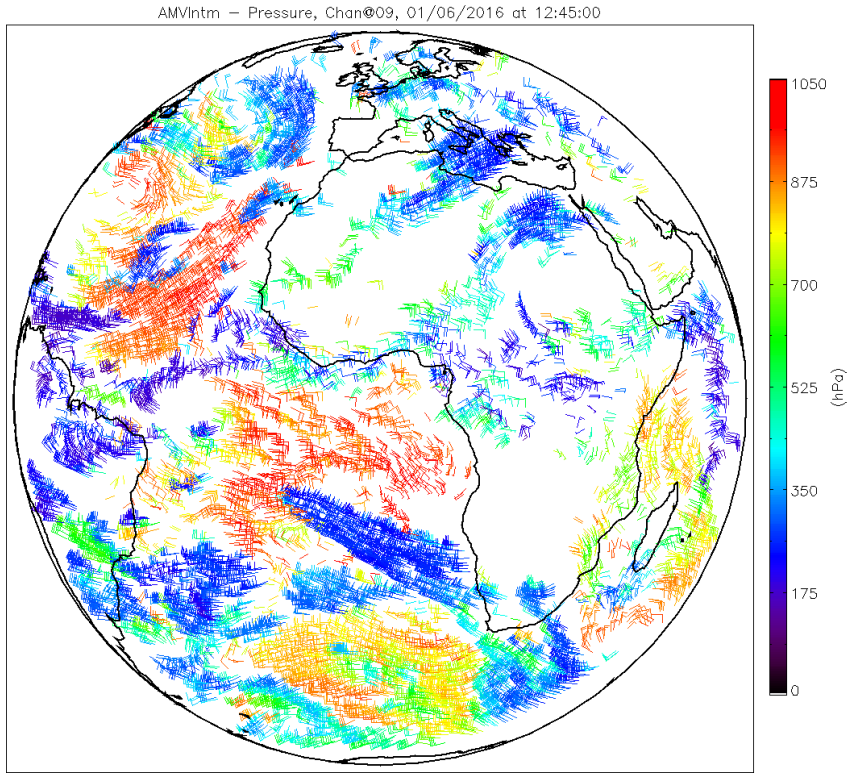
(Ceamanos et al. 2018)

From the AMV roadmap activities…

- MTG-FCI
  - ✓ Comparison MSG-MTG performances of AMV algorithms
  - ✓ Scientific validation started with other satellite data sources (Himawari-8/9) and AMV algorithm (GEOKompsat)
- EPS-SG METImage
  - ✓ Preparation of MetImage AMV prototype code (by Q3 2019).
- IR 3D winds
  - ✓ Software released to use both T, Q and O3. Adapted to use IASI L2 product.
  - ✓ Demonstration period (June 2017) produced and sent to users (Q3 2018)
  - ✓ Inter-comparison/validation of 3D IASI winds
  - ✓ Evolution towards continuous operations (by 2020).
- S3/SLSTR
  - ✓ AMV prototype code adapted to ingest outputs of reprojection tool using AVHRR data. Ready to be adapted to SLSTR data when reprojected data available (during 2019).

AMV perspectives for MTG-FCI

- Improvements expected from MTG-FCI data
  - Repeat cycle: 15 min (MSG SEVIRI)10 min (MTG FCI)
  - Pixel size: 3 km (MSG SEVIRI) 2 km (MTG FCI)
- Main changes from MSG AMV scheme
  - Use 3 images instead of 4 (1/2 hourly product)
  - No averaging process
  - Better Cloud product expected to set the altitude
- MTG FCI AMV prototype developed
  - Adapted to both MSG data and Himawari data



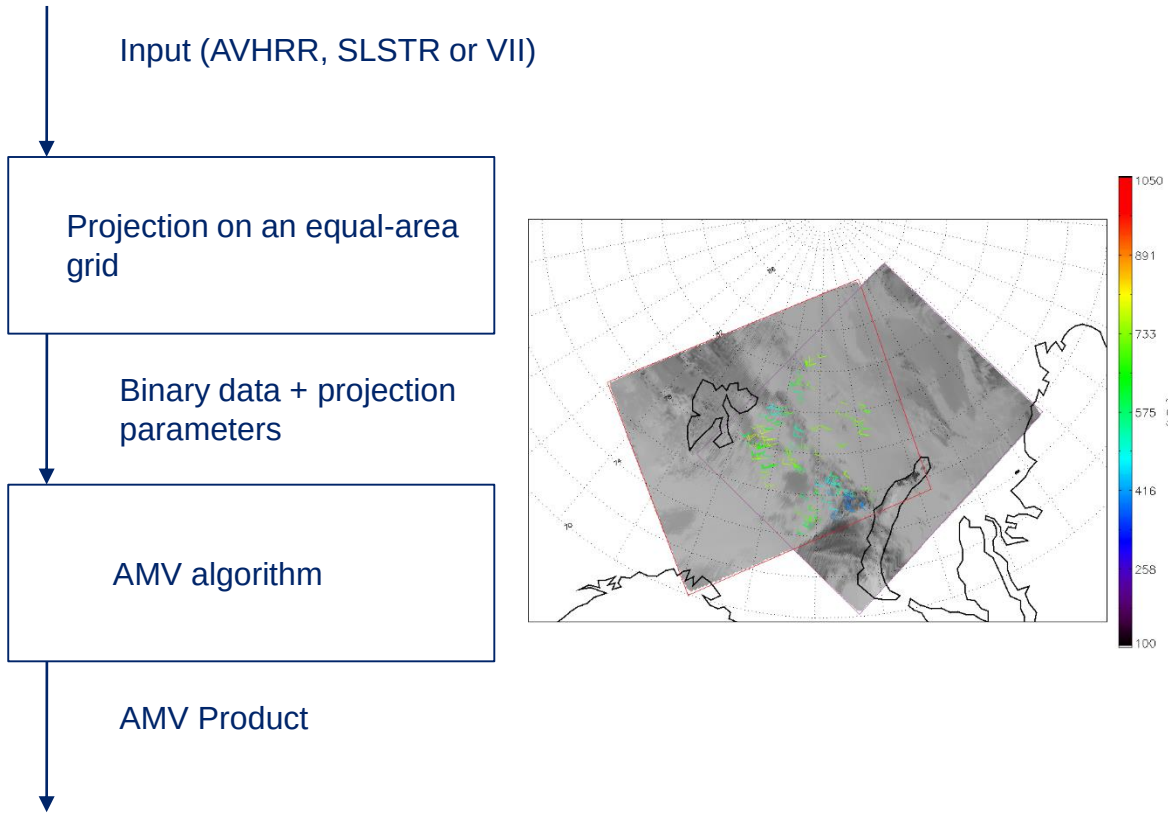
Example of AMV extraction from MTG-FCI algorithm using MSG data on 01/06/2016 at 12:45 (IR10.8 channel).

Common AMV Framework for LEO Satellites

- Common framework for S3 SLSTR, EPS-SG VII (and EPS AVHRR): data are first projected onto an equal-area grid, and AMVs are derived from the resulting images.

- Projection tool developed at EUMETSAT (INRC team).

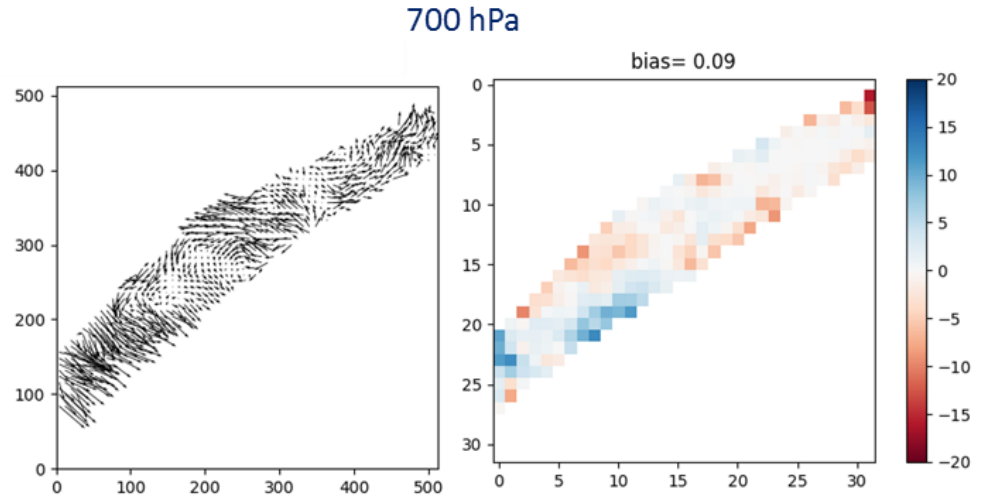
De Bartolomei. M., Generic Projection Tool - Technical Note, EUMETSAT Doc. EUM/RSP/TEN/18/1030434, 2019

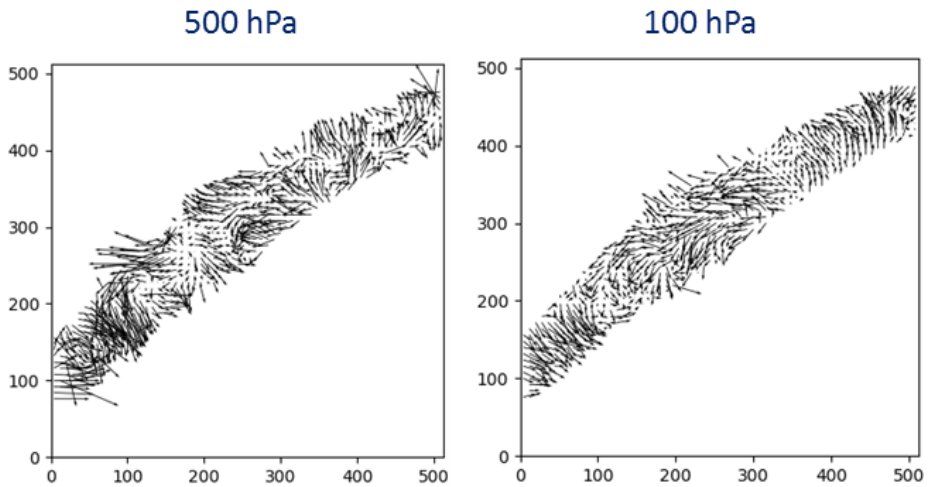


[left] flowgram of the method, [right] AMV derived from a pair of projected SLSTR images of the Arctic Ocean on 04/07/2018, UTC time: 15:53:21 (purple contour) and 17:34:20 (red contour).

Perspectives 3D winds from IR sounders

- 3D winds product is in development from IASI L2 humidity, ozone and temperature profiles.
- Dense wind fields obtained using optical flow methods.
- Operational production expected in Q3 2020.





Example of 3D IASI winds extracted:

- at 700, 500 and 100 hPa
- from *Metop A* and *Metop B* consecutive orbits
- over northern polar areas on 4 July 2018 at 00:46:09 UTC.

Speed bias against forecast fields is shown for the 700 hPa retrieval

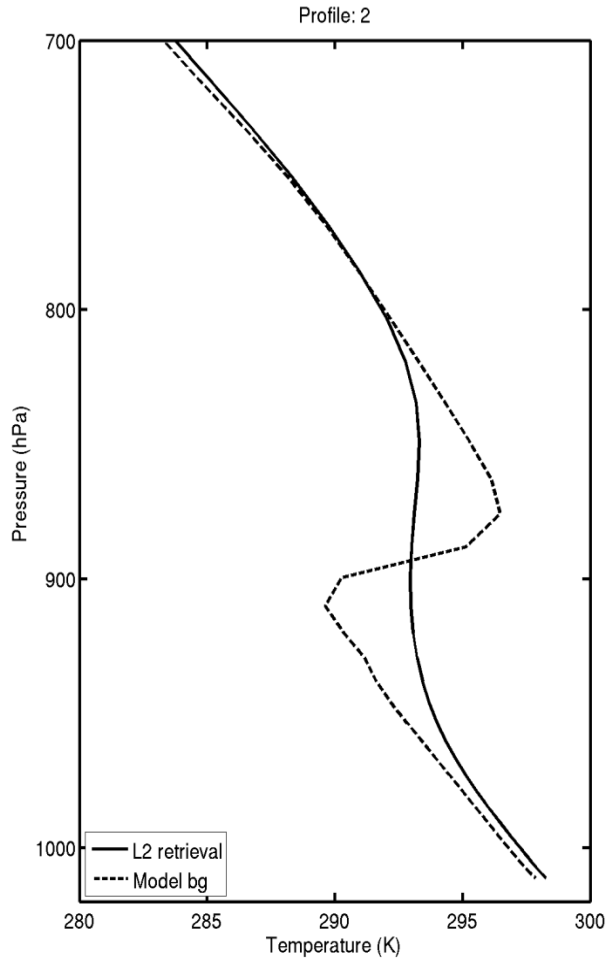
Hyperspectral InfraRed (HSIR) Scientific Roadmap

- **Scientific Product Development Roadmap for HSIR approved Autumn 2018**
- Two of the main activities outlined in the Roadmap are:
  - The developments of a **common L2 toolbox for IASI/IASI-NG/IRS**
  - Support user preparations for Nowcasting – e.g. running ESSL testbed activities with IASI L2 profile data as a preparation for IRS (soundings from IASI: 2/day → IRS: 48/day!!)

→ IASI v6.5 roll-out, currently on GS/2, will be the first release of the L2 toolbox common to all EUMETSAT HSIR instruments

ESSL = European Severe Storms Laboratory, Wiener Neustadt, Austria

A note on the vertical resolution of IASI/IASI-NG/IRS



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

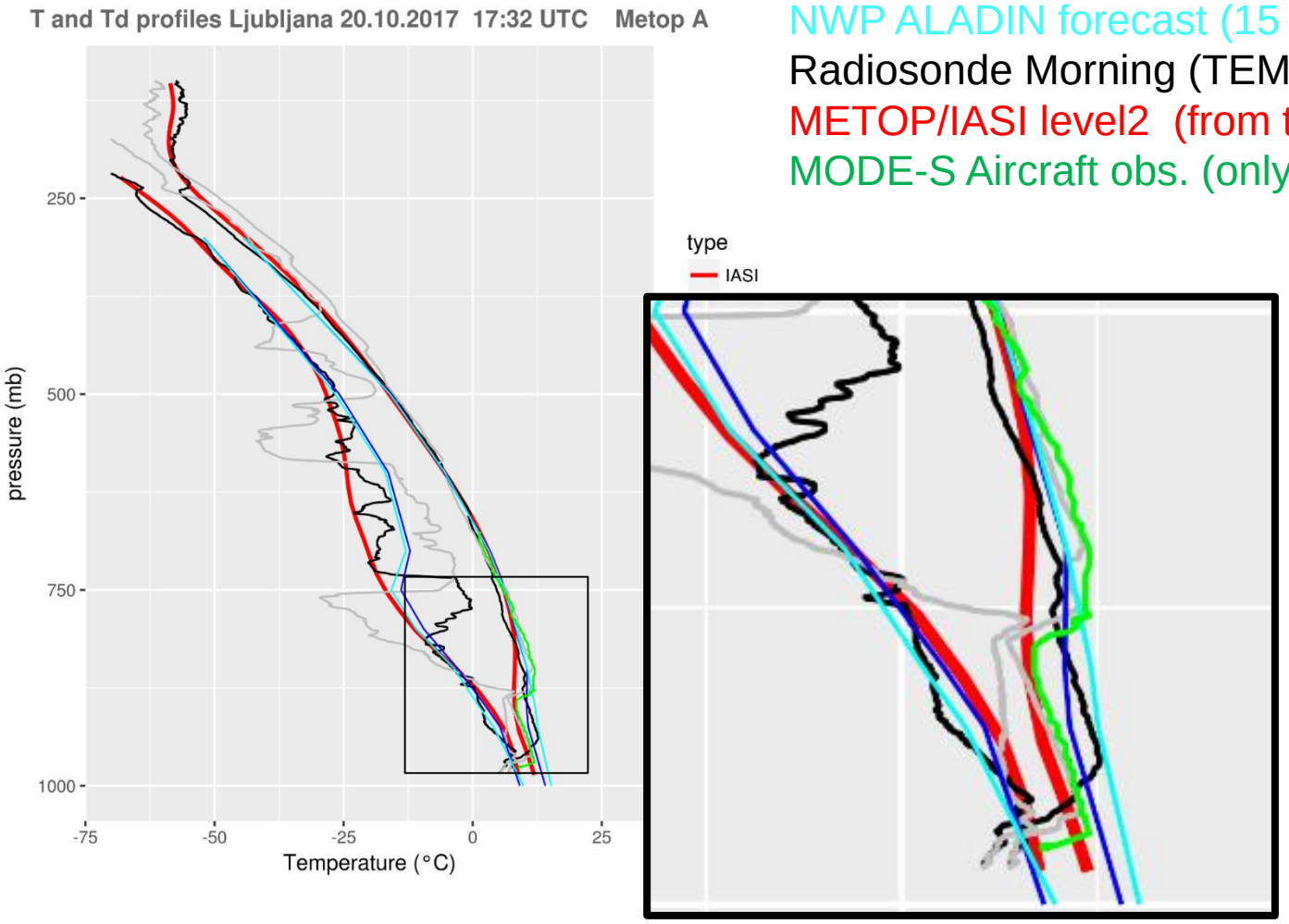
Small vertical structures do not affect the radiances at the top of the atmosphere.

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

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

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

Case study: Ljubljana 20 November 2017



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

First results:

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

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

Data: Mateja Irsic, ARSO

Radio Occultation

- **Scientific Product Development Roadmap for RO approved Spring 2018**

- Metop-A/-B/-C
  - GRAS data quality of Metop-C highly consistent with Metop-A and –B;
  - Operational level 1 dissemination has commenced on 7 Mar 2019, jointly with ROM SAF level 2;
  - First Metop-C products operational.

- Operational GRAS processor to be updated with improved wave optics (includes uncertainty estimates).

- Ongoing specification and test data preparation for EPS-SG and Jason-CS.

- Ongoing evaluation of Precise Orbit Determination (POD).

From the Atmospheric Chemistry roadmap activities…

- Focus on inter-operability of MTG-S UVN/Sentinel-4 and EPS-SG UVNS/Sentinel-5
  - ✓ Encourage common on-ground calibration and characterisation practices
  - ✓ Develop a common in-house level 1 reference processor framework
  - ✓ Develop common level 2 product processor elements
  - ✓ Develop multi-mission radiance, irradiance, and trace gas product monitoring capabilities
  - ✓ Develop a common radiance, irradiance and trace gas calibration & validation plan, incorporating common tools and methods
- Directly support the development of multi-sensor retrievals (e.g. IASI-NG and Sentinel-5)

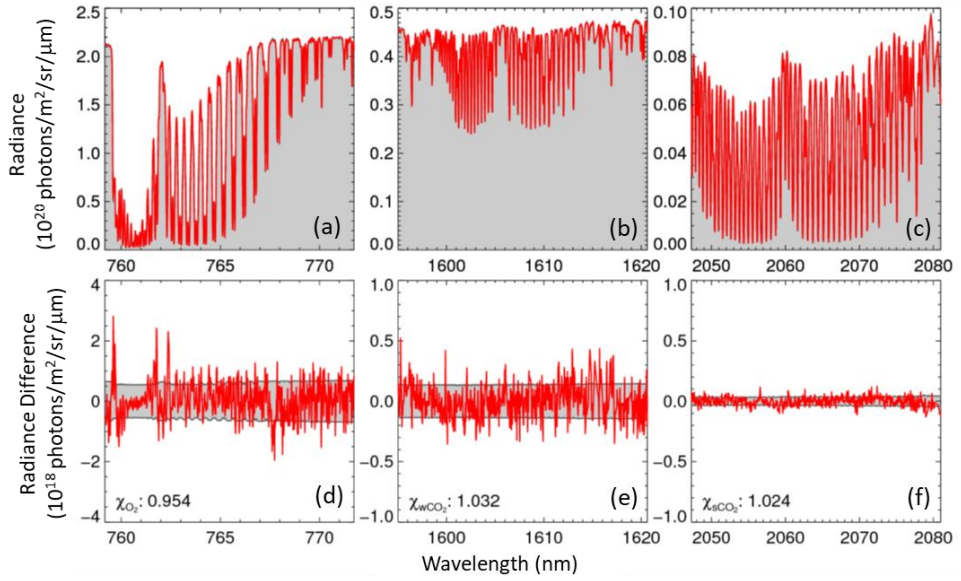
Opportunities for Cross-Calibration (GSICS)

EUMETSAT & Copernicus Reflective Solar Spectrometers

- Metop GOME-2
- MTG-S Sentinel-4
- EPS-SG Sentinel-5
- Future CO_2 monitoring (constellation anticipated so cross-calibration important!)

Activities for Reflective Solar Spectrometers

- Solar Spectrum comparison and reference
- White Paper on Ground-based Characterisation
- Cross-comparison during match-ups
  (LEO vs LEO Simultaneous Nadir Overpass, Chasing Orbits (Opportunistic Formation Flying, LEO under flights of GEO)
- Cross-comparison at Target Sites
  (Sahara, Pacific, Ice sheets, Salt pans …)
- Cross-calibration below 300nm

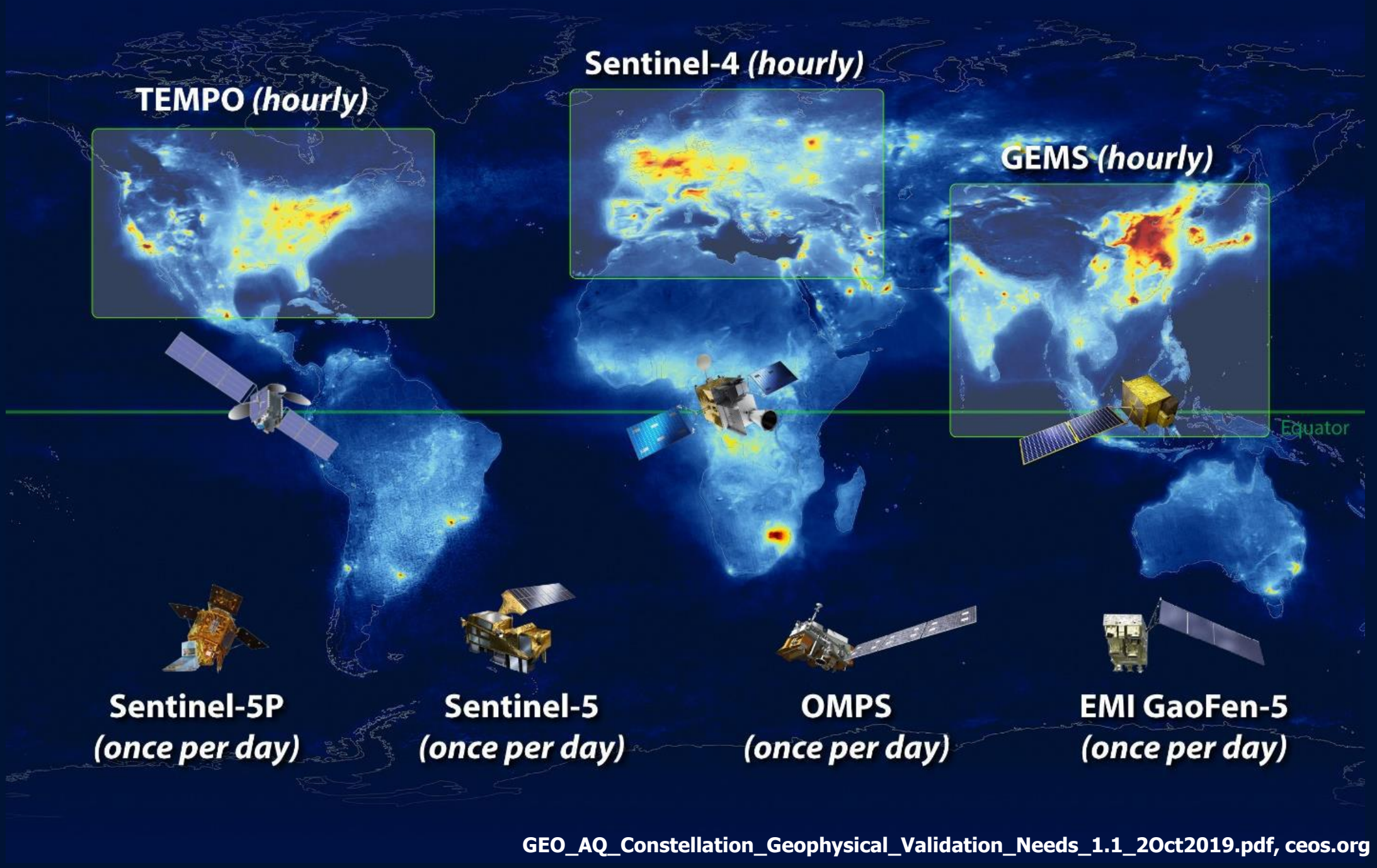


Credit: Reuter et al. 2017

Common Validation Approach (Trace Gas Products)

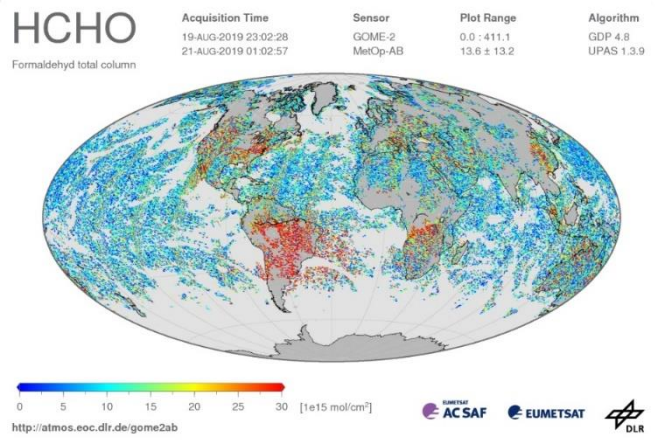
3 phases: commissioning, pre-operational, operational/routine

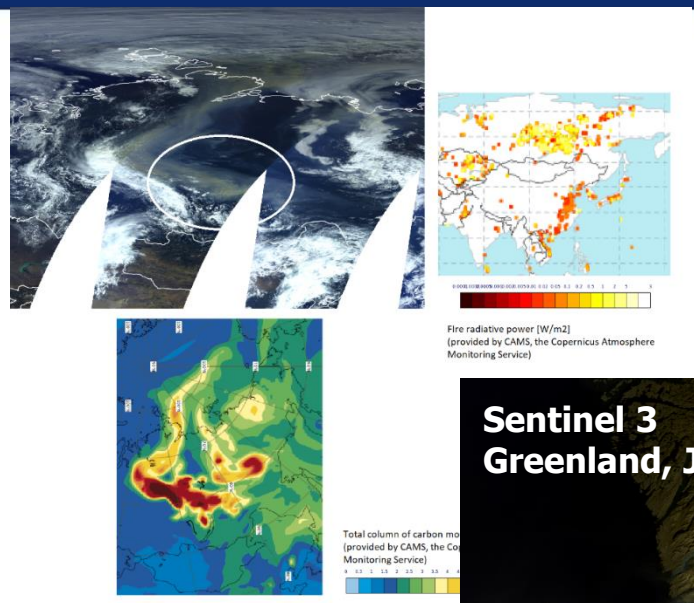
- **Ground-based observations:**
  - Networks of stations: NDACC, Pandonia, WOUDC, Eubrewnet, TCCON, AERONET, MPLNET, EARLINET, GALION
  - Data Centres/archives: EVDC, AVDC, GAWSIS, ACTRIS
  - Instrument types: MAX-DOAS, BREWER, FTIR/FTS, MWR, Spectral UV, Sonde, Lidar, SAOZ, Aircore
- **Measurements from instruments on board of other LEO/GEO satellites:**
  - OMPS, TROPOMI, GEMS, TEMPO, GF-5 EMI, OCO-2, OCO-3, GOSAT-2, Tansat …
- **Cross-comparison/validation among EUMETSAT products:**
  - GEO/LEO UVNS inter-comparison: GOME-2, Sentinel-5/UVNS and Sentinel-4/UVN
  - GEO/LEO IR spectrometers: IASI, IASI-NG and IRS
  - UVNS/IR inter-comparison: Sentinel/5/IASI-NG and Sentinel-4/IRS
  - Copernicus CO_2M constellation (plus with other GHG missions)
- **Dedicated campaigns (if needed, operations only):**
  - Ground-based
  - Aircore/Sondes
  - Balloon and/or Airborne campaigns
- **Model-based validation?**
  - Direct assimilation of trace gas products (e.g. CAMS)
  - CAMS re-analysis



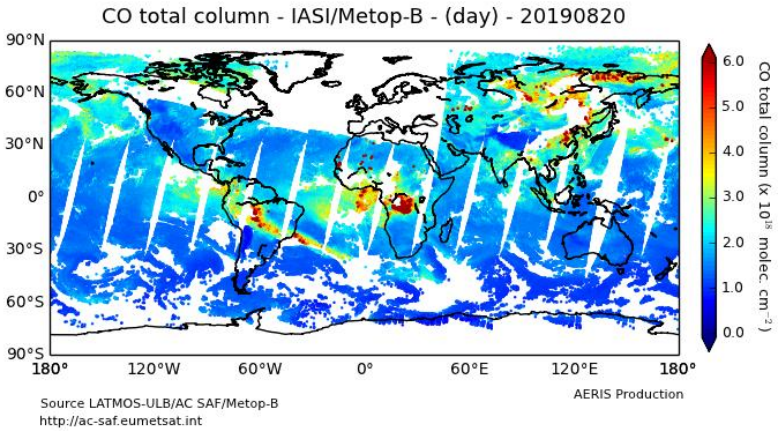
GEO_AQ_Constellation_Geophysical_Validation_Needs_1.1_2Oct2019.pdf, ceos.org

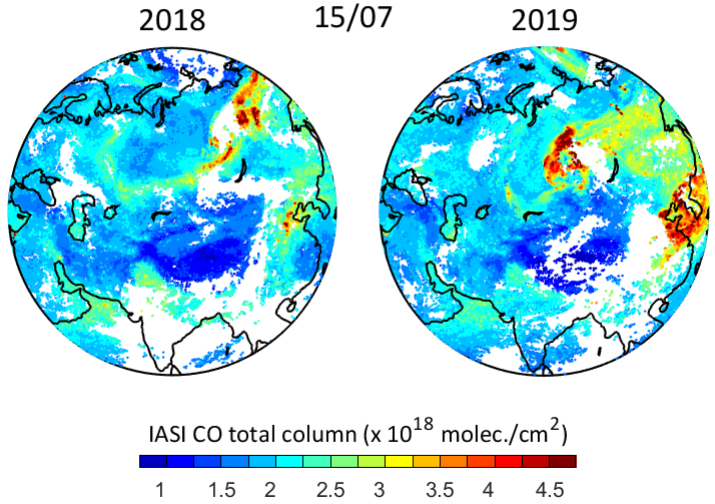
Synergy of Observation Missions: 2019 Stories on Fires





IASI CO and GOME-2 Formaldehyde – Amazon data





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Meteosat Third Generation: Mission

- Primary mission: support nowcasting/ Short Range Forecasting of high impact weather
  - Continuity and enhancement of MSG imagery
  - Addition of a new lightning imaging capability
  - New, innovative infrared hyper-spectral sounding
- Secondary mission: air quality monitoring over Europe
  - Synergy between Sentinel-4, IRS and imagery

Meteosat Third Generation: Imaging mission (MTG-I)

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

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

Meteosat Third Generation: Sounding mission (MTG-S)

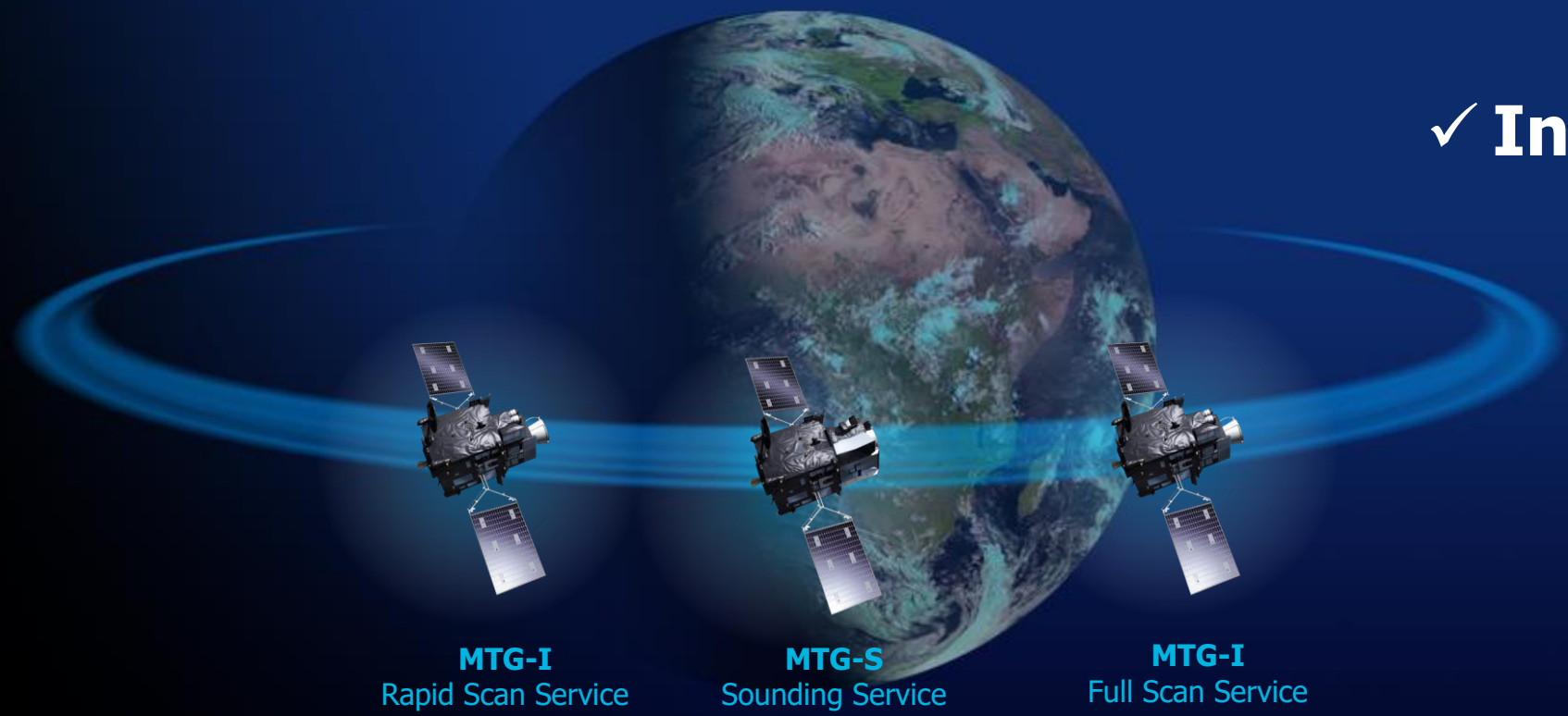
- Hyperspectral infrared sounding mission
- 4D weather cube: temperature, water vapour, O_3, every 30 minutes over Europe
- Air quality monitoring and atmospheric chemistry in synergy with Copernicus Sentinel-4 instrument

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

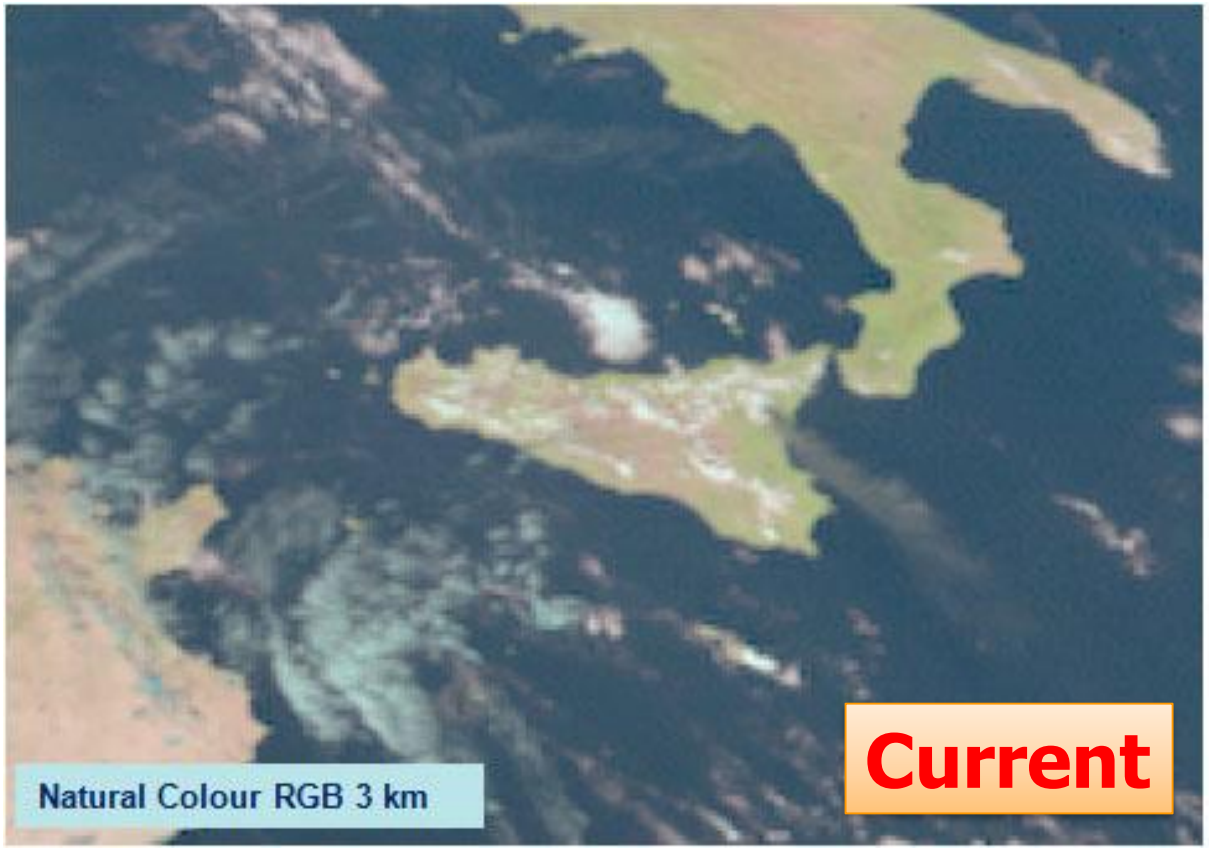
MTG full operational configuration: ~ 2026

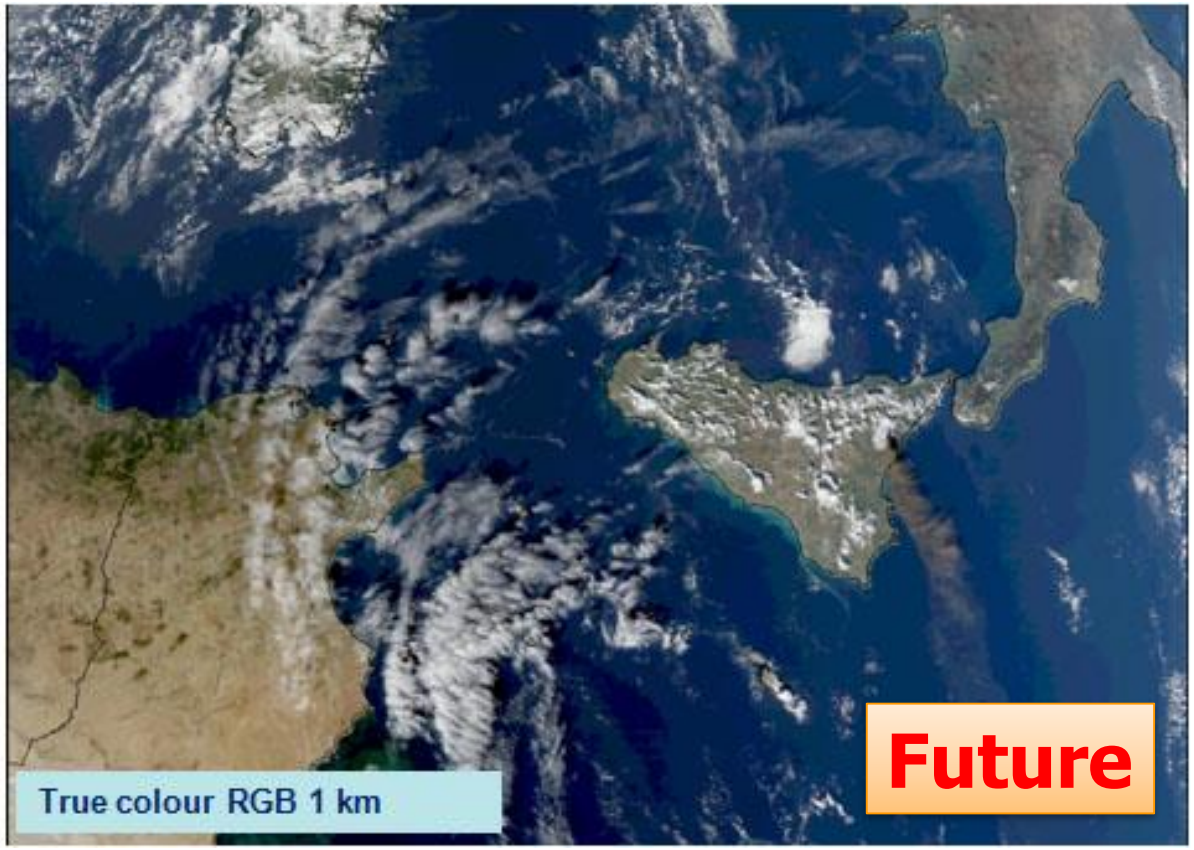
✓ **Continuity**

✓ **Innovation**



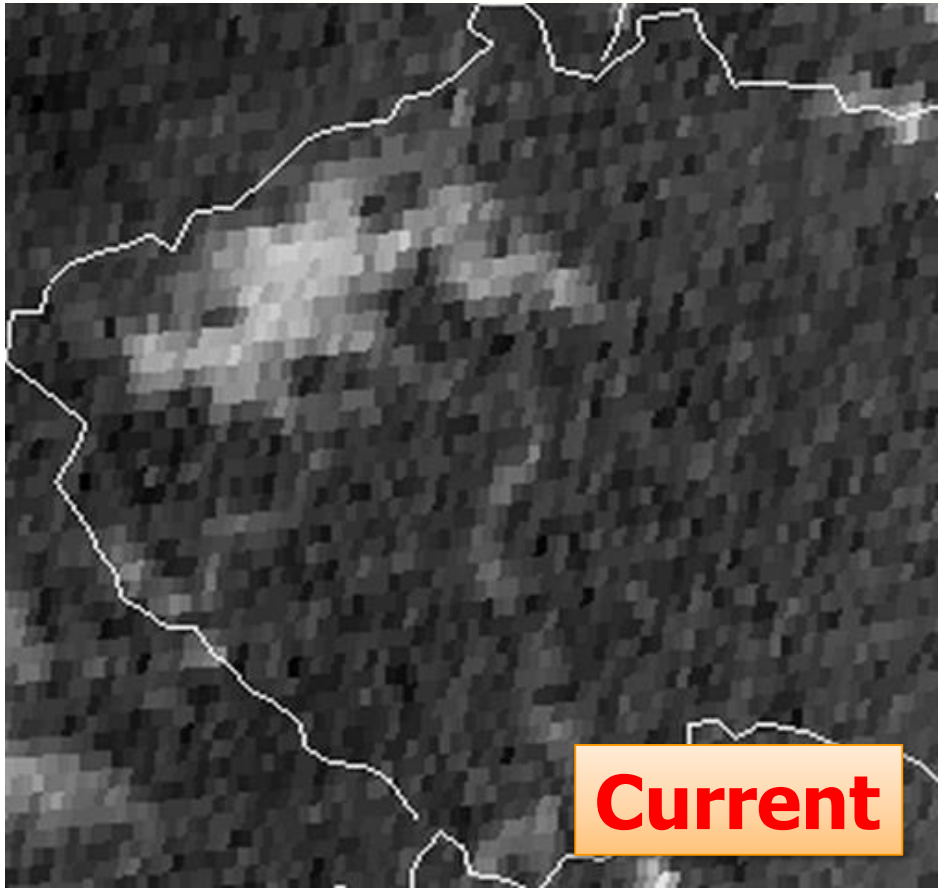
MTG Imager (FCI): higher spatial resolution imagery

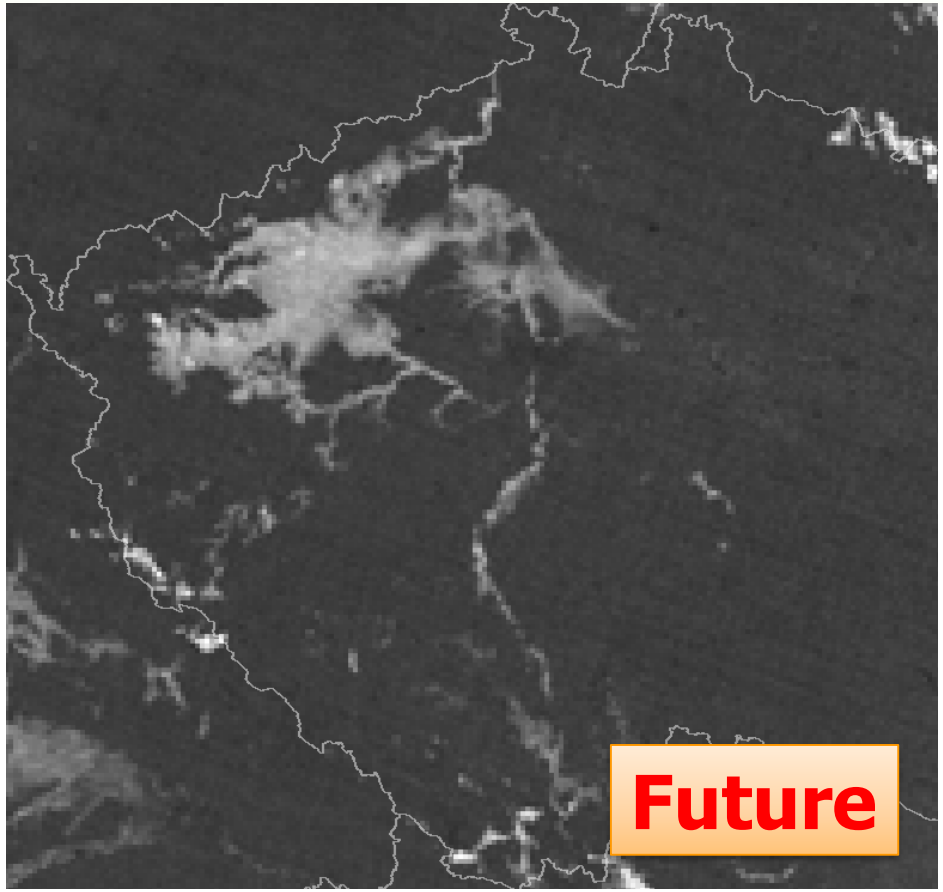




Example of ash detection, SEVIRI Natural Colour RGB, 12:15 UTC, 26 November 2006 (left), MODIS True Colour RGB, 12:20 UTC, 26 November 2006

MTG Imager (FCI): higher spatial resolution imagery

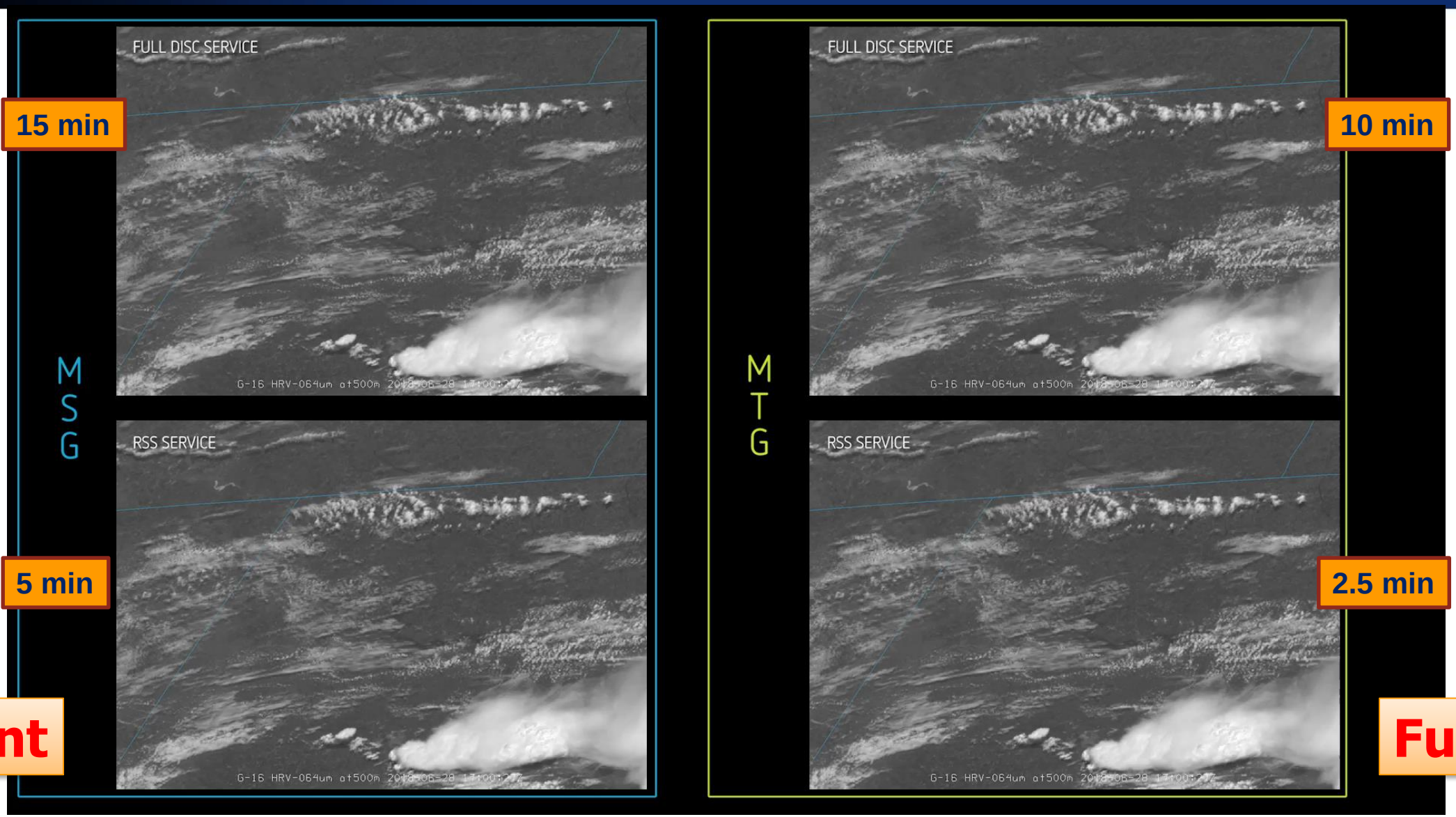




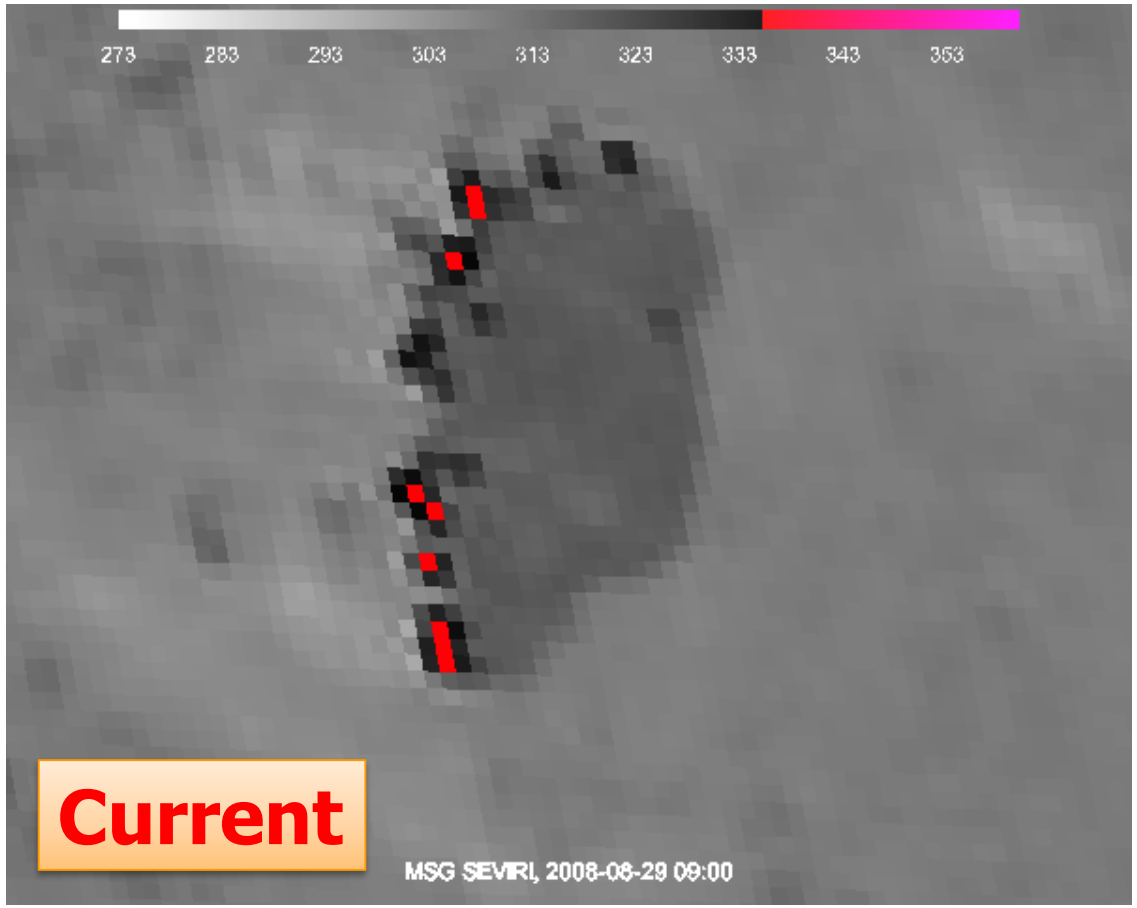
Example of fog detection over Czech Republic

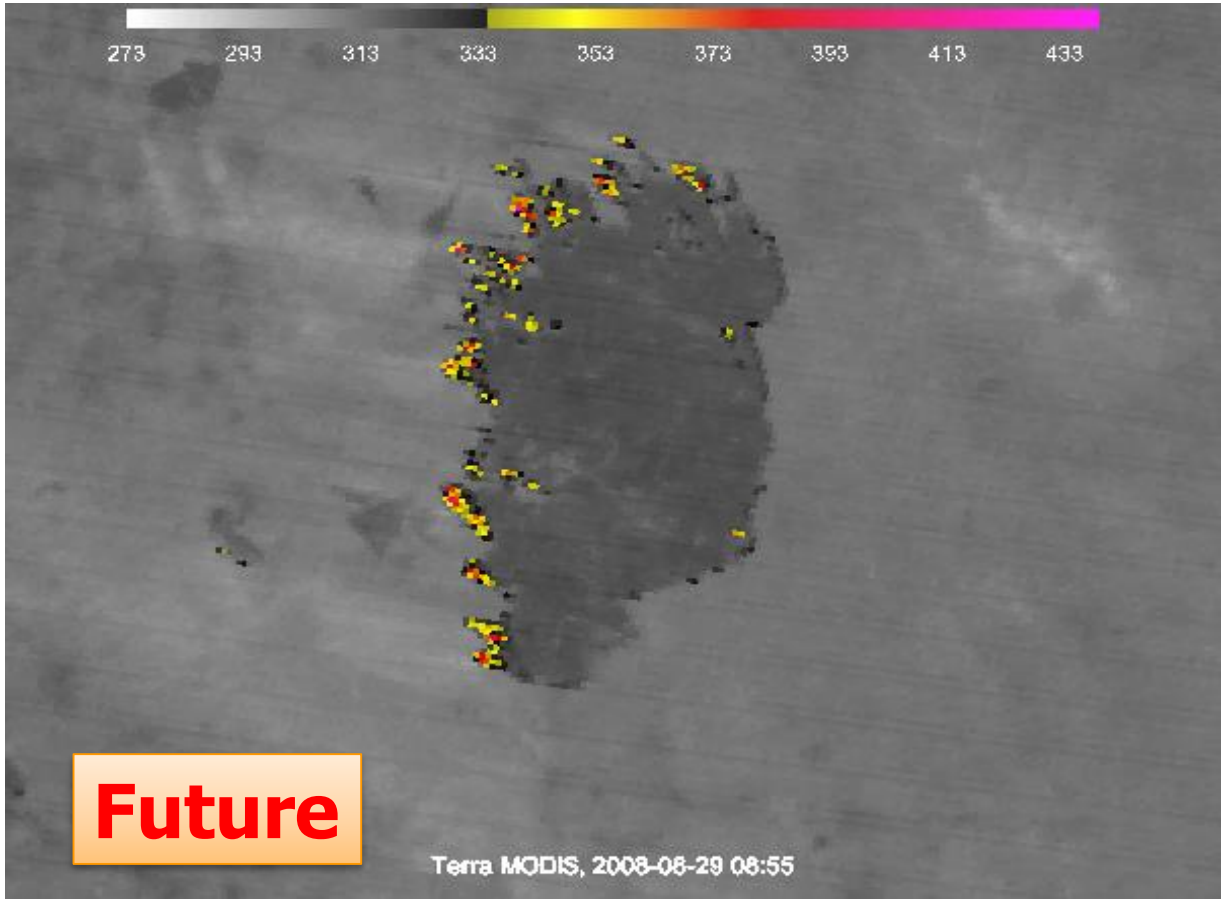
Source: M. Setvak, J. Kerkmann; 16 Nov 2018, 01.37 UTC
Right panel: simulated FCI imagery at ~2 km horizontal resolution (1 km at nadir), based on NOAA Suomi-NPP VIIRS data
Left panel: MSG SEVIRI imagery at 5 km horizontal resolution (3 km at nadir)

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



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





Botswana, August 2008

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

MTG-I:

Fires in USA, GOES-16 ABI, Fire Temperature RGB

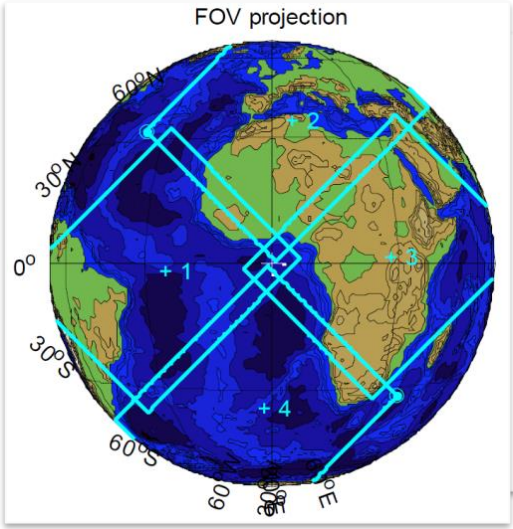
6 March 2017

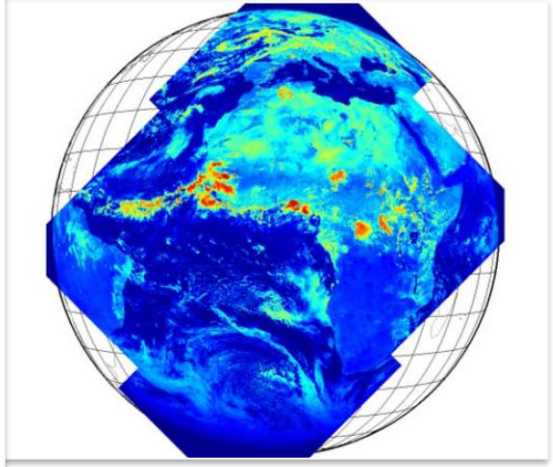
…MTG higher resolution provides better pin-pointing of fires

=> better decision tools for emergency services

MTG Lightning Imager mission: *Why do we care?*

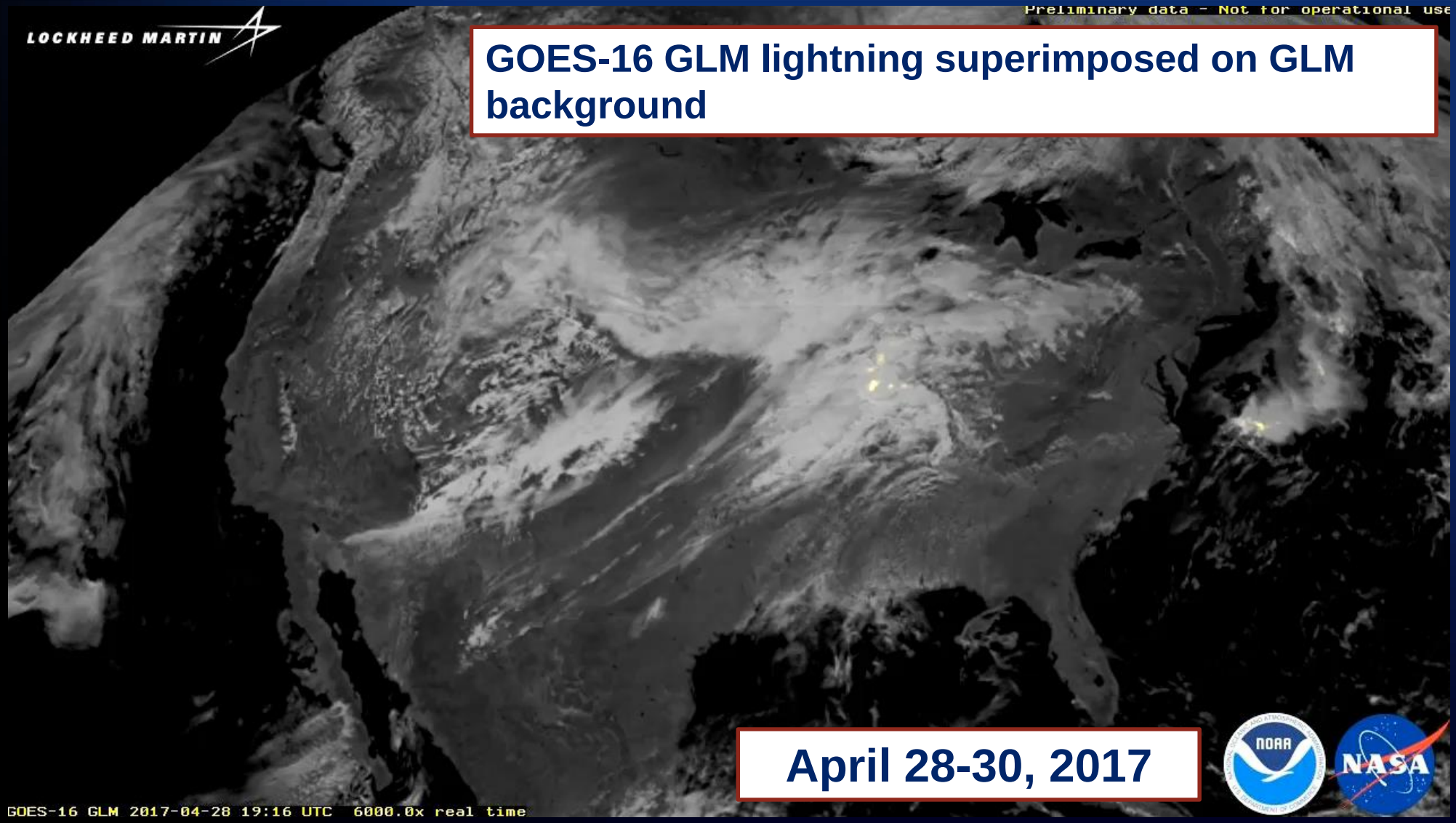
- Lightning is a precursor of severe weather, with a lead time of up to tens of minutes
- Most ground-based lightning location systems are mainly sensitive to cloud-to-ground lightning (CG)
- Often, no increase in CG due to "weather intensification" observable → Total lightning is the parameter of interest



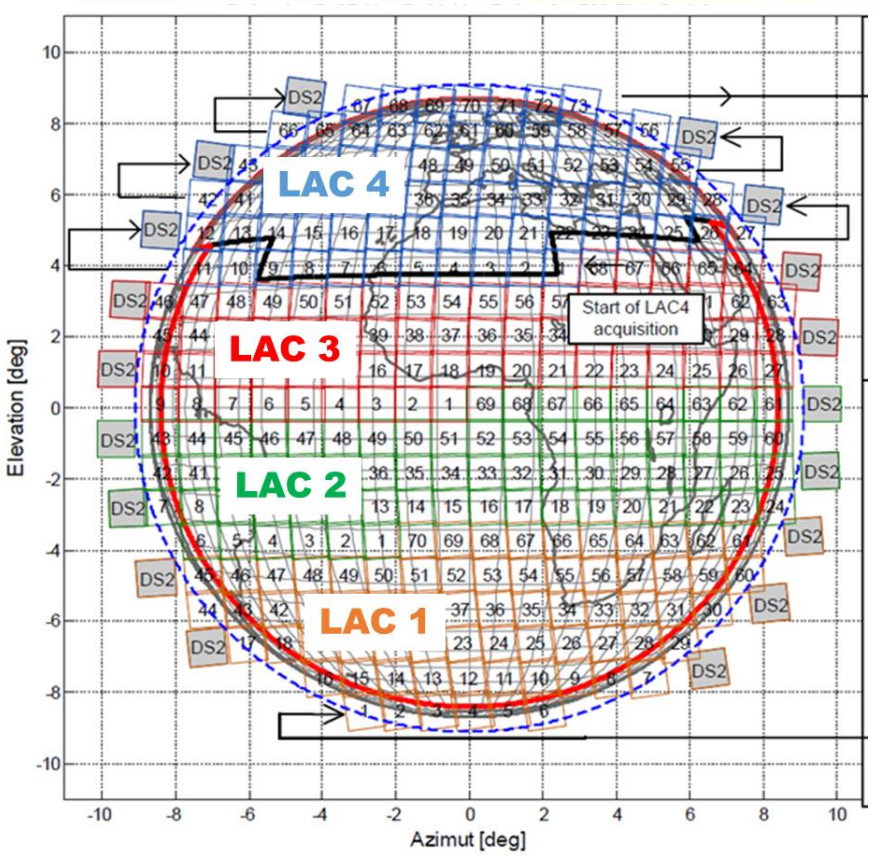


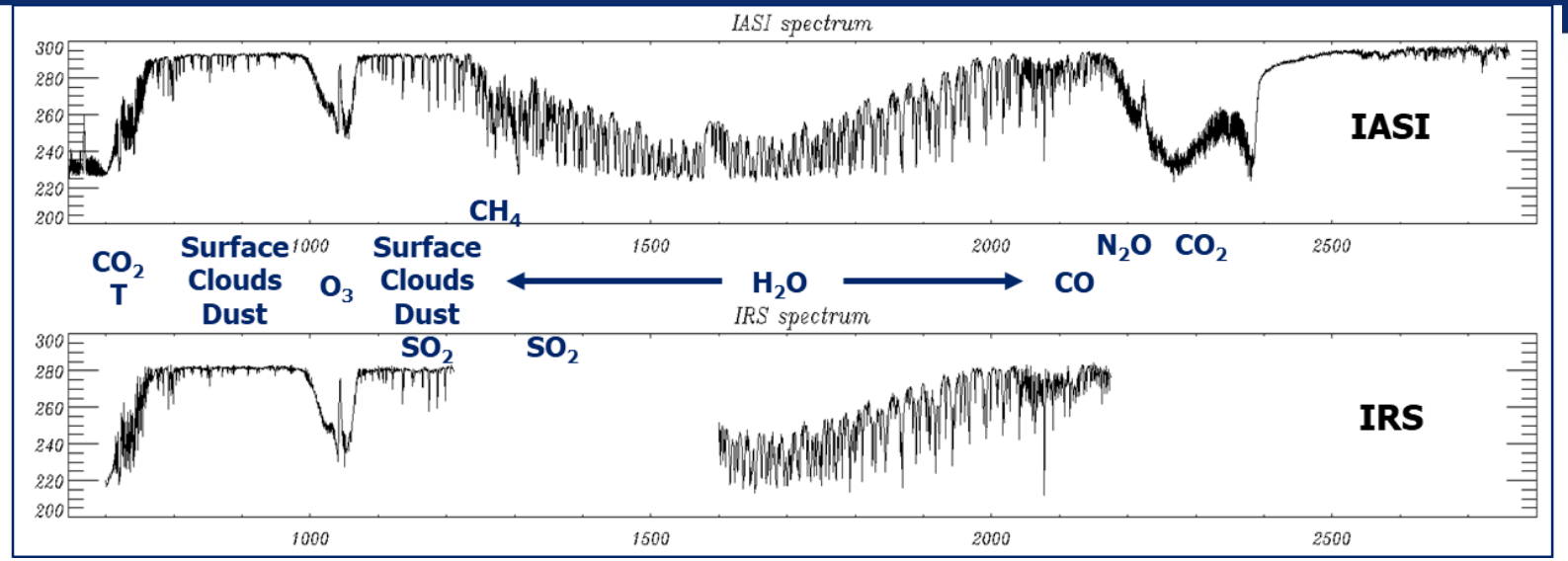
Total lightning =
cloud-to-ground
+ cloud-to-cloud lightning

MTG Lightning Imager (LI): US Proxy Data



MTG Infra-Red Sounder (IRS)

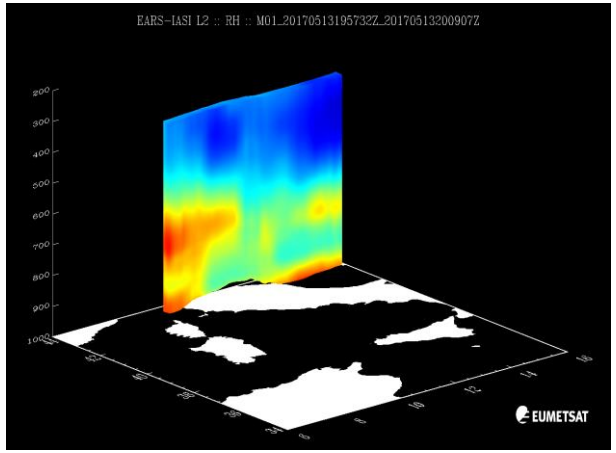




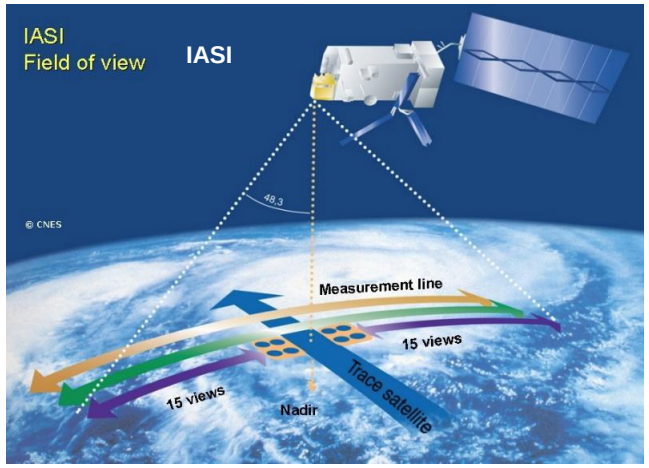
4 Local Area Coverage (LAC):

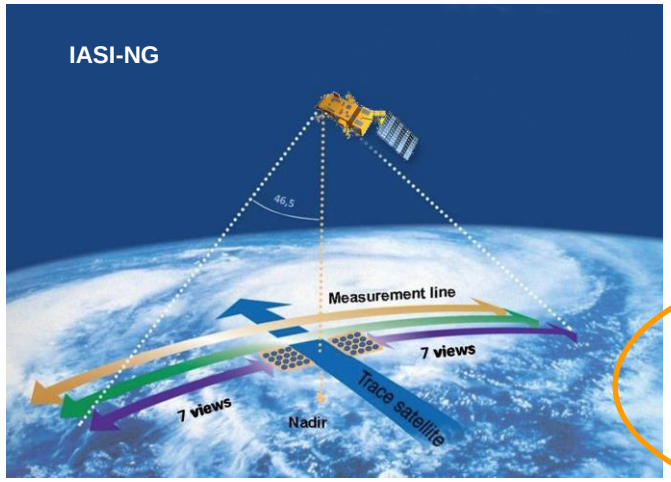
- One LAC acquired within 15’
- Overlapping step & stare dwells
- 160x160 pixels, ~4km at Nadir
- Europe (LAC 4) observed every 30’

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



From IASI to IASI-NG and the IRS



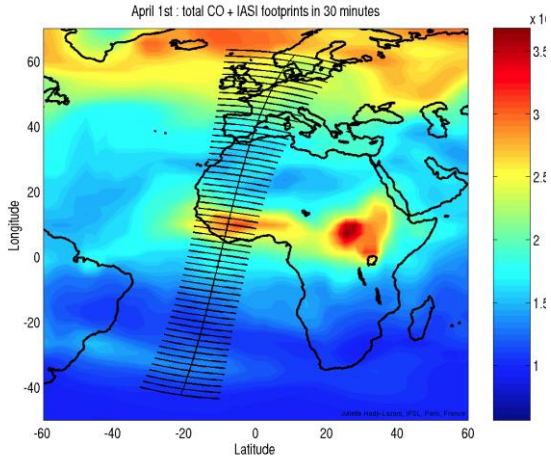


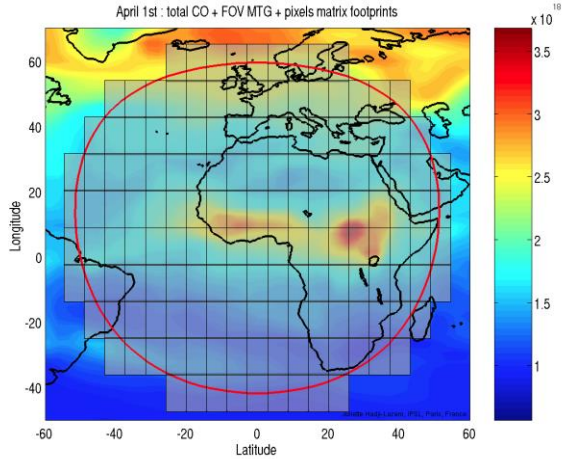
IASI-NG

- CO, SO_2, O_3, HNO_3, NH_3,CH_4, CO_2,... with improved detection limits and vertical sensitivity

IRS

- NH_3, CO, SO_2, O_3 with improved temporal and spatial resolution





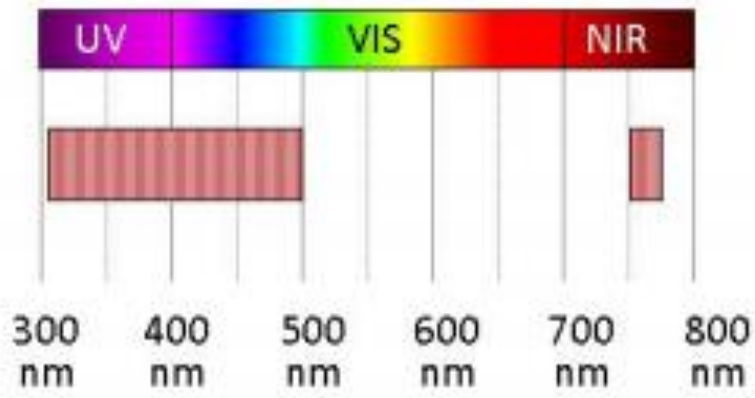
	IASI-NG	IRS
S:N	IASI x 2	O3: ~IASI CO: ~IASI/2
Spectral Resolution	IASI / 2	IASI x 1.5
Pixel Size	IASI (12km)	IASI / 3

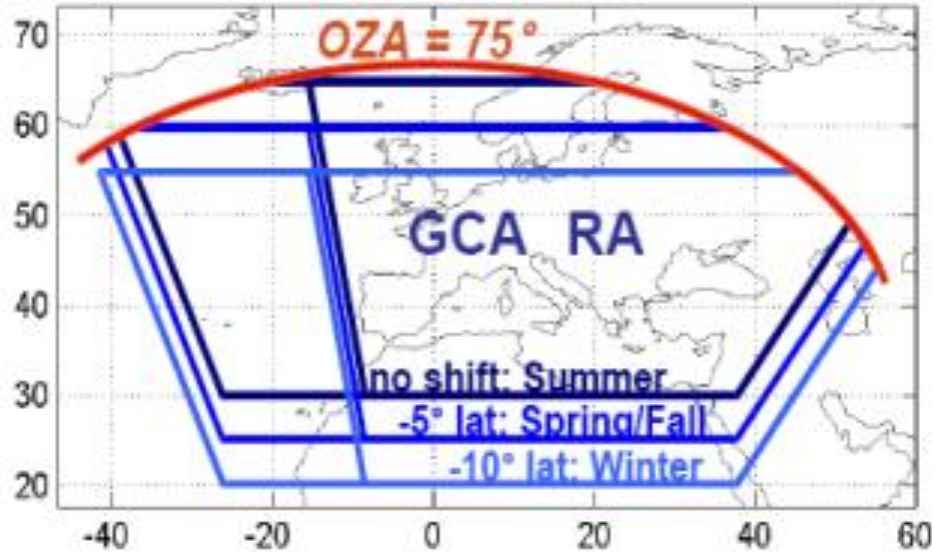
Courtesy ULB/LATMOS

Copernicus Sentinel-4 on MTG: Monitoring atmospheric composition


pixabay.com

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





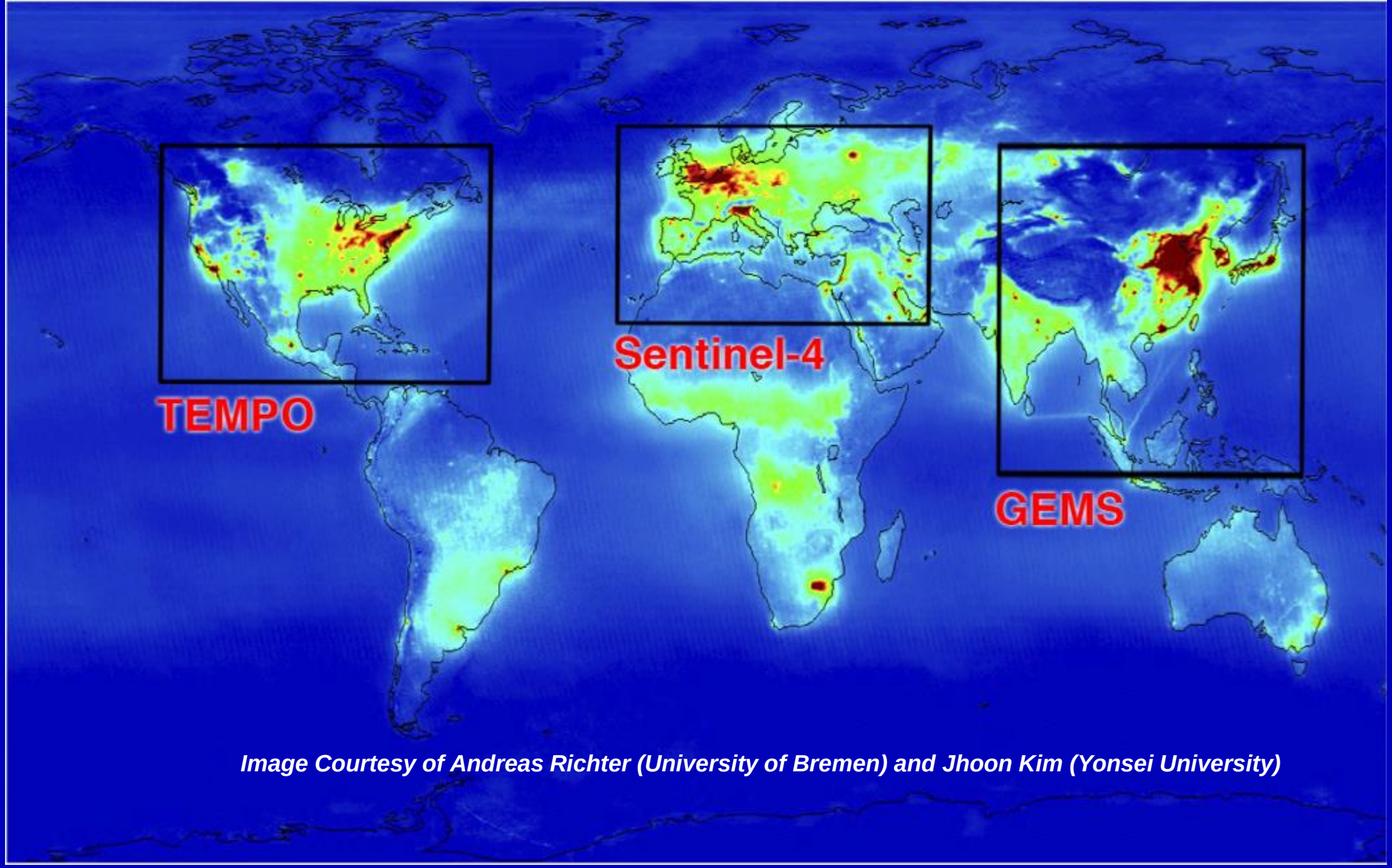
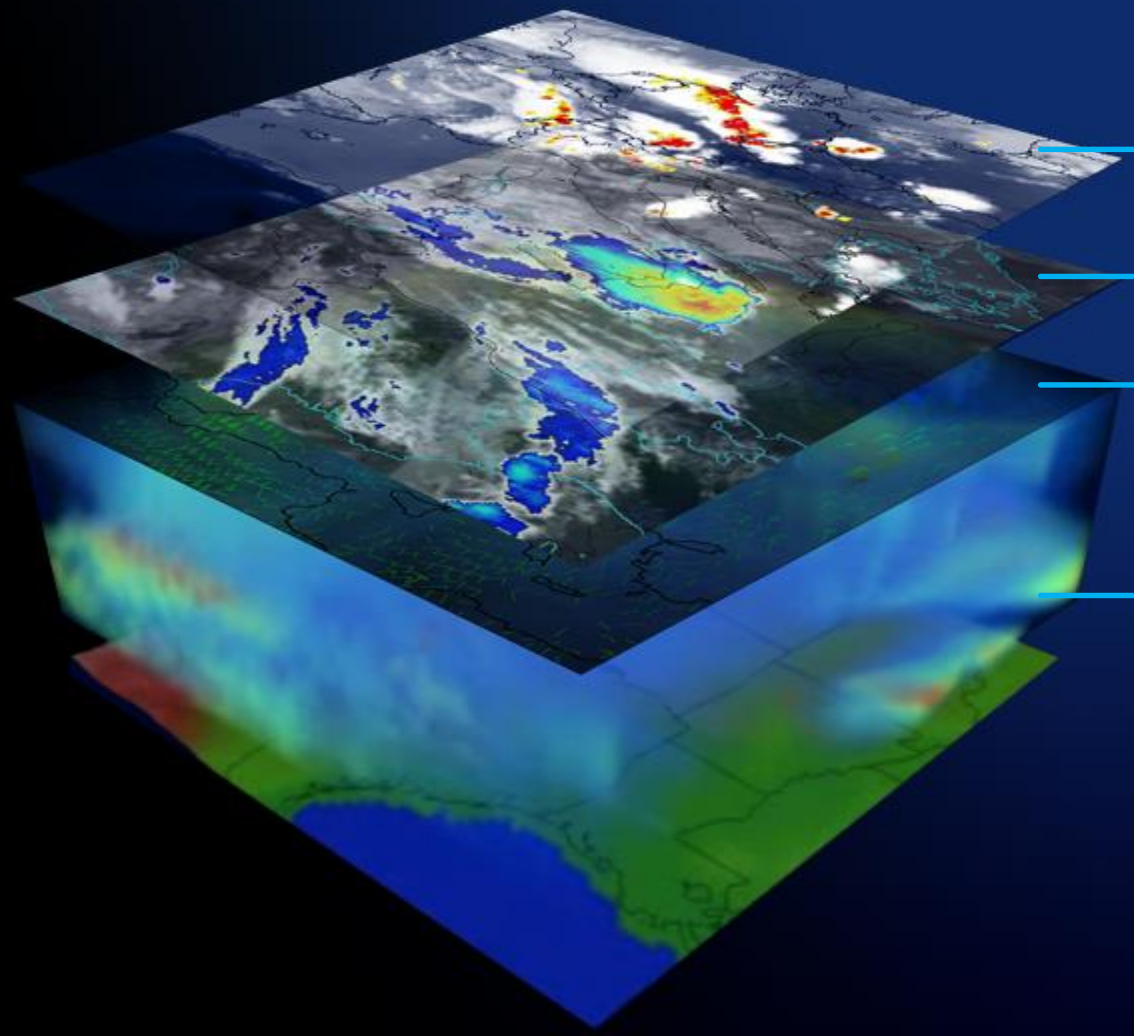


Image Courtesy of Andreas Richter (University of Bremen) and Jhoon Kim (Yonsei University)

MTG Summary: 4D Weather Cube



- Lightning
- Convection
- Winds
- Atmosphere

Every 30 min over Europe

Topics

- EUMETSAT product development in a nutshell
- Concept of Science Roadmaps – medium-term product evolution
- Highlights and some examples of product development in the Science Roadmap context
- EUMETSAT's next generation satellite programmes with expected improvements
  - Meteosat Third Generation (MTG), **2022** →
  - EUMETSAT Polar System Second Generation (EPS-SG), **2023** →
- Summary

EUMETSAT Polar System – Second Generation Programme Objectives

- **Primary mission: further improve observational inputs to Numerical Weather Prediction models.**
- **Continuation and enhancement of service from mid morning polar orbit in 2023 – 2043.**
- **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 (first generation).**

EUMETSAT Polar System – Second Generation A (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

EUMETSAT Polar System – Second Generation B (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

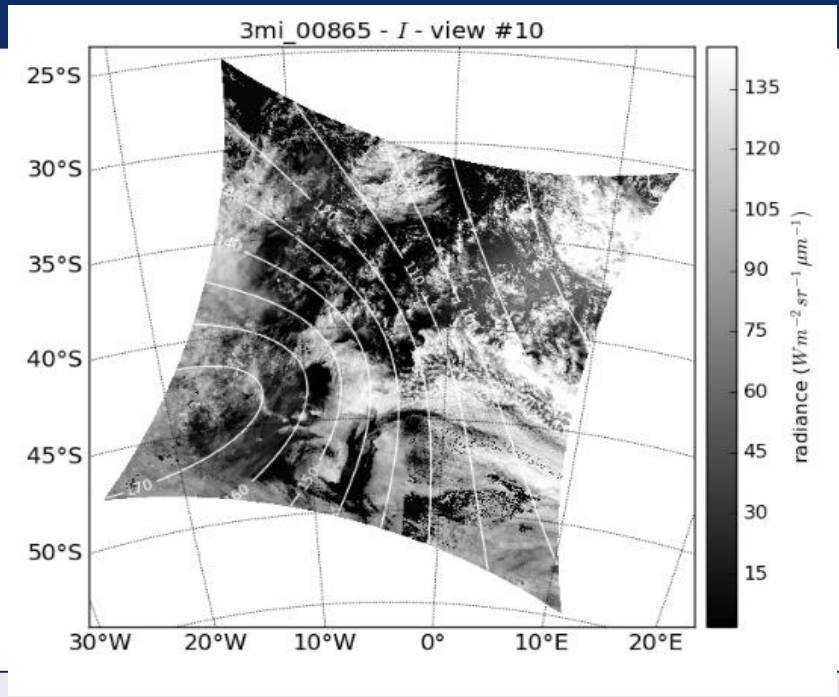
EPS-SG Sounding missions: Enhancements and Innovations

Main Payload	Enhanced Capabilities	Innovative Capabilities	Applications Benefitting
High-Resolution Infrared Sounding **(IASI-NG)** **Metop Heritage: IASI**	+75% information in temperature profiles +30% in water-vapour profiles	More trace gases and their vertical profiles	NWP, Nowcasting (NWC), Atm Composition (AC), Climate Monitoring (CM)
Microwave Sounding **(MWS)** **Metop Heritage: AMSU, MHS**	Enhanced spatial over-sampling, five more spectral channels	Ice-cloud info in support of humidity profiling	NWP, NWC, CM
Radio Occultation Sounding **(RO)** **Metop Heritage: GRAS**	Large increase of number of radiooccultations, implementation on A- and B-satellites	Tracking of Galileo and Compass/Beidou signals	NWP, CM
Nadir viewing UV/VIS/NIR/SWIR Sounding **(Sentinel-5)** **Metop Heritage: GOME-2**	Drastic increase of spatial resolution, extension into UV and short-wave infra-red	Additional trace gas measurements; CO_2 being studied	Air Quality, CM, AC

EPS-SG Imaging Missions: Enhancements and Innovations

Main Payload	Enhanced Capabilities	Innovative Capabilities	Applications Benefitting
VIS/IR Imaging **(METimage)** **Metop Heritage: AVHRR**	Better radiometric and spatial resolution	Far more variables measured with higher accuracy	NWC, NWP, Operational Oceanography, Hydrology, CM
Scatterometry **(SCA)** **Metop Heritage: ASCAT**	Higher spatial resolution and coverage	Cross polarisation for higher wind speeds	NWP, NWC, Operational Oceanography, Hydrology, CM
Multi-viewing, -channel, -polarisation Imaging **(3MI)**	**New mission**	Aerosol parameters	Air Quality, CM, NWC
Microwave Imaging **(MWI)**	**New mission**	Precipitation observations	NWP, NWC, Hydrology, Operational Oceanography, CM
Ice Cloud Imaging **(ICI)**	**New mission**	Cloud microphysics parameters	NWP, NWC, Hydrology, Operational Oceanography, CM

Multi-viewing multi-channel multi-polarisation Imaging (3MI)



Novel Mission on EPS-SG

Objectives / products

- Aerosol – optical thickness, particle size, type, height, absorption
- Volcanic Ash
- Cloud phase, height, optical depth
- Surface albedo

Applications benefitting

- Climate monitoring
- Nowcasting
- Air quality

Breakthrough:

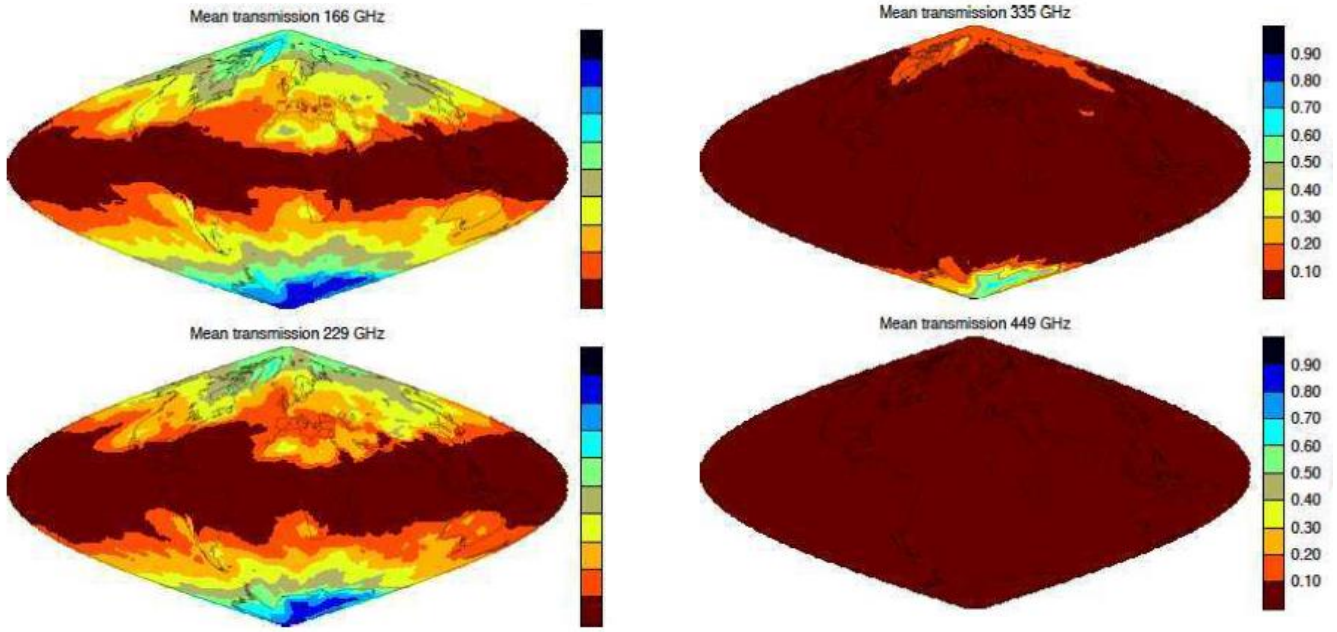
- **Enhanced spatial sampling (4 km)**
  - Improves separation of cloudy areas
- **12 spectral channels (9 polarised), extending into the SWIR**
  - Better aerosol characterisation
- **Higher angular resolution (14 views)**
  - Better phase function characterisation

Ice cloud imaging (ICI)

Novel Mission on EPS-SG

Objectives / products

- Cloud products, in particular ice clouds
- Snowfall detection and quantification
- Water-vapour profiles and imagery



Applications benefitting

- Numerical weather prediction
- Nowcasting
- Hydrology
- Climate monitoring

Breakthrough: 11 sub mm channels

- **Establishes operational ice-cloud imaging mission**
- **Support of weather forecast, hydrology, and climate monitoring**

Radio occultation sounding (RO)

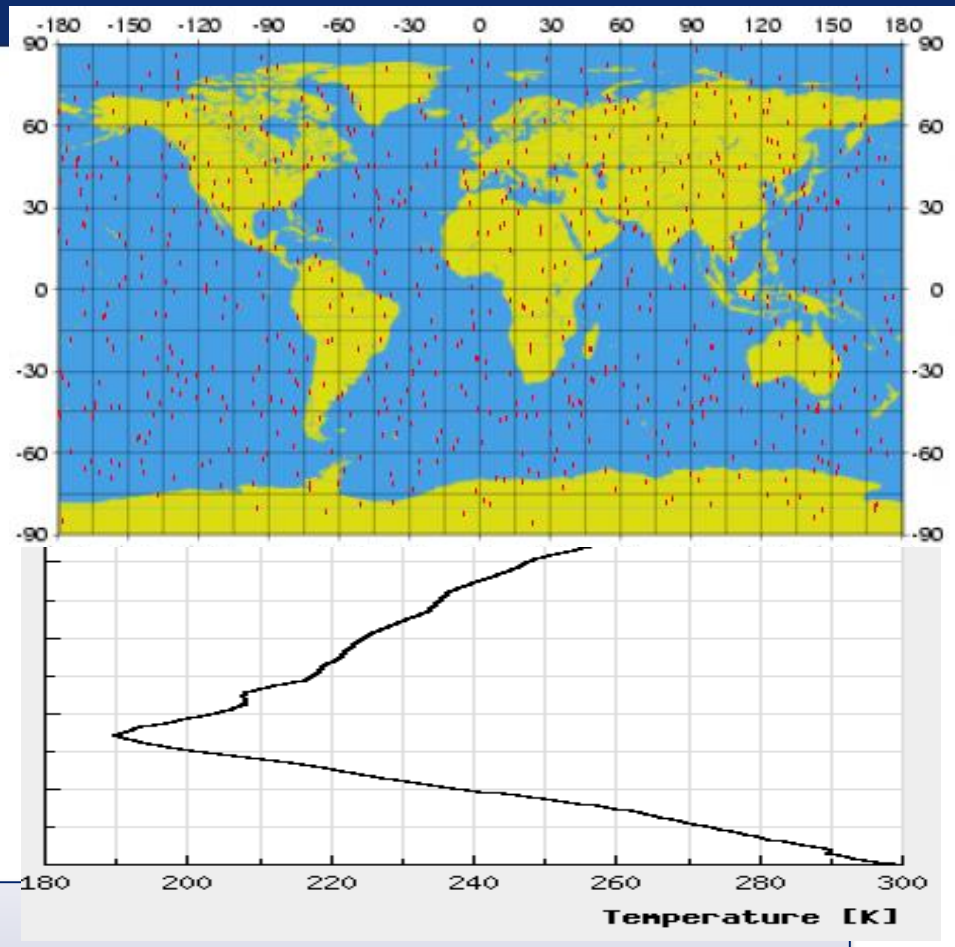
EPS Heritage: GRAS

Objectives / products

- Refractivity profiles at high vert. resolution
- Temperature / humidity profiles
- PBL top and tropopause height
- Ionospheric electron content

Applications benefitting

- Numerical weather prediction
- Climate monitoring
- Space weather



Breakthrough

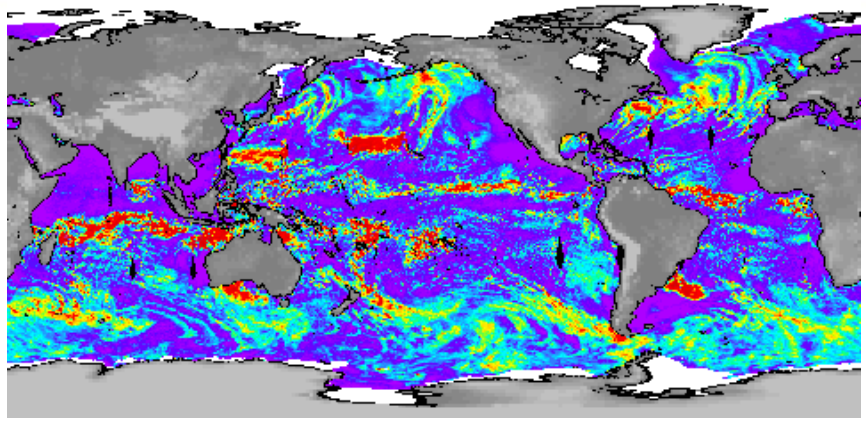
- **Tracking of GPS and Galileo satellites to double the number of occultation measurements**
- **RO mission on board Metop-SG A and B satellites.**

Micro-wave imaging (MWI)

Novel mission on EPS-SG

Objectives / products

- Precipitation and cloud products
- Water vapour imagery
- Sea-ice, snow, sea surface wind



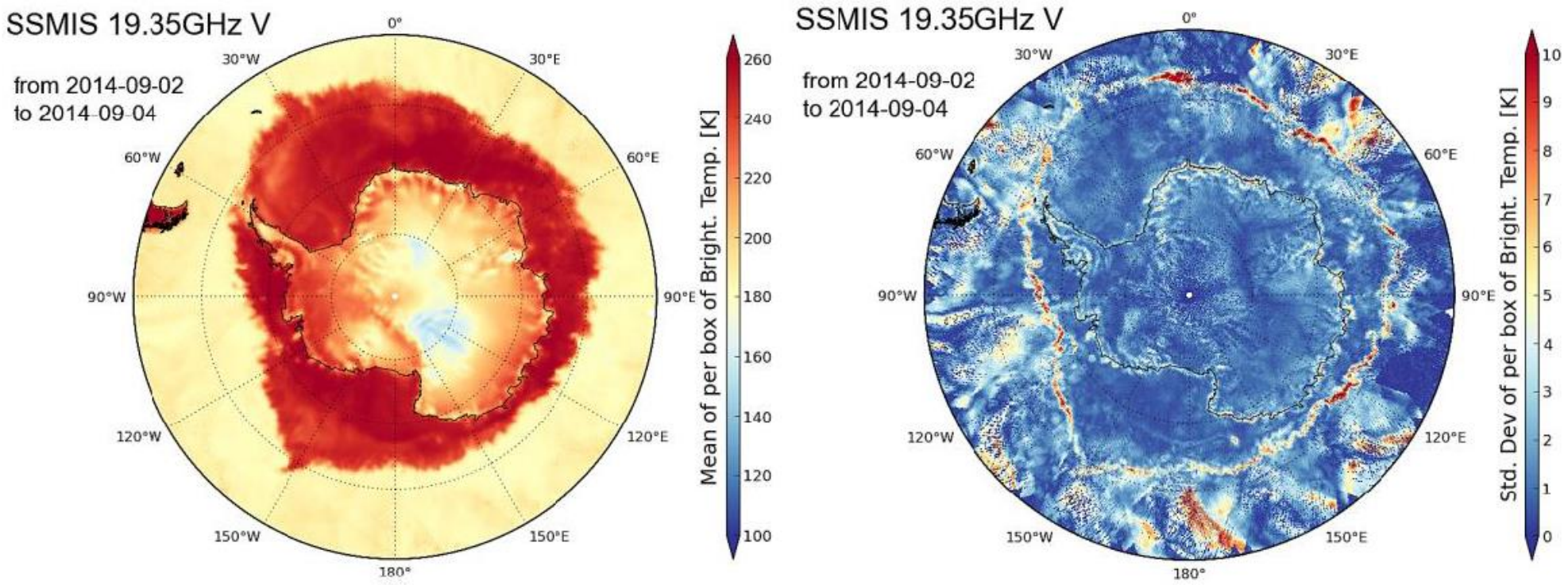
Applications benefitting

- Numerical weather prediction
- Nowcasting
- Oceanography
- Hydrology
- Climate monitoring

Breakthrough: 18 channels

- **Continuity of key microwave imager channels for weather forecast**
- **Inclusion of dedicated sounding channels (118.75 GHz)**
  - Enhanced precipitation measurements through inclusion of dedicated sounding channels
- **Extended suite of 183.31 GHz channels**
  - water-vapour and cloud profiling

Sea Ice – SSMIS 19.35 GHz channel



Mean value and standard deviation of 19 GHz SSMI/S brightness temperatures over Antarctica for a two-day averaging window (2. to 4. Sept. 2014).

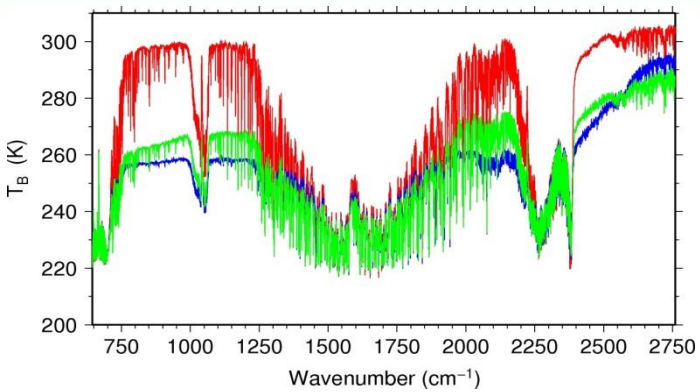
ANPAC study

- **Continuation of Sea Ice Data record**
- **Edges of Sea Ice clearly seen**

Hyper-spectral Infrared Sounding (IASI-NG)

Objectives

- Temperature/humidity profile at high vertical resolution
- Clouds, trace gases (CO, SO_2, O_3, HNO_3, NH_3,CH_4, CO_2 ...)
- Sea/land/ice surface temperature
- Aerosols, Volcanic Ash

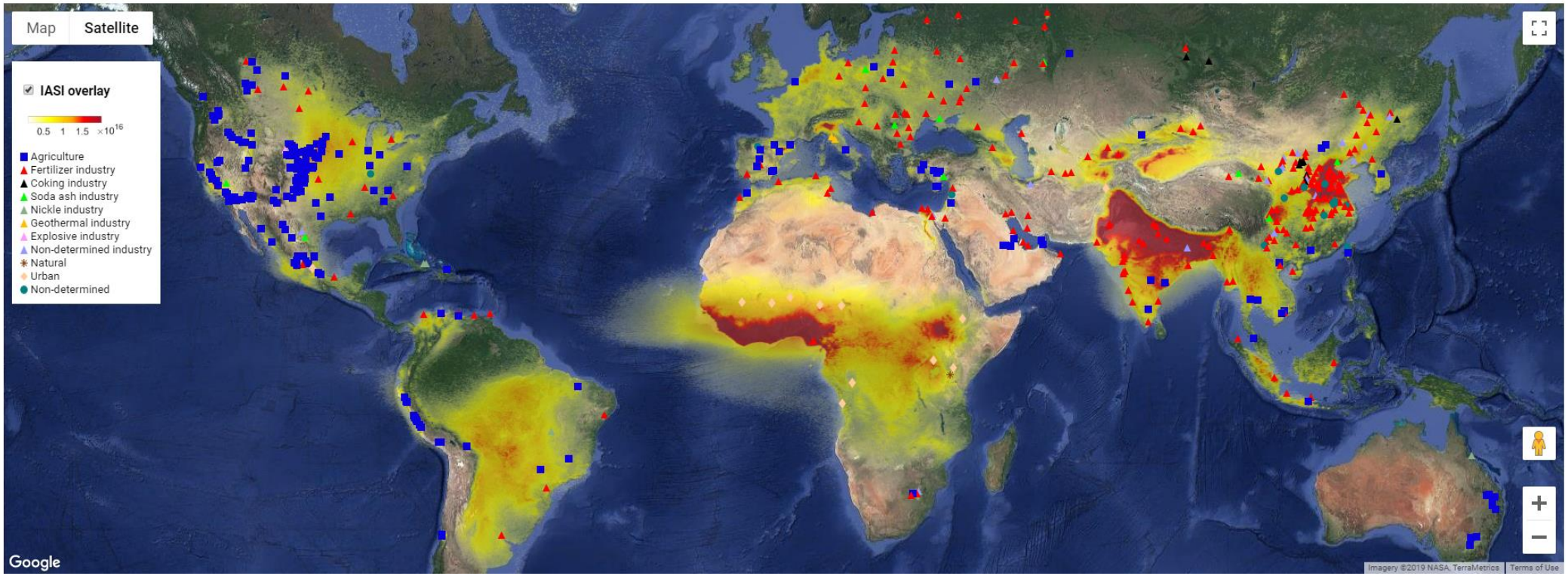


Breakthrough

- **Doubling of radiometric and spectral resolution of IASI for the benefit of weather forecast and atmospheric composition**
  - 75% more information in temperature profiling, particularly PBL
  - 30 % more information in water vapour profiling
  - Quantification of trace gases which are currently only detected
  - Vertical resolution of trace gases instead of columnar amounts only

IASI Ammonia (NH_3)

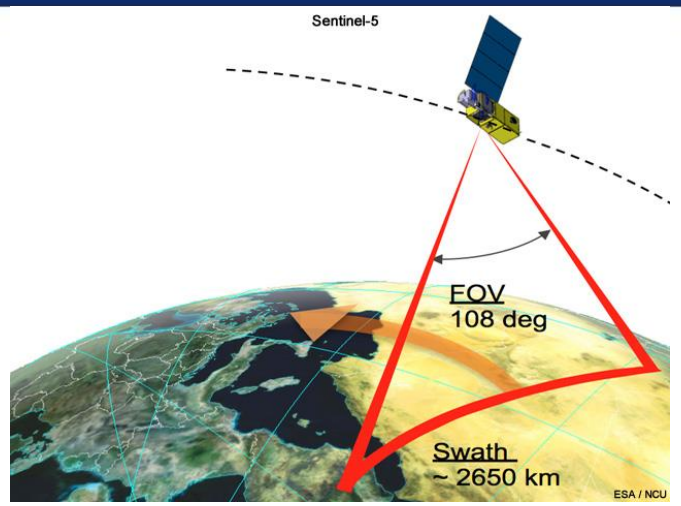
https://www2.ulb.ac.be/cpm/NH3-IASI.html

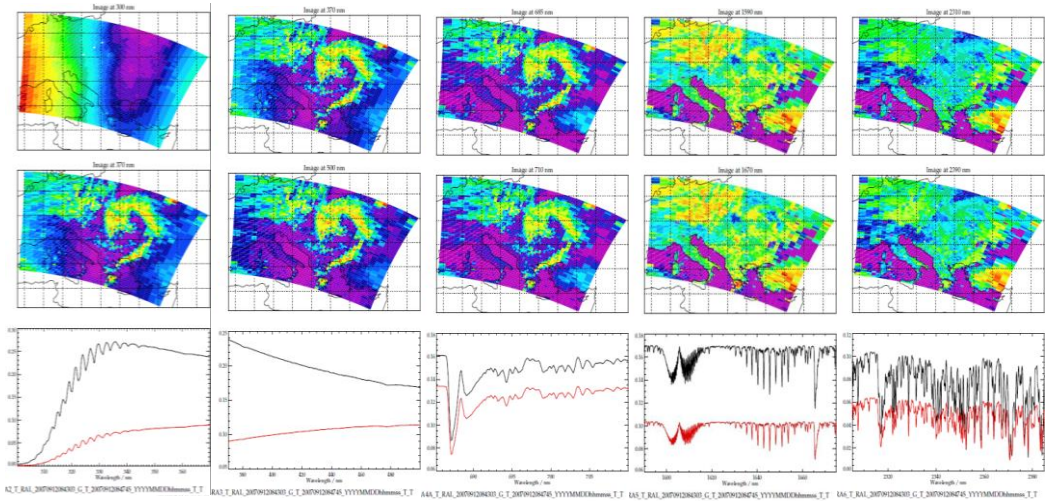


Courtesy: ULB/LATMOS

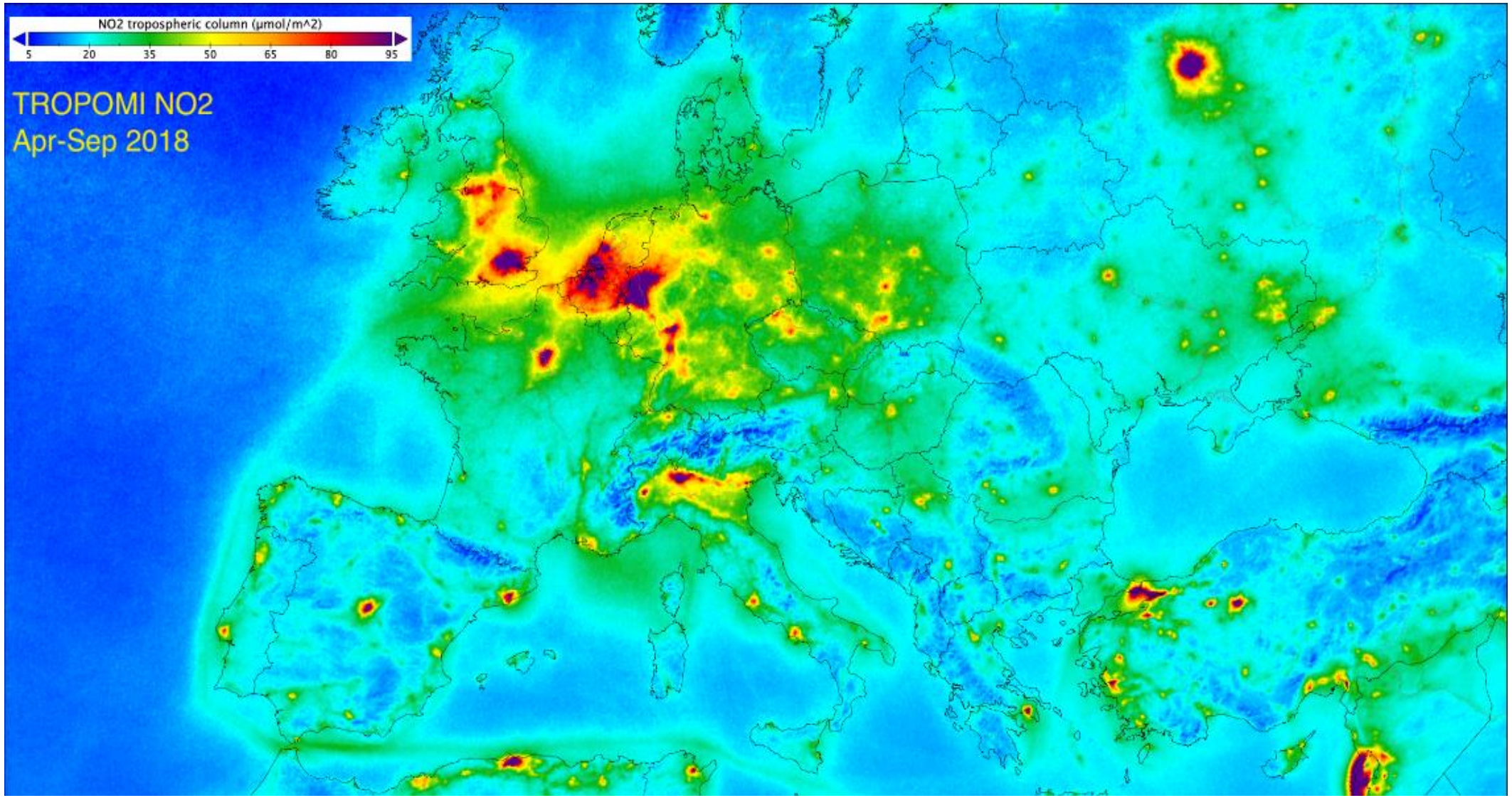
EPS-SG Sentinel-5/UVNS: UV-NIR-SWIR Spectrometer

- Sentinel-5 will build on the heritage from the GOME/SCIAMACHY/GOME-2/OMI series of instruments and will provide continuity with these instruments
- The spatial resolution will be significantly improved compared to previous missions (~ 7 x 7 km at SSP), which is important to support development of air quality applications
- Sentinel-5 level 1 and 2 products will be produced operationally by EUMETSAT
- Products: O_3, NO_2, SO_2, HCHO, CH_4, CO, CHOCHO, UV, AAI, AOD, ALH, CLD, HSC, SUR

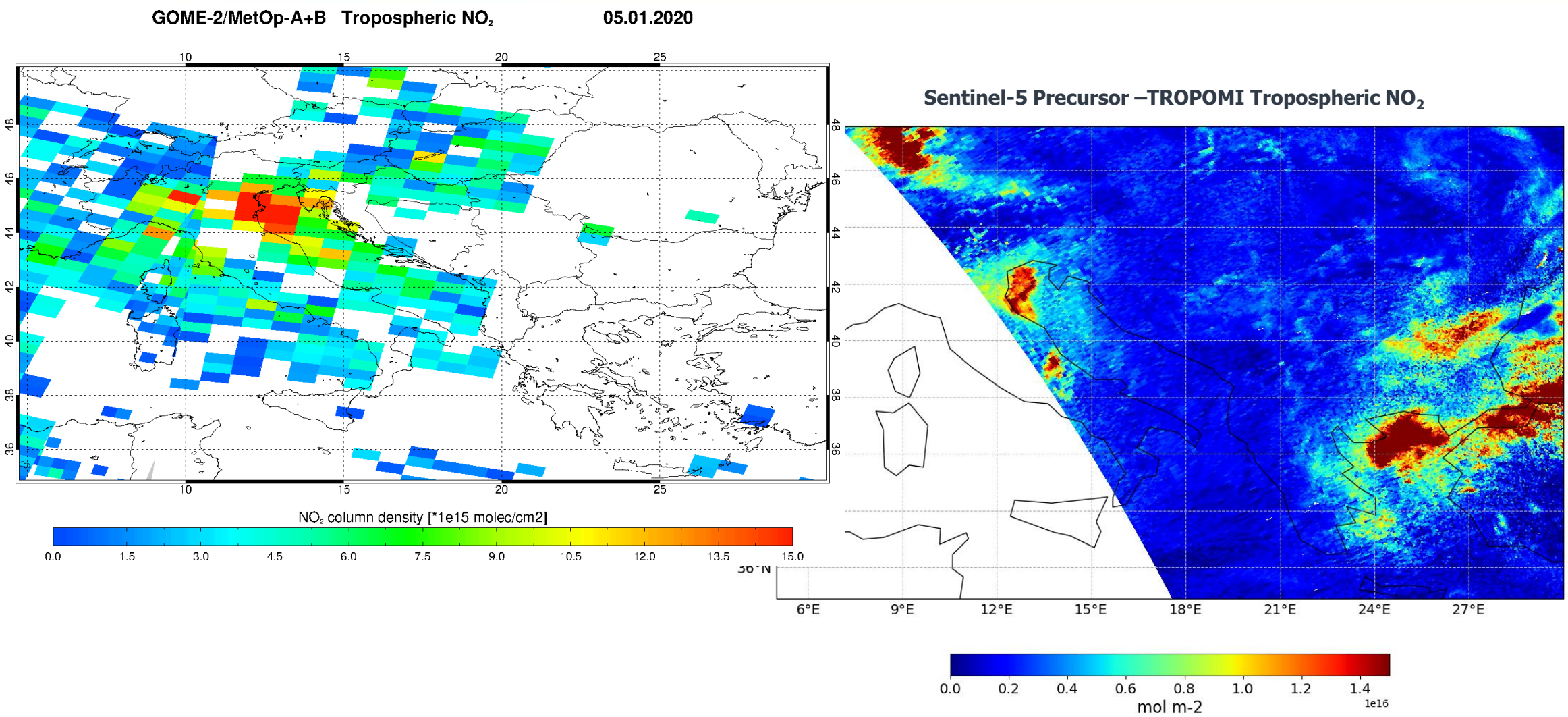




Copernicus Sentinel-4 on MTG & Sentinel-5 on EPS-SG: Monitoring atmospheric composition



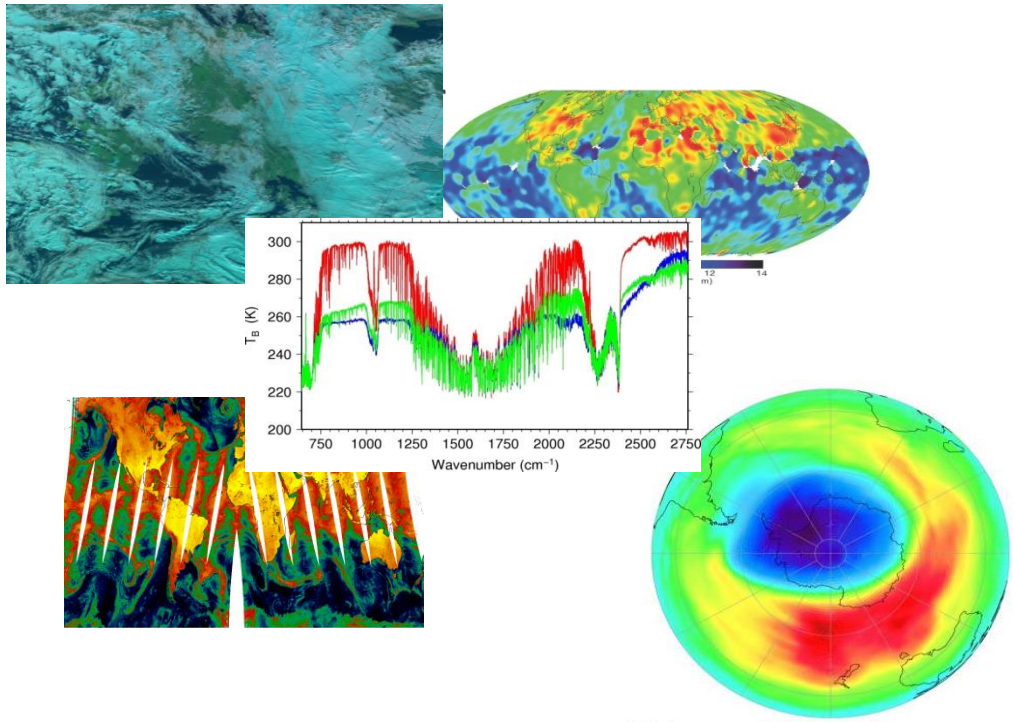
Advances for Air Quality Applications



Synergy of Observation Missions

Observation missions are highly complementary

- Co-registration of measurements will allow to optimise the information extraction
- Synergy has been considered in payload distribution of a dual satellite configuration

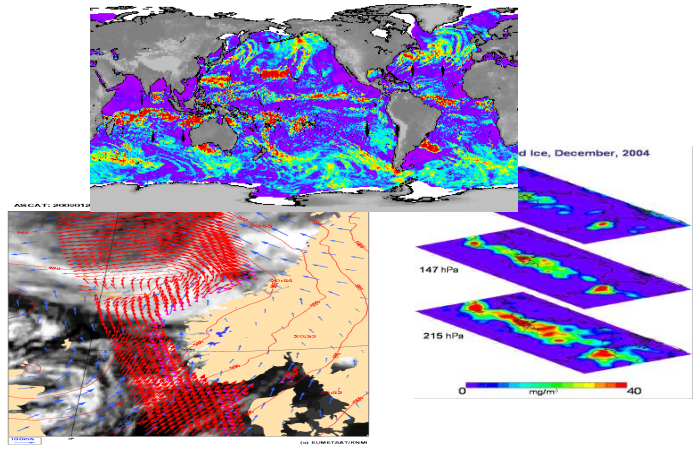


Essential co-registrations

- IASI-NG – METimage – S5/UVNS
- MWI - ICI

Desired co-registrations

- IASI-NG – MWS
- METimage – 3MI
- IASI-NG – S5/UVNS – 3MI
- MWI – SCA – METimage



Towards an EPS-SG Hyper-Instrument

3MI/S5/IASI-NG/VII - MAP

Combining co-locations of VII/Sentinel5/IASI-NG observations with co-registered multi-viewing observations (3MI) on 3MI multi-viewing fixed grid.

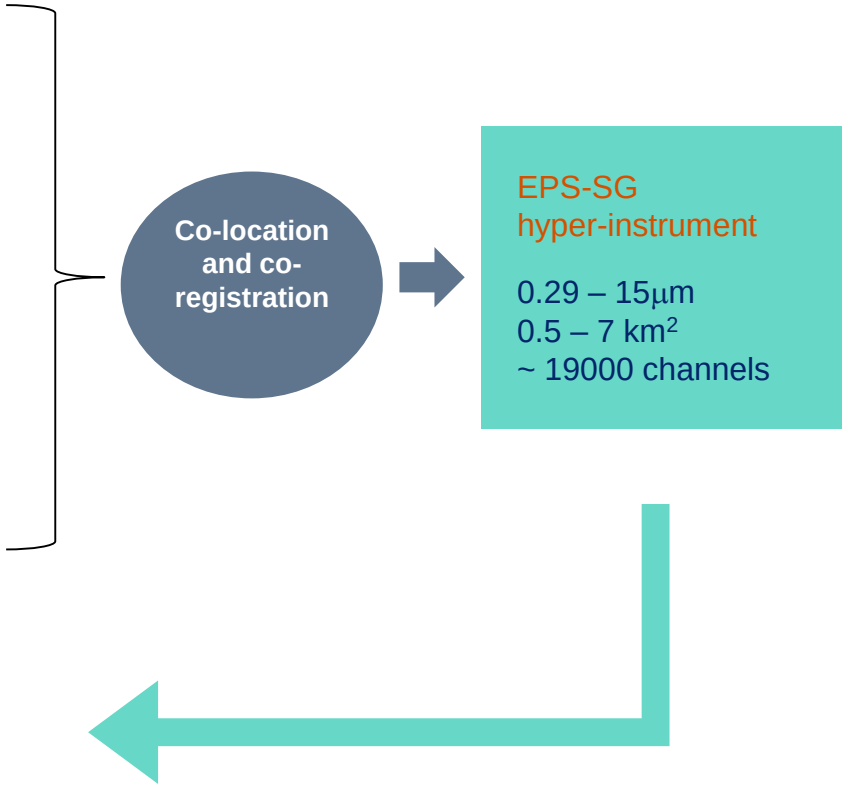
EPS-SG Platform

Sentinel-5
UV-Vis-SWIR hyper spectral sounder

IASI-NG
IR hyper spectral sounder

METimage
Very high spatial resolution,
multi channel imager

3MI
Multi-viewing,
Multi-polarisation,
Multi-channel imager



Initial product: Multi-sensor Aerosol product (MAP)

Topics

- EUMETSAT product development in a nutshell
- Concept of Science Roadmaps – medium-term product evolution
- Highlights and some examples of product development in the Science Roadmap context
- EUMETSAT's next generation satellite programmes with expected improvements
    - Meteosat Third Generation (MTG), **2022** →
    - EUMETSAT Polar System Second Generation (EPS-SG), **2023** →
- Summary

Summary

- The EUMETSAT Scientific Roadmaps serve the mid-term planning of product developments
- The roadmap process includes an internal assessment of the state of the field, in consultation with the SAFs, the Member States, Partner Agencies, and International Organisations;
- Work ongoing in all of the roadmap thematic areas to improve existing products and bringing novel developments to the user community
- New and improved capabilities of future GEO and LEO observations of EUMETSAT missions (MTG and EPS-SG) greatly benefit the applications in the years and decades to come