EUMETSAT Polar System Second Generation

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EUM/MET/VWG/12/0440
Issue 1
27/09/2013

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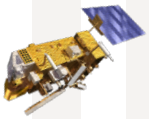
EUMETSAT Programmes: 2020-2040 outlook

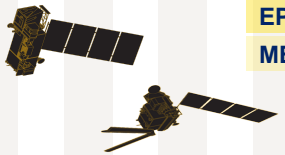
METEOSAT FIRST GENERATION
METEOSAT-7
METEOSAT SECOND GENERATION
METEOSAT-8
METEOSAT-9
MSG-3/METEOSAT-10
MSG-4/METEOSAT-11*

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



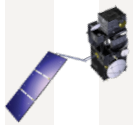
EUMETSAT POLAR SYSTEM (EPS)
METOP-A
METOP-B
METOP-C



EPS-SECOND GENERATION (EPS-SG)
METOP-SG: SOUNDING AND VIS/IR IMAGERY
METOP-SG: IMAGERIE MICRO-ONDES

JASON
JASON-2
JASON-3

JASON SERVICE CONTINUITY (JASON-CS)
SUPPORT TO COPERNICUS
SENTINEL-3



SENTINEL-4 ON MTG-S
SENTINEL-5 ON EPS-SG

Optional and third Party Programmes

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

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Issue 1
27/09/2013

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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

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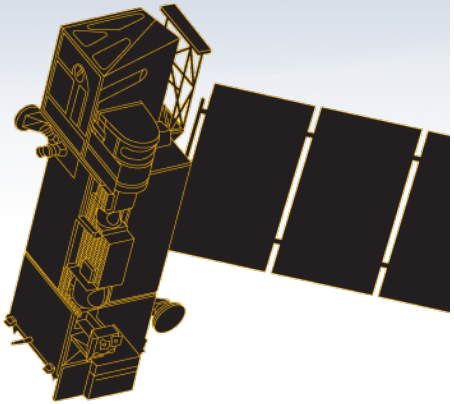
Commissioning Results: Products Status Metop-B end of July 2013

		Special Trial Dissemination	Pre-Op Dissemination	End of Cal / Val
AMSU-A	L1	28/09/12	11/12/12	07/12/12
AVHRR	L1	05/10/12	11/12/12	07/12/12
HIRS	L1	26/10/12*	11/12/12*	07/12/12*
MHS	L1	02/10/12	11/12/12	07/12/12
ASCAT	L1	23/10/12	04/12/12	15/03/13
GOME	L1	12/12/12	13/02/13	06/05/13
GRAS	L1	01/10/12	15/11/12	26/10/12
IASI	L1	22/01/13	20/02/13	17/04/13
IASI	L2	07/03/13	26/06/13	18/07/13
AVHRR Winds	L2	18/03/13	26/06/13	26/06/13
ATOVS	L2	n/a	04/06/13	19/07/13
ASCAT SOMO	L2	13/11/12	11/12/12	15/03/13

*noise degradation since January 2013

EPS Second Generation (EPS-SG)

- Configuration in orbit with two satellites:
  - Metop-SG A : optical imagery and sounding
  - Metop-SG B : microwave imagery
- Continuity of EPS/Metop: 2021 – 2042
- Primary Mission: Improvement of Numerical Weather Prediction
- Other applications
  - Nowcasting at high latitudes
  - Marine meteorology and oceanography
  - Hydrology
  - Air quality monitoring (synergy with Sentinel – 5)
  - Climate monitoring



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EPS-SG in the frame of international co-operation

Joint Polar System
with the US

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Issue 1
27/09/2013

EUMETSAT

EPS-SG

- **Continuity of the EUMETSAT Polar System Services beyond 2020**
  - Provision of continuous long-term datasets in support of operational meteorological and environmental forecasting and global climate monitoring
- **EPS-SG will be part of the NOAA/EUMETSAT Joint Polar System**
  - Service in the mid-morning orbit
- **EPS-SG will fulfil the European contribution to the GOS as concerns the space-based observations from polar orbits**
- **EPS-SG will rely on international cooperation for the development and on national contributions for key instruments**
  - ESA: development of the space segment
  - CNES: development IASI-NG
  - DLR: development of METimage

Observation missions

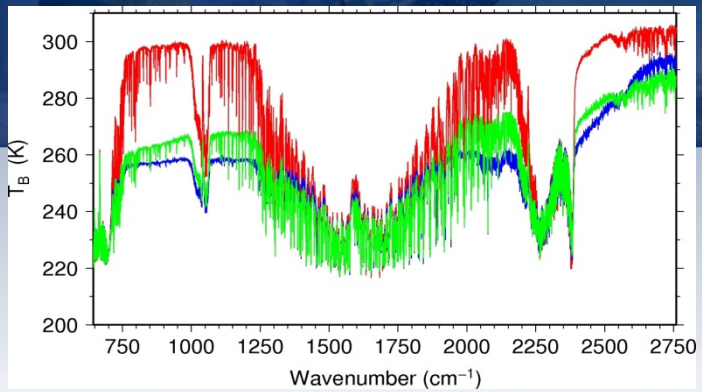
Mission	Instrument	Applications Benefitting
Hyper-spectral Infrared Sounding	IASI-NG	NWP, NWC, Air Quality, CM
Visible/Infra-red Imaging	METimage	NWC, NWP, CM, Hydrology, Oceanography
Microwave Sounding	MWS	NWP, NWC, CM
Radio Occultation Sounding	RO	NWP, CM
Nadir viewing UV/VIS/NIR/SWIR Sounding	Sentinel 5	Ozone-UV, Air Quality, CM, Composition-Climate interactions
Multi-viewing, -channel, -polarisation Imaging	3MI	Air Quality, CM, NWC
Scatterometry	SCA	NWP, NWC, Oceanography, Hydrology
Microwave Imaging	MWI	NWP, NWC, Hydrology, CM, Oceanography
Ice Cloud Imaging	ICI	NWP, NWC, Hydrology, CM

NWP: Numerical Weather Prediction; NWC: Nowcasting; CM: Climate Monitoring

EPS-SG benefits to activities of NMSs

Main Payload	Enhanced Capabilities	Innovative Capabilities	Applications Benfitting
High-Resolution Infrared Sounding	+75% information in T-profiles +30% in WP-profiles	More trace gases and their vertical profiles	NWP, NWC, AC, CM
Microwave Sounding	Enhanced spatial over-sampling		NWP, NWC
Radio Occultation Sounding	Large increase of number of radio-occultations	Tracking of Galileo signals	NWP, CM
Nadir viewing UV/VIS/NIR/ SWIR Sounding	Drastic increase of spatial resolution	Additional trace gas measurements; CO_2 being studied	Air Quality, CM, AC
VIS/IR Imaging	Better radiometric and spatial resolution	Far more variables measured with higher accuracy	NWC, NWP, CM
Multi-viewing, -channel, -polarisation Imaging	New mission	Aerosol parameters	Air Quality, CM, NWC
Scatterometry	Higher spatial resolution and coverage	Cross polarisation for higher wind speeds	NWP, NWC
Microwave Imaging	New mission	Precipitation observations	NWP, NWC, Hydrology, CM
Ice Cloud Imaging	New mission	Cloud microphysics parameters	NWP, NWC, Hydrology, CM

Hyper-spectral infrared sounding
IASI – NG (New Generation)



Objectives

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

Implementation

Development of Fourier Transform Spectrometer IASI-NG by CNES

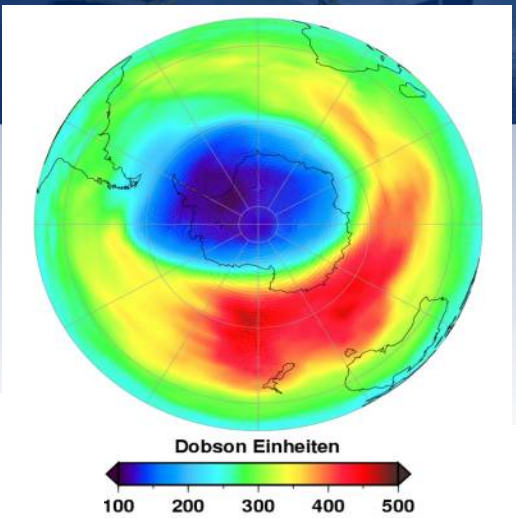
Key performances

- spectral range: 645 – 2760 cm-1
- spectral resolution: 0.25 cm-1
- radiometric calibration: 0.25 K
- stability: 0.1 K
- Radiometric noise: 0.045 – 1.1 K
- pixel size: 12 km
- spatial sampling: 25 km
- cross-track scan

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

UVNS
Nadir viewing UV/VIS/NIR/SWIR sounding



Objectives

- Ozone profile and column
- Columns of CO_2,SO_2, NO_2, H_2O, CO, CH_4,
- Aerosol optical depth
- Columns of BrO, HCHO, OCHCHO
- Volcanic Plumes

Implementation

Copernicus (GMES) **Sentinel-5** to be embarked on Metop-SG, ESA development

Key performances

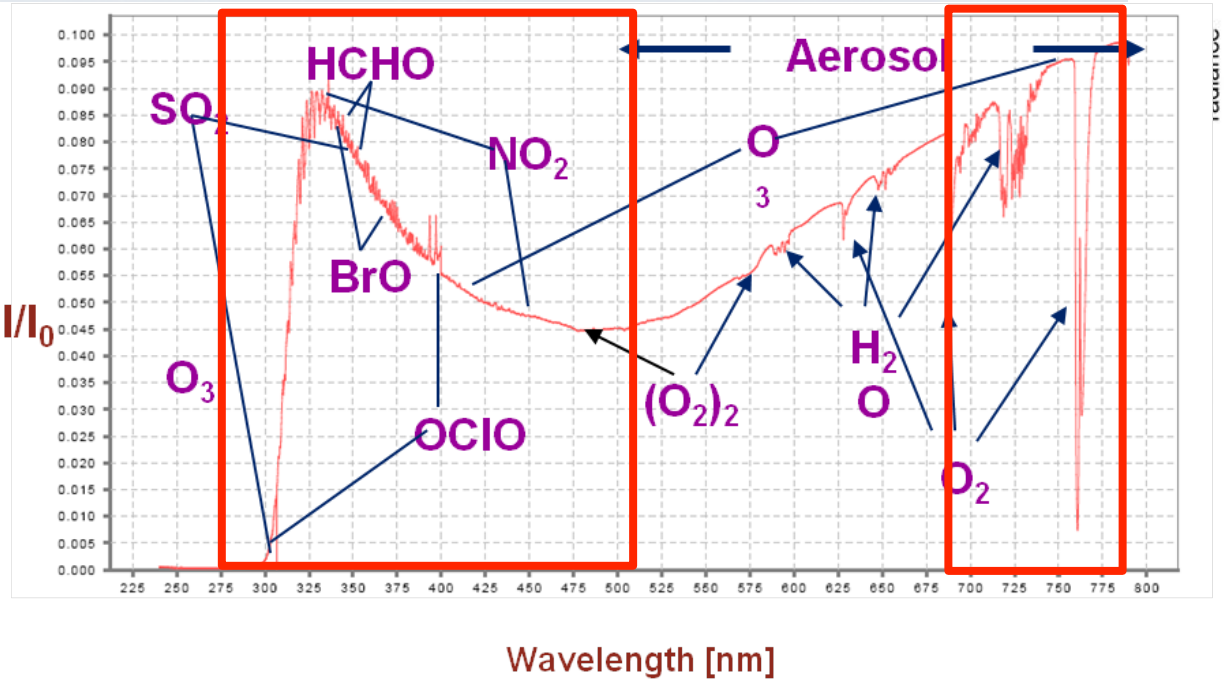
- spectral range: 0.27 – 2.385 µm
  spectral resolution: 0.25 – 1 nm
- radiometric calibration: 1 – 2%
- SNR: 120 - 1500
- spatial sampling: 7 km
- Cross-track scan

Breakthrough

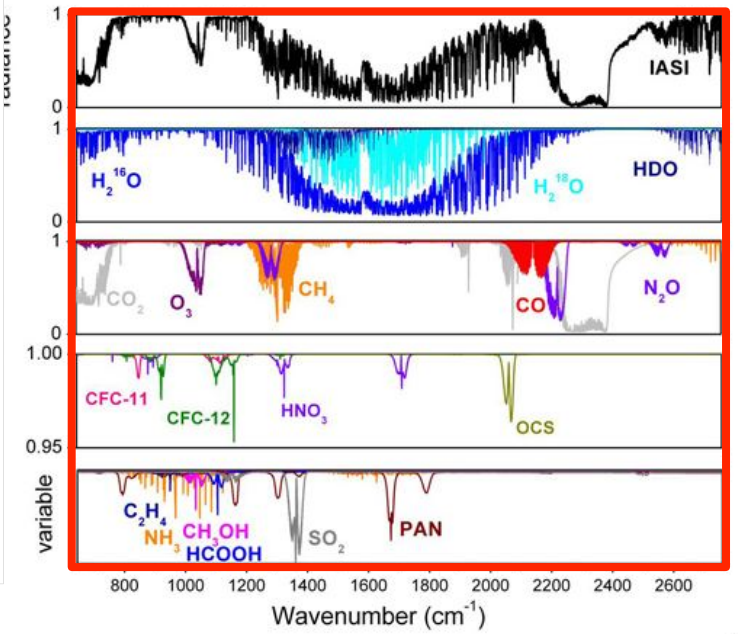
- **Drastically increased spatial sampling (7 km)**
  - for the benefit of air quality monitoring
- **Extended spectral range into the near and shortwave infrared regions**
  - to measure aerosols as well as methane and carbon monoxide in the PBL

IASI-NG and Sentinel-5 on Metop-SG A: a unique synergy for monitoring atmospheric composition

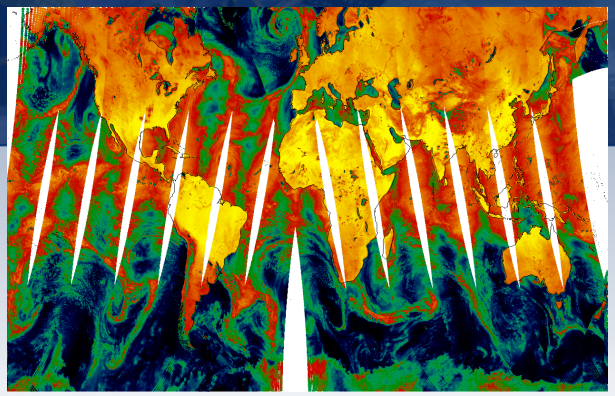
COPERNICUS SENTINEL-5



EPS-SG IASI-NG



Microwave sounding



Objectives

- Temperature/humidity profiles in clear and cloudy air
- Cloud liquid water total column
- Imagery: precipitation

Implementation

ESA development

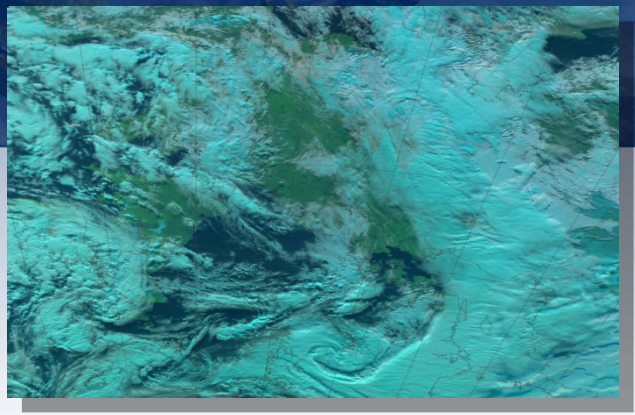
Key performances

- 24 channels: 23.8 – 229 GHz
- absolute calibration: 0.5 K
- radiometric noise: 0.2 – 1.6 K
- footprint size: 17 – 40 km
- cross-track scan

Breakthrough

- **Addition of a quasi-window channel at 229 GHz (recommended by ITSC-11)**
  - Cirrus cloud information giving a better humidity retrieval performance
- **Addition of sounding channels**
  - **+ 2 channels at 53-54 GHz**
  - **+ 3 channels at 183.31 GHz**
  - More information on temperature and water vapour profiles

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
  250 m at 0.67 and 0.865 µm
- cross-track scan

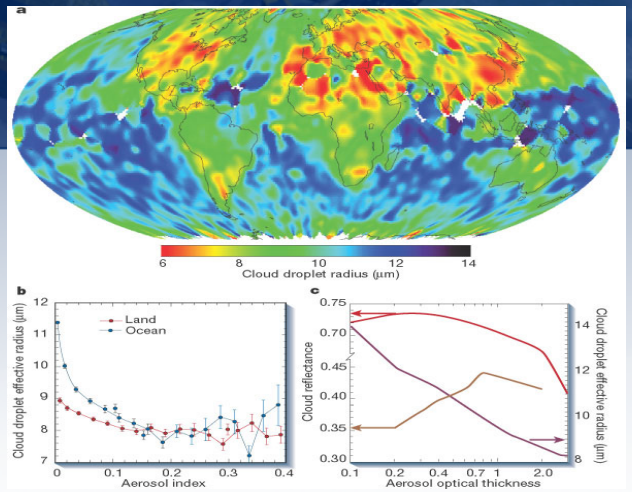
Breakthrough

- **Far more spectral channels than AVHRR for the benefit of measuring more variables**
- **Higher spatial resolution (250 - 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

Objectives of a new mission

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



Kaufman et al. (2002)

Implementation

ESA development

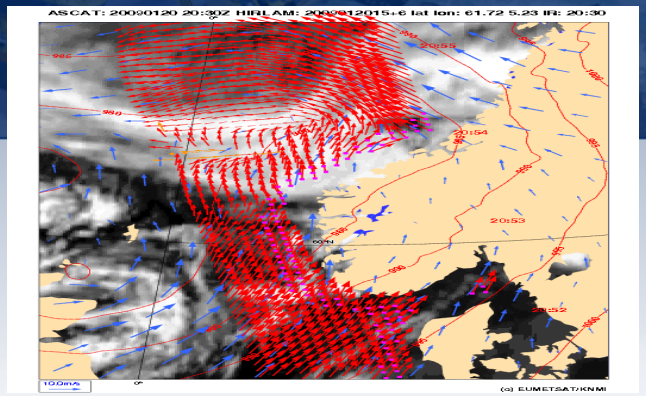
Key performances

- 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

Scatterometry



Objectives

- ocean surface wind vectors
- soil moisture
- snow equivalent water
- sea-ice type

Implementation

ESA development

Key performances

- C-band carrier frequency
- VV + VH polarisation
- measurement range: 4 – 40 m/s
- Radiometric resolution: 3%
- spatial resolution: 25 km
- dual swath: 550 km each

Breakthrough

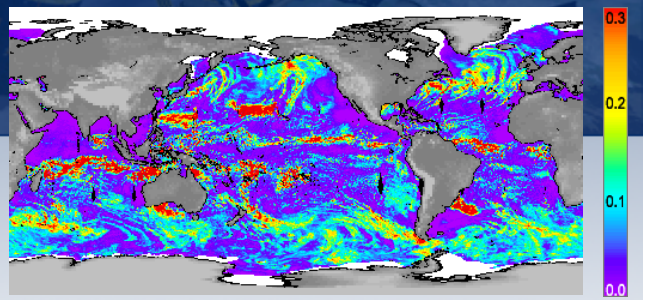
- **Increase of spatial resolution to 25 km**
  - Better approach of coast lines
- **Increase of swath width to >1100 km**
  - Enhanced coverage
- **Addition of VH polarisation**
  - Covers higher wind speeds without saturation, will benefit observation of tropical and extra-tropical storms

Microwave imaging

Objectives of a new mission

- precipitation and cloud products
- water vapour profiles and imagery
- sea-ice, snow, sea surface wind

RSS (2011)



Cloud Liquid Column mm

Implementation

ESA development

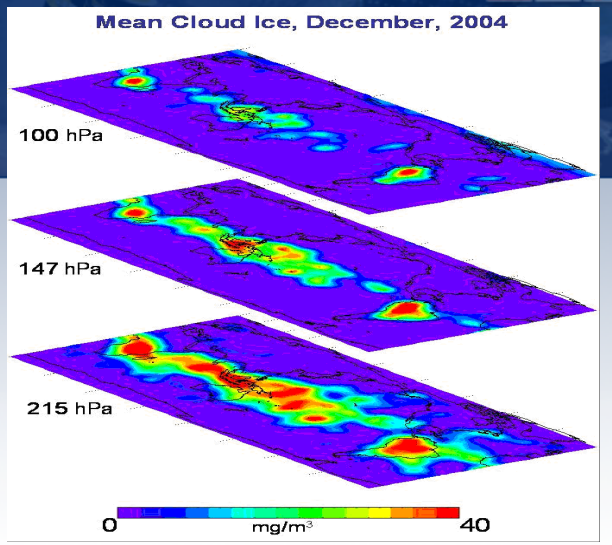
Key performances

- 18 channels: 18.7 – 183 GHz
- dual polarisation (V, H) up to 89 GHz
- V polarisation at higher frequencies
- radiometric accuracy: 1 K
- radiometric sensitivity: 0.6 – 1.2 K
- Footprint size: 10 – 50 km
- spatial sampling: 7 km
- conical scan

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

Ice cloud imaging



NASA: Aura/MLS

Objectives of a new mission

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

Implementation

ESA development

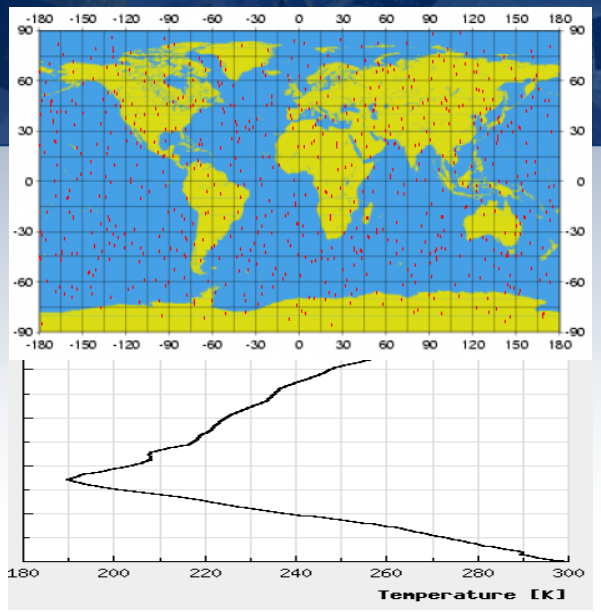
Key performances

- 11 channels: 183 – 664 GHz
- single polarisation (V) for all channels
- dual polarisation (V, H) at 243 and 664 GHz
- radiometric accuracy: 1 – 1.5 K
- radiometric sensitivity: 0.6 – 1.9 K
- Footprint size: 15 km
- spatial sampling: 7.5 km
- conical scan

Breakthrough: 11 channels

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

Radio occultation sounding



Objectives

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

Implementation

- ESA development

Key performances

- tracking of GPS and Galileo satellites
  optional: GLONASS and COMPASS
- RO on two satellites: > 2600 occultations per day
- bending angle accuracy: 0.5 µrad or 0.2%

Breakthrough

- **Tracking of GPS and Galileo satellites to double the number of occultation measurements**
- **Equipment of both Metop-SG satellites with RO in case of a dual satellite configuration**

Synergy of observation missions

Observation missions are highly complementary

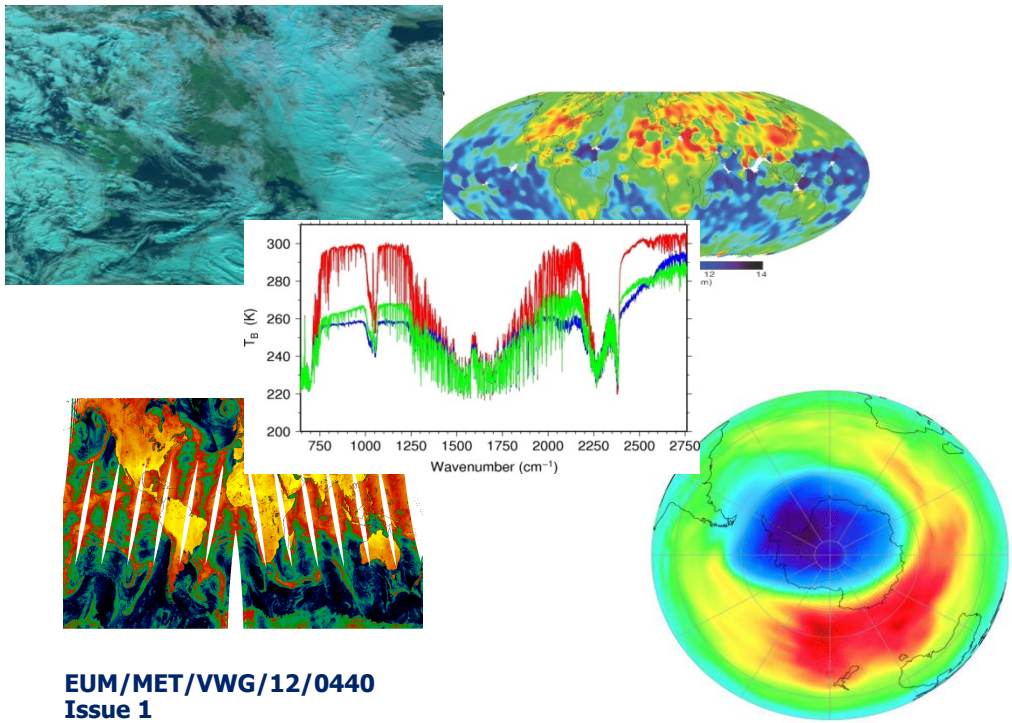
- Co-registration of measurements will allow to optimise the information extraction
- Synergy to be considered in payload distribution of a dual satellite configuration

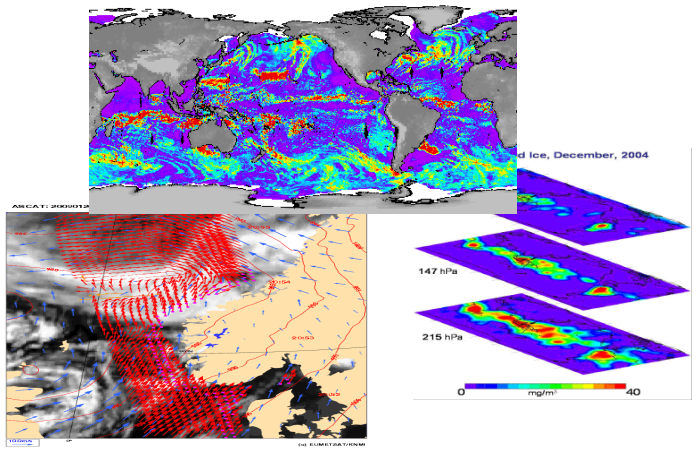
Essential co-registrations

- IAS – VII – UVNS
- MWI - ICI

Desired co-registrations

- IAS – MWS
- VII – 3MI
- IAS – UVNS – 3MI
- MWI – SCA – VII





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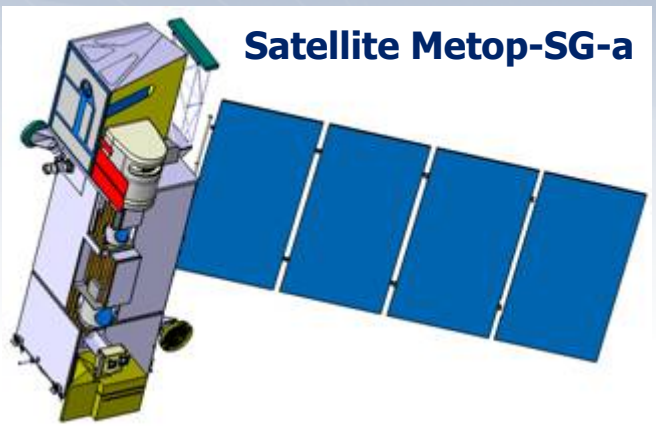
EPS-SG in-orbit configuration

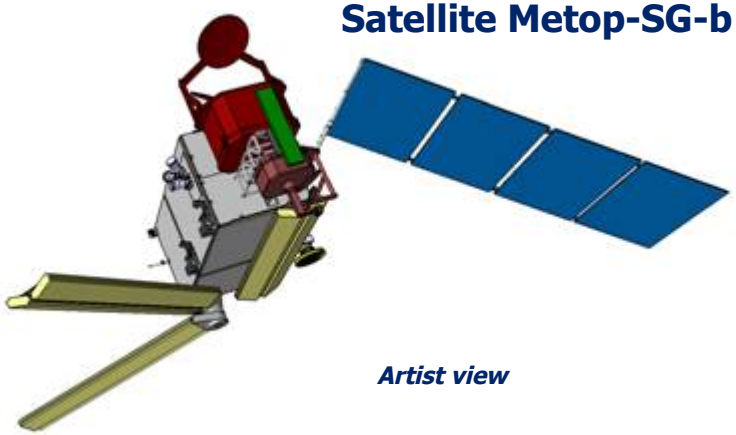
Satellite Metop-SG-a



Artist view

Satellite-a Payload	METimage IASI-NG MWS 3MI Sentinel-5 RO
Dry mass	~ 3250 kg
Launch mass	~ 3661 kg
Power	~ 2.3 kW
P/L data rate	~ 54 Mb/s

Satellite Metop-SG-b



Artist view

Satellite-b Payload	SCA MWI ICI ARGOS-4 RO
Dry mass	~ 2928 kg
Launch mass	~ 3339 kg
Power	~ 2.0 kW
P/L data rate	~ 6.3 Mb/s

EPS-SG space segment
Two-Satellite Configuration

Overall lifetime
21 years

Earliest launch date (first satellite)
end 2020

Orbit
Metop orbit @ 09:30 LTDN

Phasing of Sat-a and Sat-b
180°

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Concluding Remarks

- Driven by User needs, innovation guarantees the operational value of EPS-SG in 20 years: good return on the investment...

  ...and the research for better algorithms

- EPS-SG, new reference of a future polar system
  - Important improvements: sounding, scatterometry, imagery
  - Upgrade in the area of passive microwave remote sensing
  - Important synergy imagery/sounding
- Unique opportunities for air quality forecasting: UV and thermal infrared
- Important decisions need to be taken in 2014: EPS-SG