EUMETSAT Contributions to the Sentinel Missions for Atmospheric Composition

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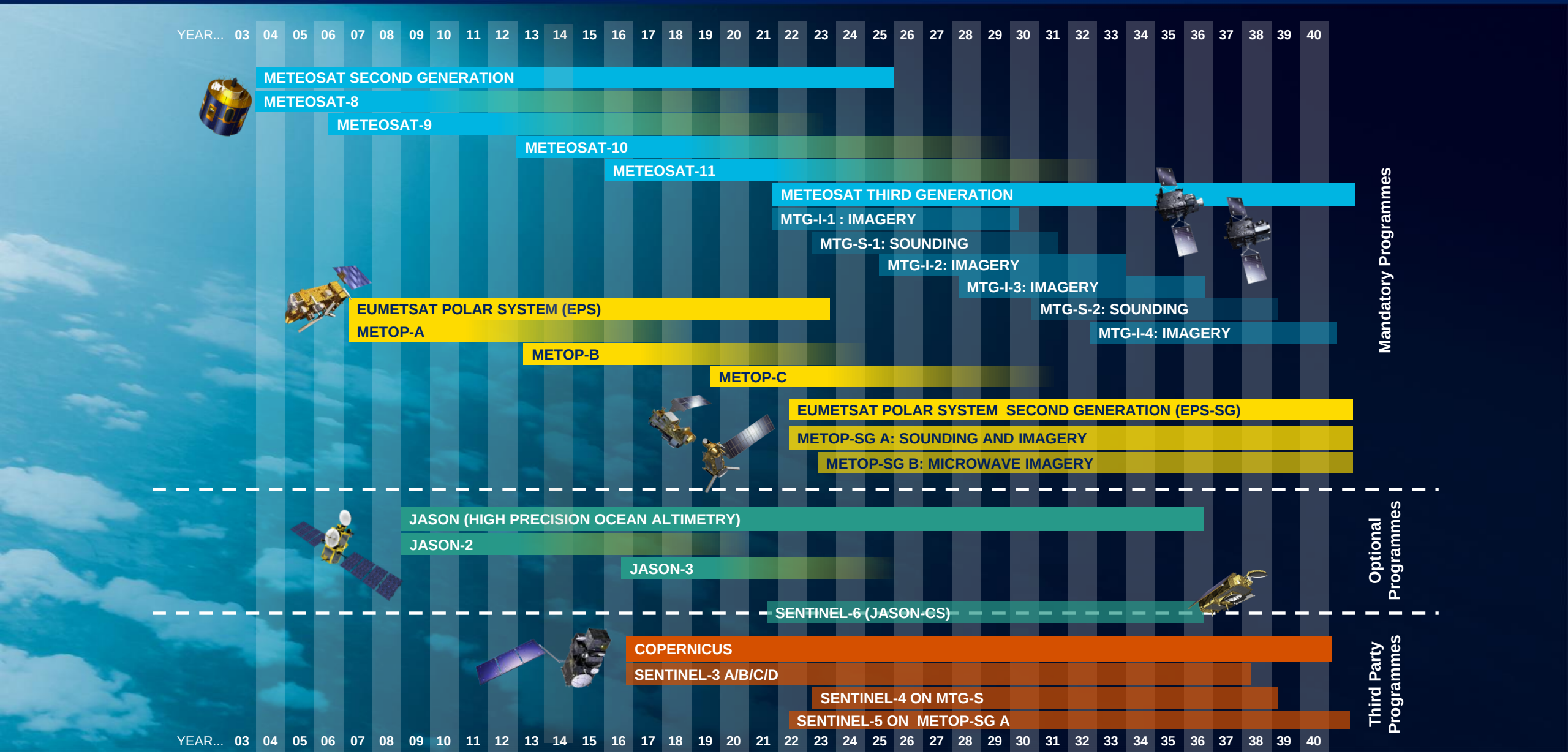
EUMETSAT Mission Planning



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EUMETSAT & Copernicus Sensors for Trace Gas Observation

Main types of sensors providing measurements for trace gas retrieval:

- Geostationary UVNS spectrometers:
  → MTG/UVN (Copernicus Sentinel-4)

- Geostationary hyperspectral IR spectrometers:
  → MTG/IRS

- Polar-orbiting UVNS spectrometers:
  → EPS/GOME-2, EPS-SG/UVNS (Copernicus Sentinel-5),
  → Copernicus CO_2 Monitoring mission
  (high priority candidate mission, not yet approved)

- Polar-orbiting hyperspectral IR spectrometers:
  →EPS/IASI, EPS-SG/IASI-NG

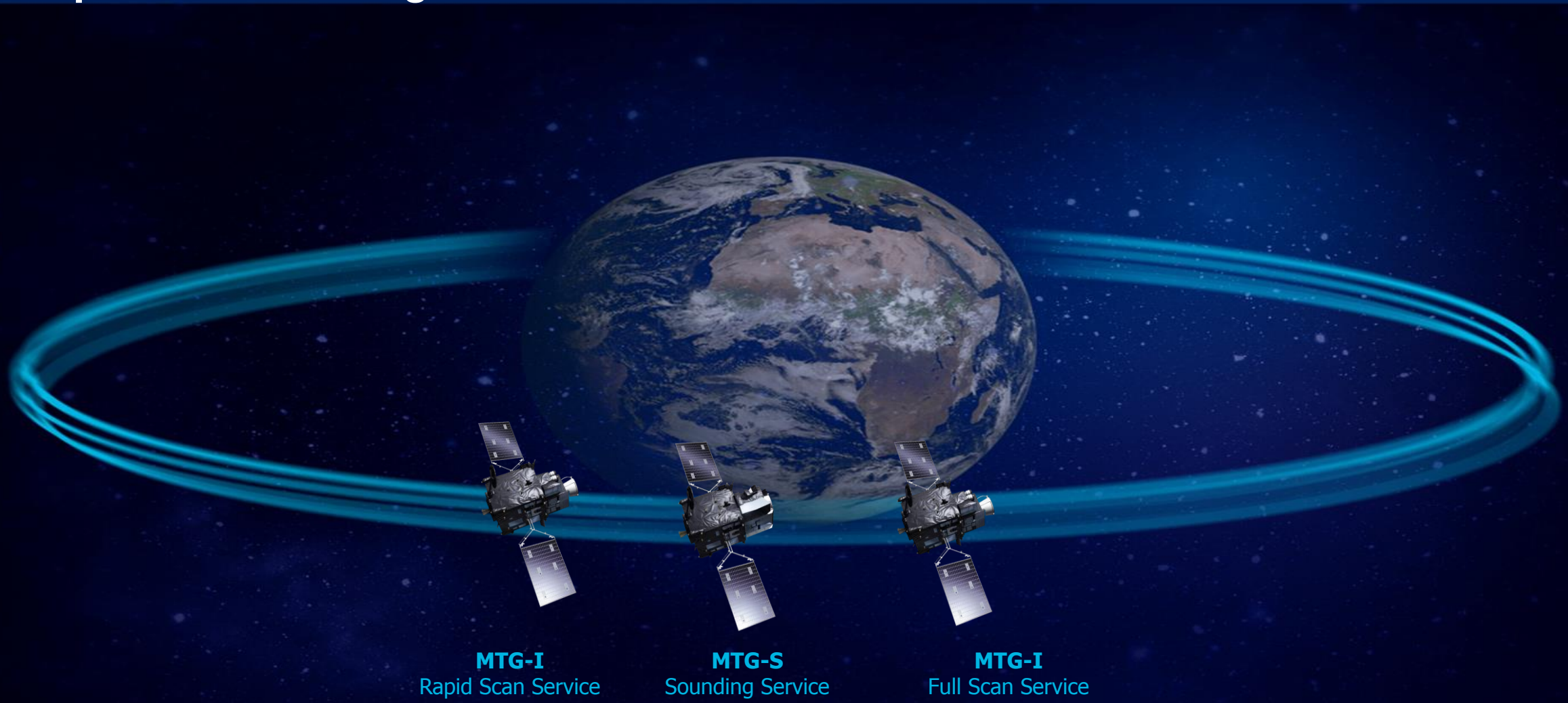
Cal/Val & End User Products for Trace Gas Missions

Product (Cal/Val & Trace Gas)	Metop GOME-2	MTG-S S4/UVN	EPS-SG S5/UVNS	Copernicus CO_2 M	Metop IASI	Metop-SG IASI-NG	MTG-S IRS
Radiance	√	√	√	√	√	√	√
Irradiance	√	√	√	√			
O_3 total column	√	√	√		√	√	√
O_3 profile (incl. troposphere)	√		√		√	√	√
O_3 tropospheric column	√	√					
NO_2 total column	√	√	√	√			
NO_2 tropospheric column	√	√	√	√			
SO_2	√	√	√		√	√	√
SO_2 Layer Height			√		√	√	
HCHO	√	√	√				
CHOCHO	√	√	√				
BrO	√		√				
OClO			√				
HNO_3					√	√	
NH_3					√	√	√
CO			√		√	√	√
CH_4			√	√	√	√	
SIF	√		√	√			
CO_2				√			
H_2O	√	√	√				
UV Products	√	√	√				
Surface Reflectance	√	√	√				

Cells coloured:

blue indicate products to be produced at EUMETSAT, green indicate products to be produced by the AC SAF, orange indicate products not yet committed but possible.
Grey indicate "Not Applicable"

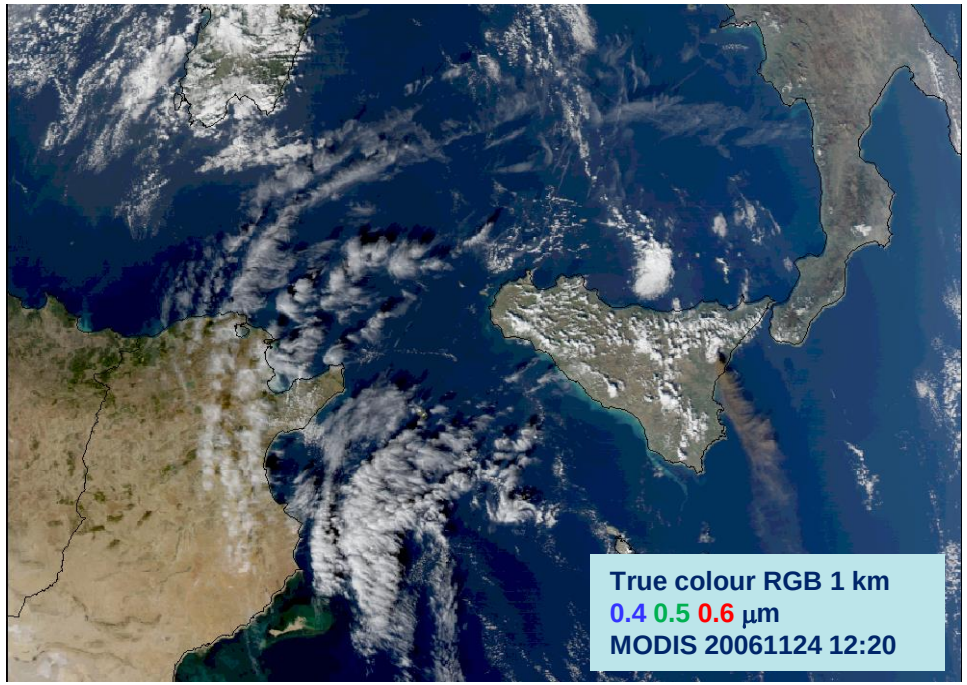
Meteosat Third Generation (MTG)
Full Operational Configuration

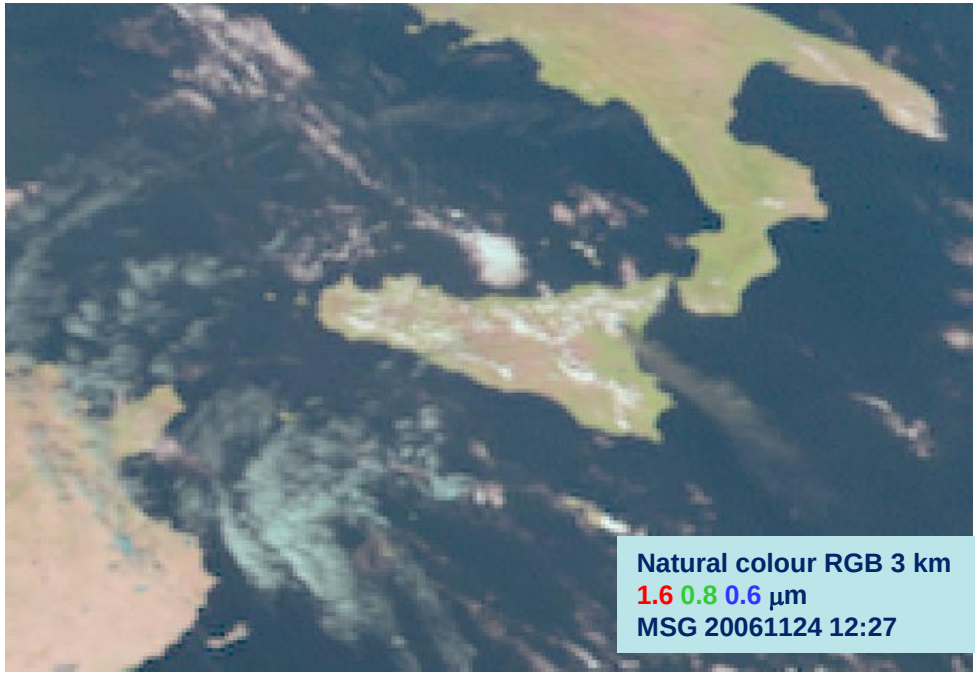


MTG-I Imaging Mission

- 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

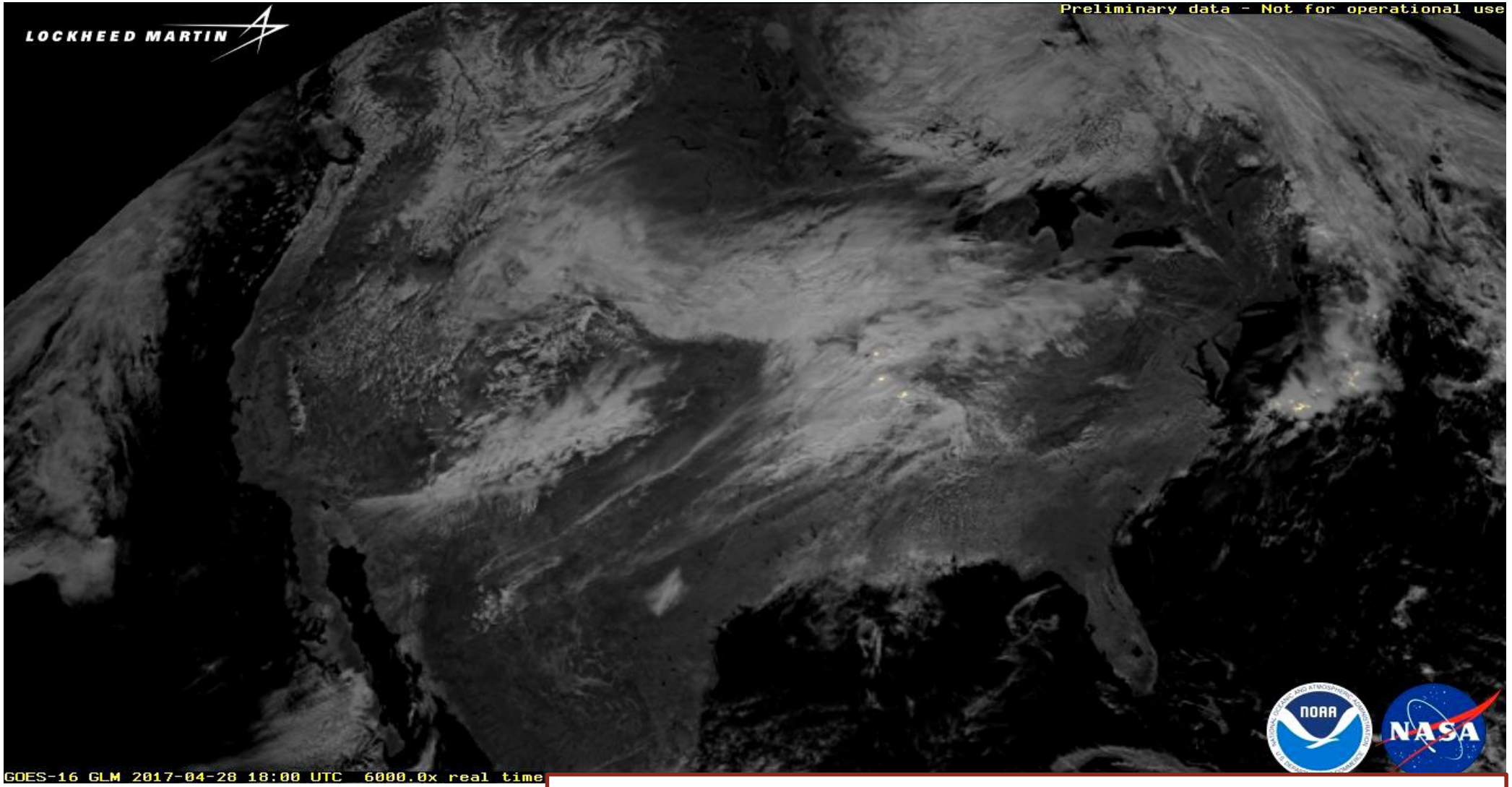
The Flexible Combined Imager
Higher Spatial Resolution and More Spectral Channels





courtesy D. Rosenfeld, Univ. Jerusalem

The Lightning Imager
Lightning Monitoring for NWC / VSRF / AC (GOES-R example)



April 28-30, 2017

GOES-16 GLM lightning superimposed on GLM background: PRE-OPERATIONAL DATA

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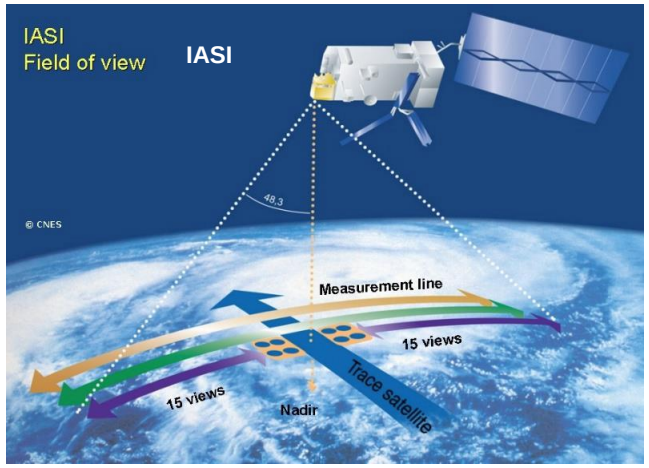
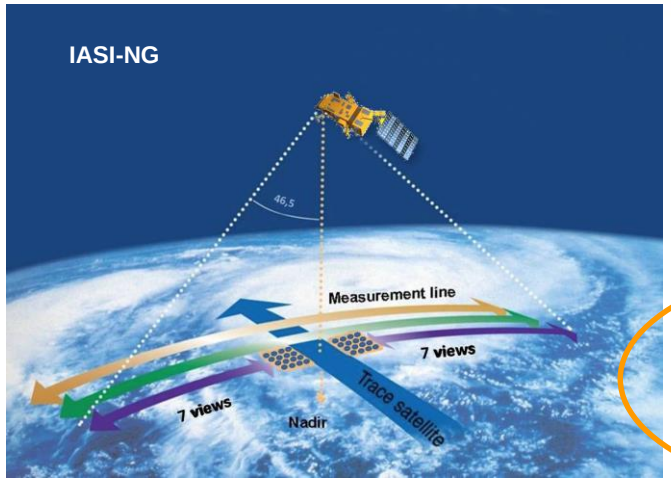
MTG-S Sounding Mission

- Hyperspectral infrared sounding mission
- 3D weather cube: temperature, water vapour, trace gases, 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

From IASI to IASI-NG and the IRS



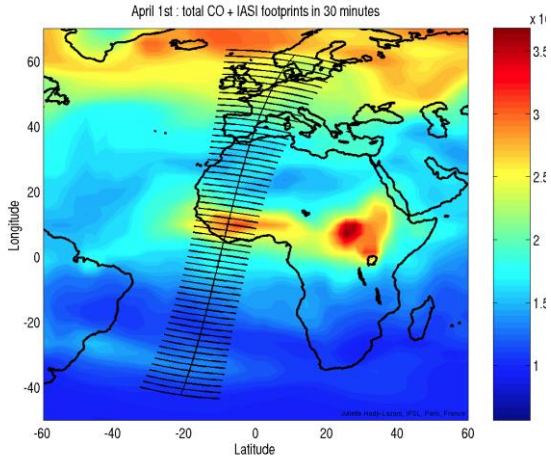


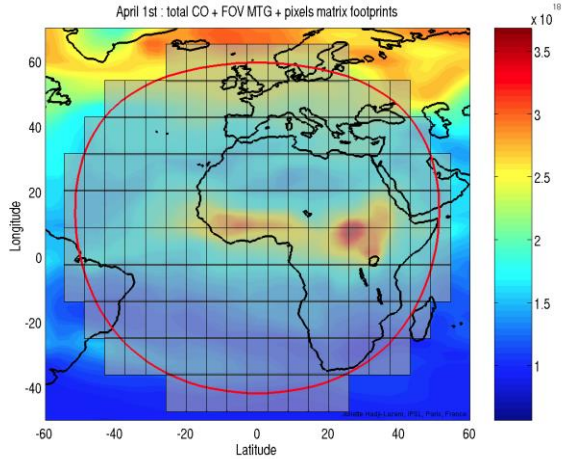
IASI-NG

- 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

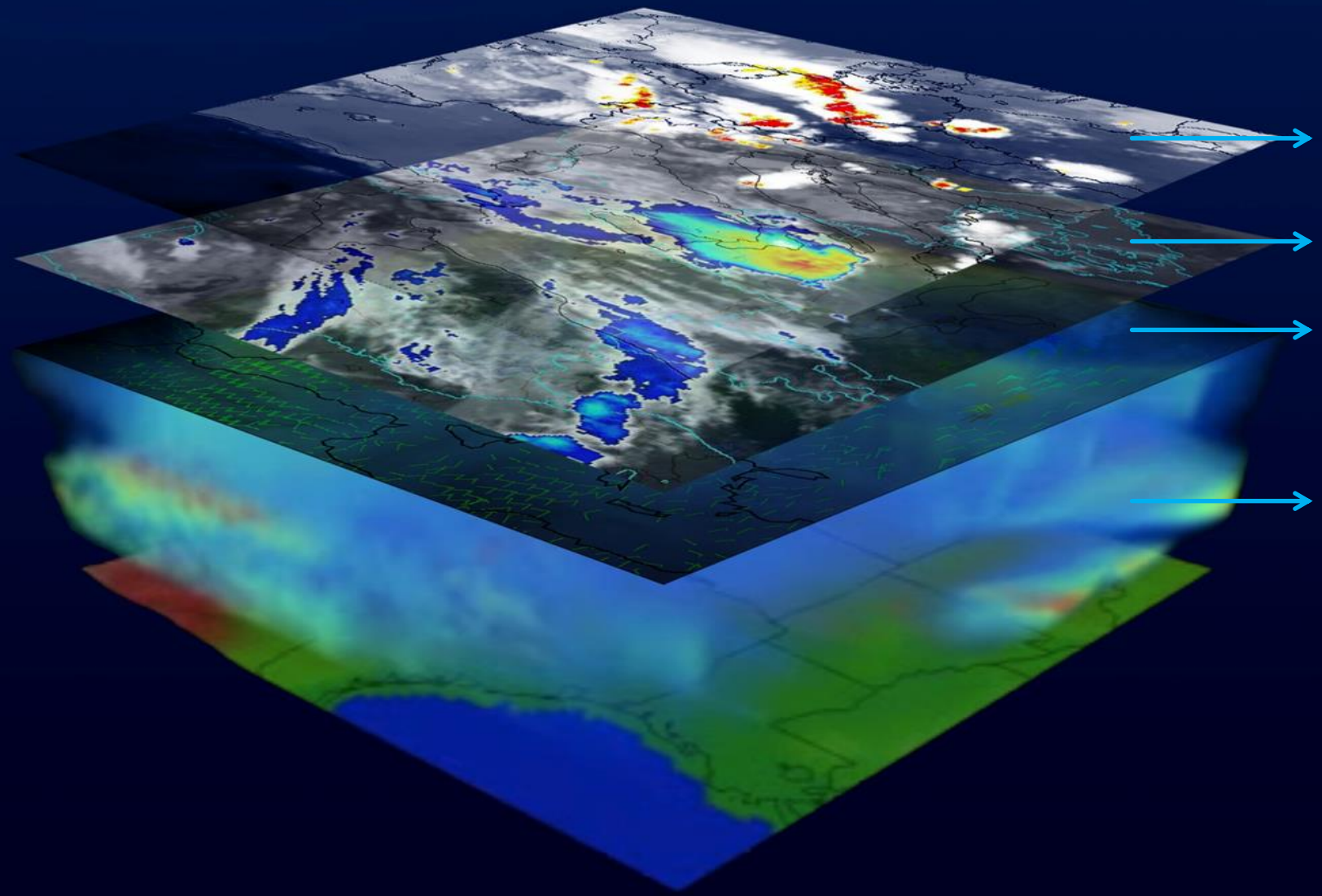




	IASI-NG	IRS
S:N	IASI x 2	O3: ~IASI CO: ~IASI/2
Spectral Resolution	IASI / 2	IASI x 1.5
Pixel Size	IASI (12km)	IASI / 3

Courtesy ULB/LATMOS

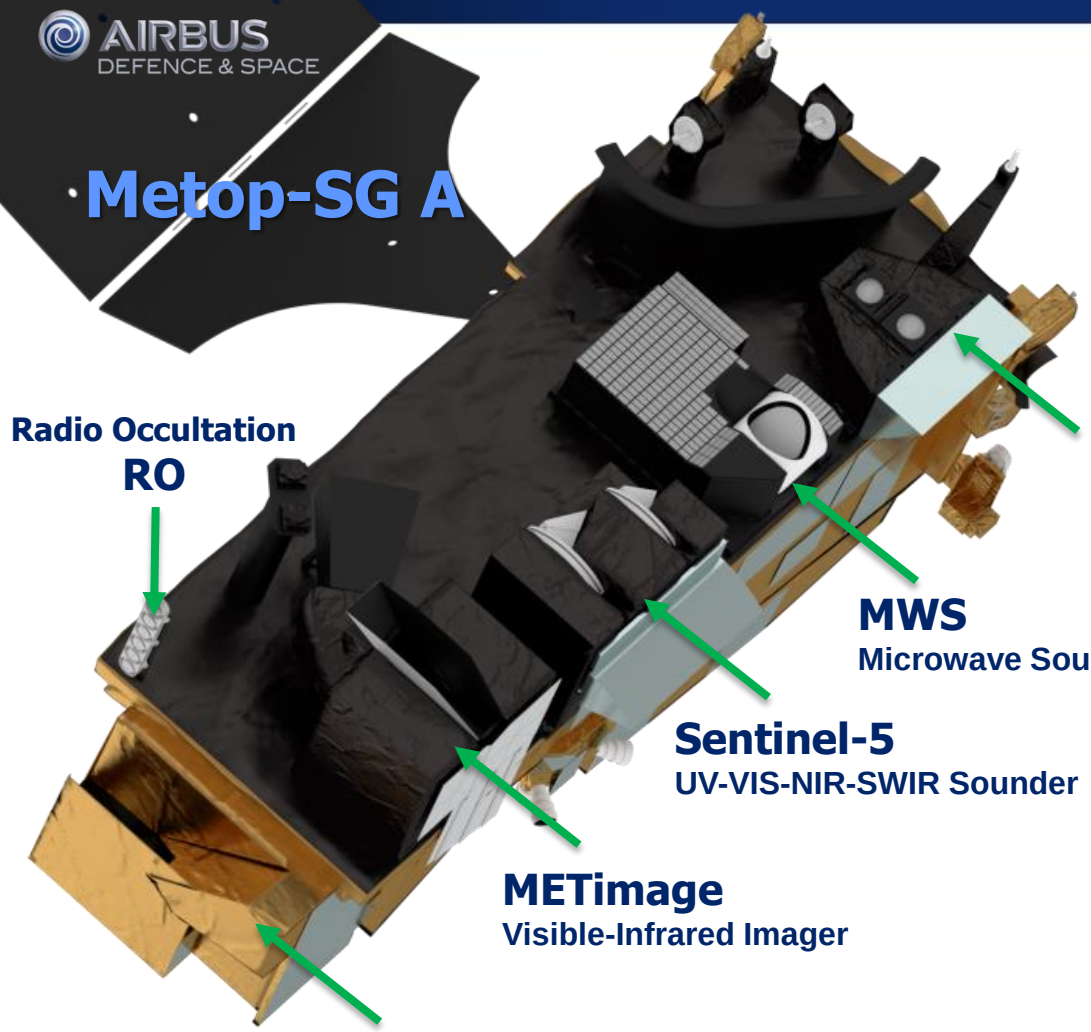
4D Weather Cube with MTG-I and MTG-S

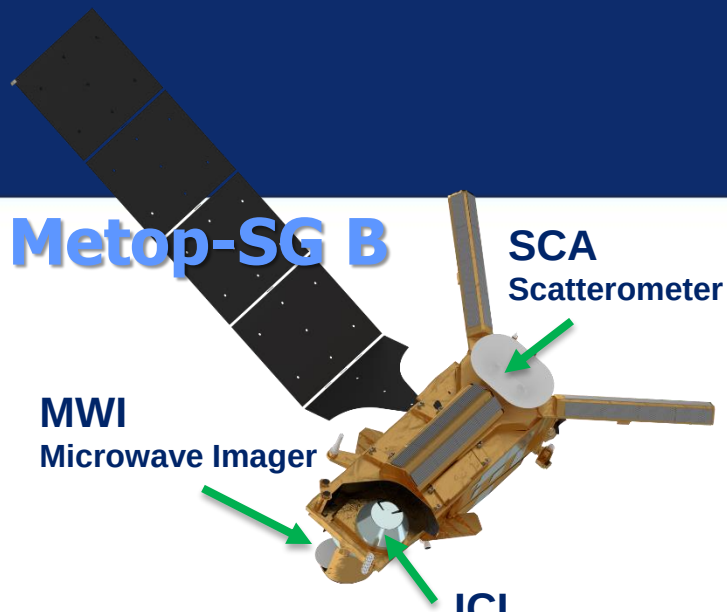


- Lightning
- Convection
- Winds
- Atmosphere

Future Mission EPS-SG:
EUMETSAT Polar System - Second Generation

AIRBUS DEFENCE & SPACE





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

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

Nominal launches:

2022 Metop-SG A1	2022 Metop-SG B1
2028 Metop-SG A2	2029 Metop-SG B2
2035 Metop-SG A3	2036 Metop-SG B3

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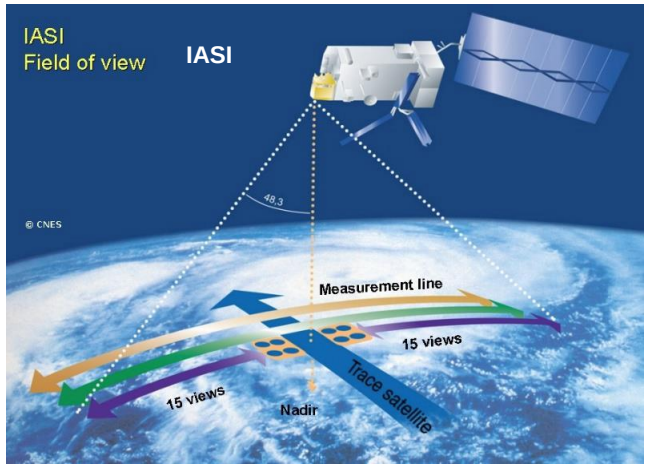
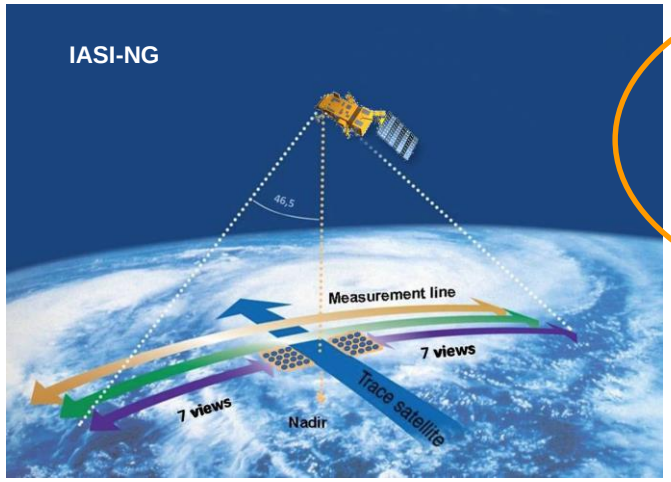
From IASI to IASI-NG and the IRS



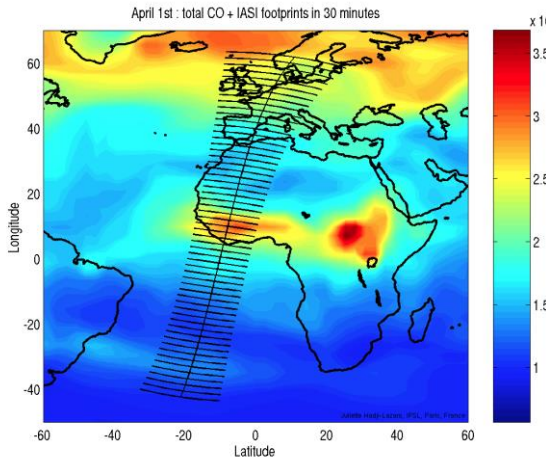


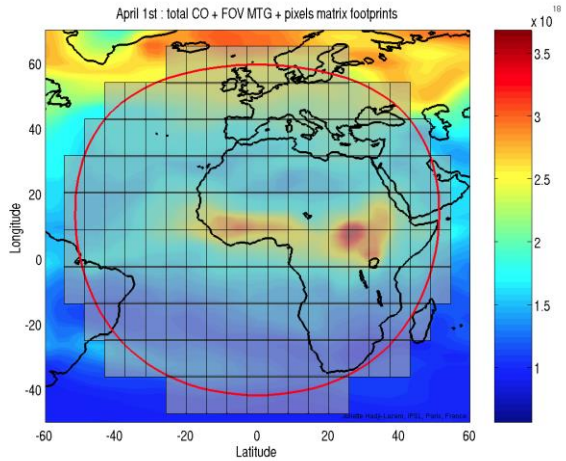
IASI-NG

- 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

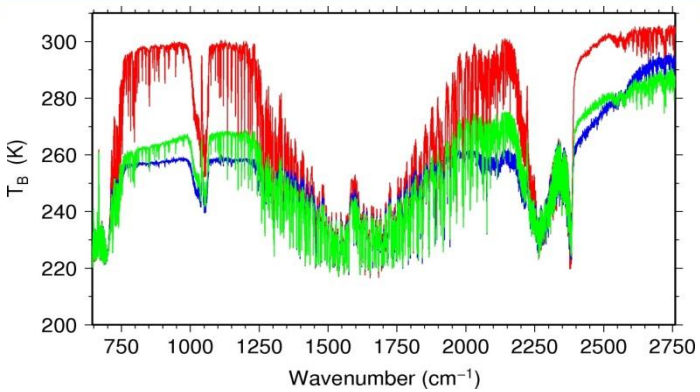
Courtesy ULB/LATMOS

Hyper-spectral Infrared Sounding

IASI-NG

Objectives

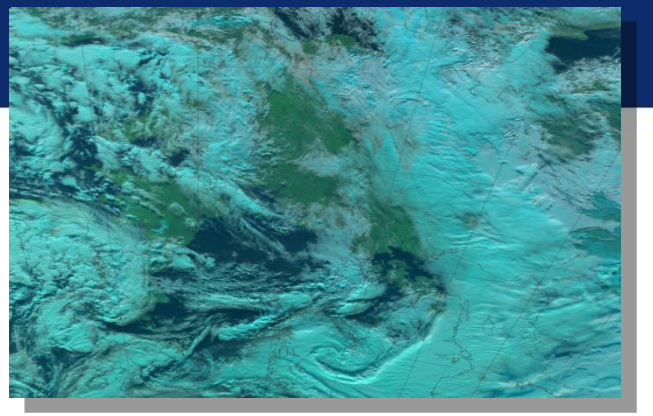
- Temperature/humidity profile at high vertical resolution
- Clouds, trace gases (CO, SO_2, O_3, HNO_3, NH_3,CH_4, CO_2 ...)
- Sea/land/ice surface temperature
- Aerosols, Volcanic Ash



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

Optical Imaging
METimage



Objectives
- Hi-res cloud products, incl. microphysics
- Aerosols
- Polar AMVs
- Vegetation, snow, fire
- Sea/ice/land surface temperature
- Support to sounding missions

Implementation
- Development of *METimage* by DLR

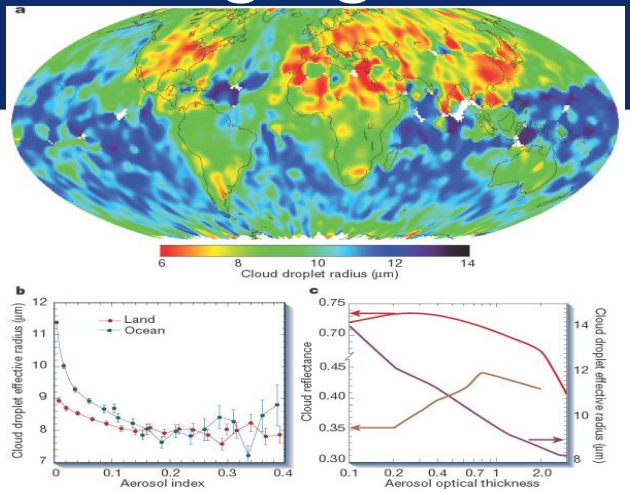
Key performances
- 20 channels: 0.443 – 13.345 µm
- absolute calibration: 5% (short-wave) 0.5 K (long-wave)
- radiometric sensitivity: SNR 60 – 500 (short-wave) 0.05 – 0.2 K (long-wave)
- spatial sampling: 500 m cross-track scan

Breakthrough

- **Many more spectral channels than AVHRR for the benefit of measuring more variables**
- **Higher spatial resolution (500 m):**
  - more complete coverage through greater likelihood to measure surface variables in partly cloud conditions
- **Better radiometric resolution for more accurate quantification of many variables**

Multi-viewing multi-channel multi-polarisation Imaging

3MI



Kaufman et al. (2002)

Objectives of a new mission

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

Implementation

- ESA development

Key performances

- 12 channels: 0.41 – 2.13 µm
- 3 polarisations: 0°, 60°, -60°
- 14 views
- radiometric bias: 3%
- SNR: 200
- spatial sampling: 4 km
- push-broom scan (2200 km swath)

Breakthrough:

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

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.

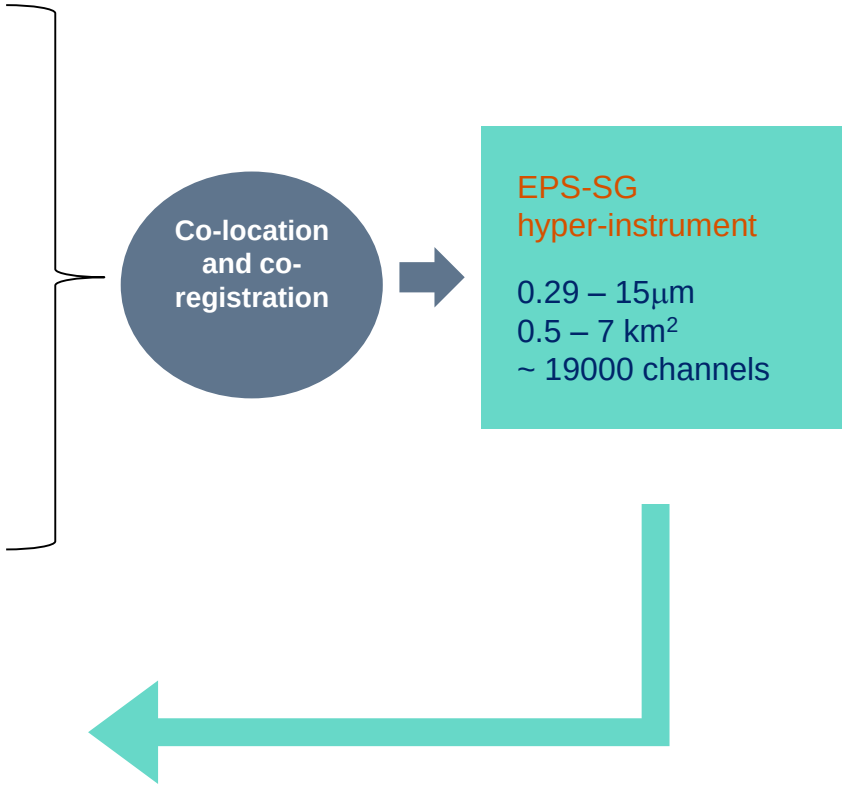
EPS-SG Platform

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

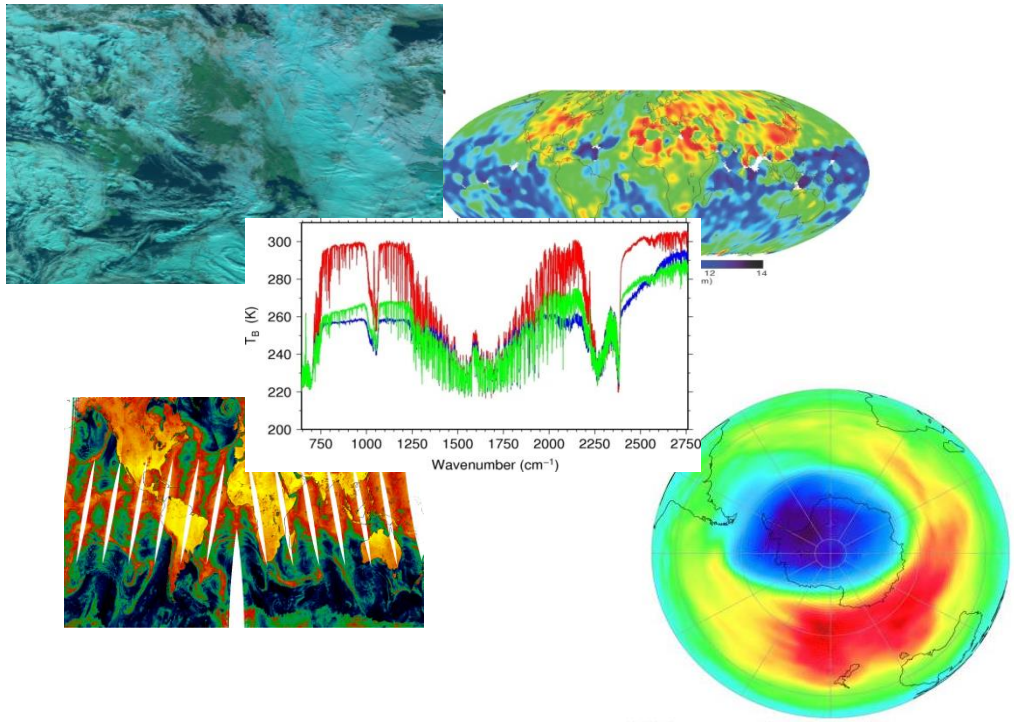


Initial product: Multi-sensor Aerosol product (MAP)

Synergy of Observation Missions

Observation missions are highly complementary

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

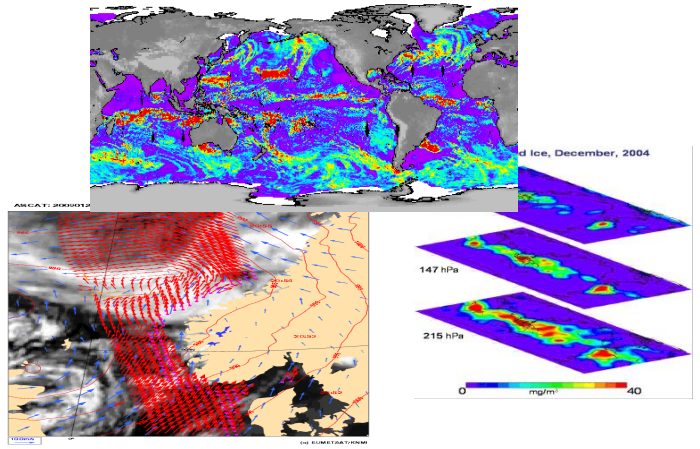


Essential co-registrations

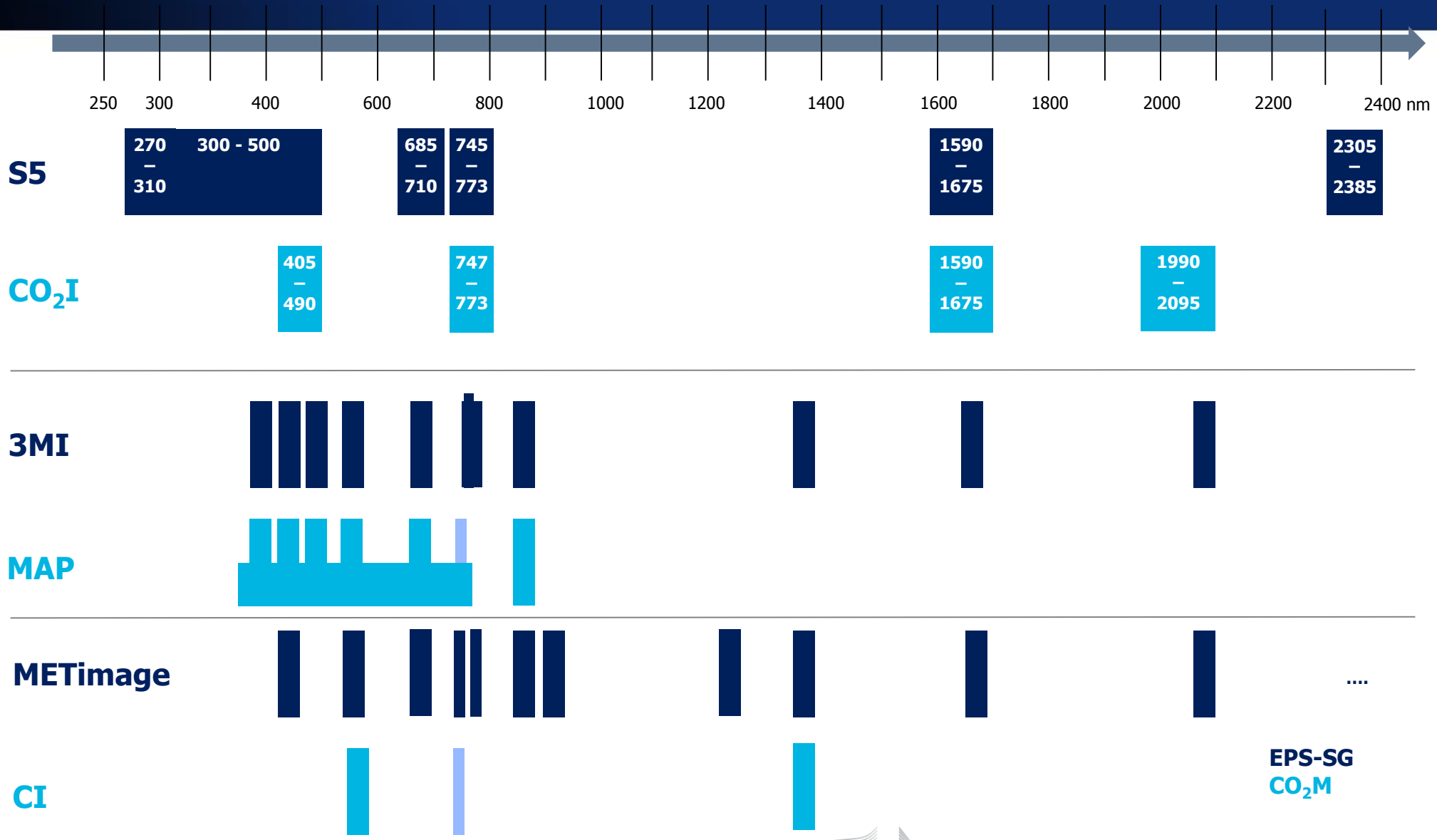
- IASI-NG – METimage – S5/UVNS
- MWI - ICI

Desired co-registrations

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



Spectral coverage: EPS-SG (S5, 3MI, METimage) vs. CO_2M



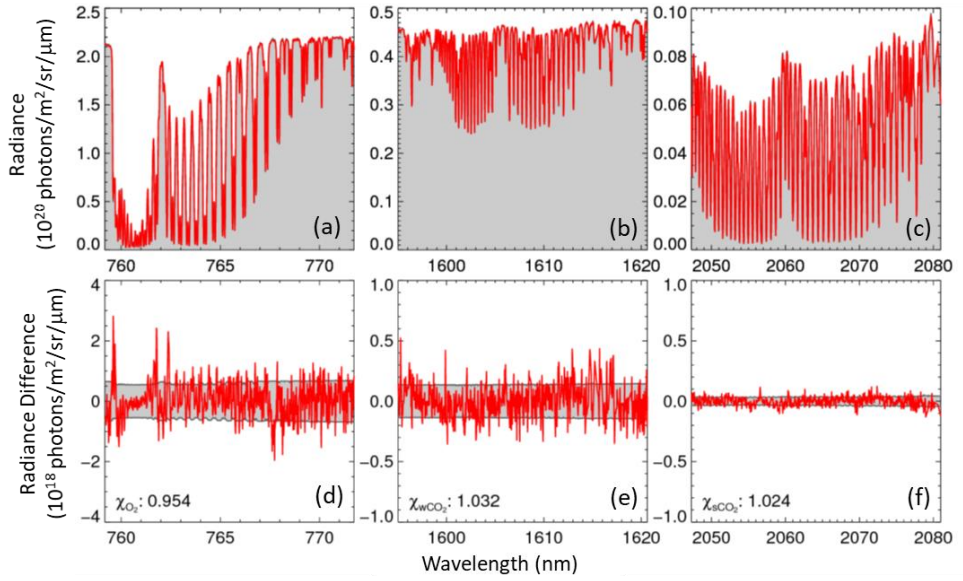
Opportunities for Cross-Calibration (GSICS)

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

Summary

- EUMETSAT will operate a number of Sentinel missions and monitor and evolve their products during the operational phase
- Many opportunities for the development of synergistic products with EUMETSAT missions
- Many synergies in (cross-)calibration / validation activities