# Overview of MetSat systems

Training Workshop on Radio Frequency matters
for the Asia-Pacific Region

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# The mission of a MetSat operator is…

- ...to deliver operational satellite data and products that satisfy the meteorological and climate data requirements of its user community (= all of us!) - 24 hours a day, 365 days a year, over decades.

- … to provide the space-based component of the WMO Integrated Global Observing System (WIGOS) for the measurement of environmental and meteorological data with geostationary (GSO) and non-geostationary (NGSO) low Earth-orbiting, mostly polar-orbiting observation satellites.

# MetSats are vital for …

## Monitoring Weather

- The high-quality observations of MetSat satellites are vital for weather forecasting.

## Monitoring Climate

- More and more climate data need to be delivered to meet the challenge of mitigating and adapting to climate change.

## Monitoring Oceans

- Operational oceanography for the delivery of ocean data over decades to monitor the state of the oceans and sea level rise.

## Atmospheric Composition

- Observations of MetSat satellites are also critical inputs to monitoring and forecasts of air quality, which are increasingly important for the health of the population.

## Distributing Data

- Delivery of satellite data and products in real-time to users worldwide.

# Observing weather and climate from space – a global undertaking! (1)

- The development and operation of meteorological and environmental satellite systems and their instruments is usually based on public investments.

- In turn, the data from the instruments (to a significant extent from active and passive microwave sensors) go back (non-profit) to the benefit of society and are used to develop products for the global public, ranging from daily weather forecasts to environmental monitoring and warnings, coverage of disasters, and long-term studies of the Earth's climate.

- The global weather community is the heaviest user of passive microwave data.

- Computer weather models use passive sensor data and data from other sources to create Numerical Weather Prediction (MWP) products. These forecasts cover different sized geographic areas from the whole globe down to small areas.

- The NWP forecasts are also passed along to countries that don't yet have this capability.

# Observing weather and climate from space – a global undertaking! (2)

- There is a global network of GSO and NGSO MetSat satellites in order to ensure global weather and climate monitoring at any time.

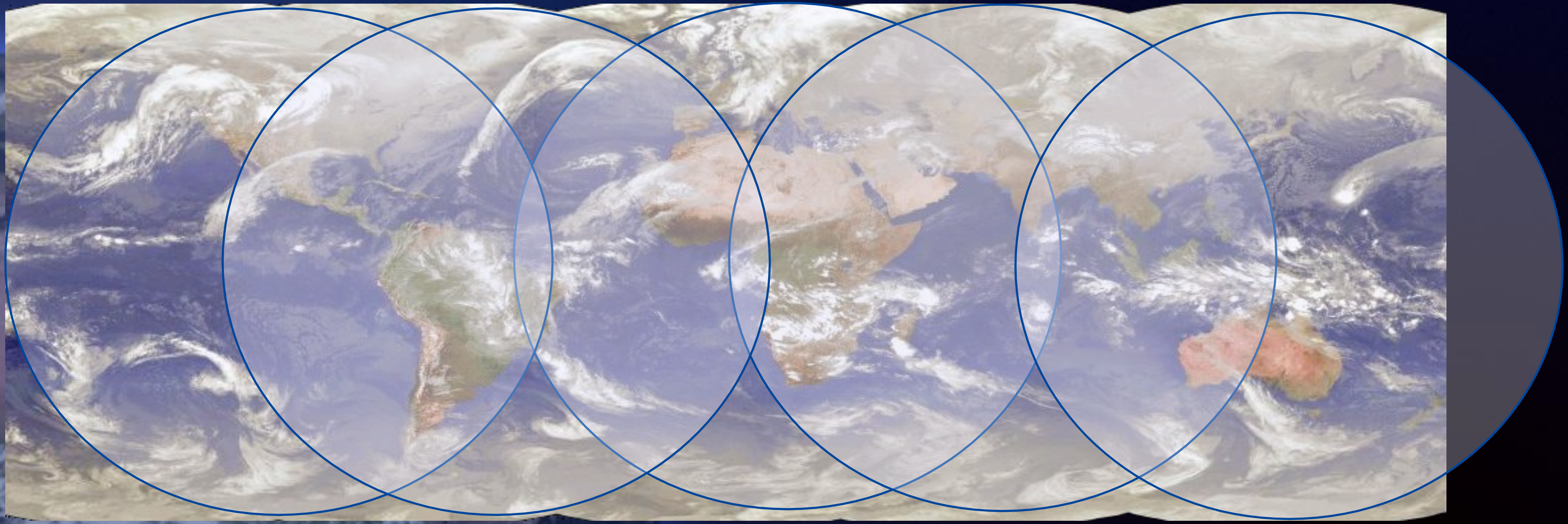
- Operational continuity in the space-based meteorological observations is ensured by replacing existing series of MetSat satellites with new or next generation MetSats.

- This continuity is coordinated among all MetSat operating agencies in the framework of CGMS (Coordination Group for Meteorological Satellites).

- Next generation MetSats have significantly increased observation capabilities and instrument resolution, resulting in corresponding higher data volume available to the meteorological user community.

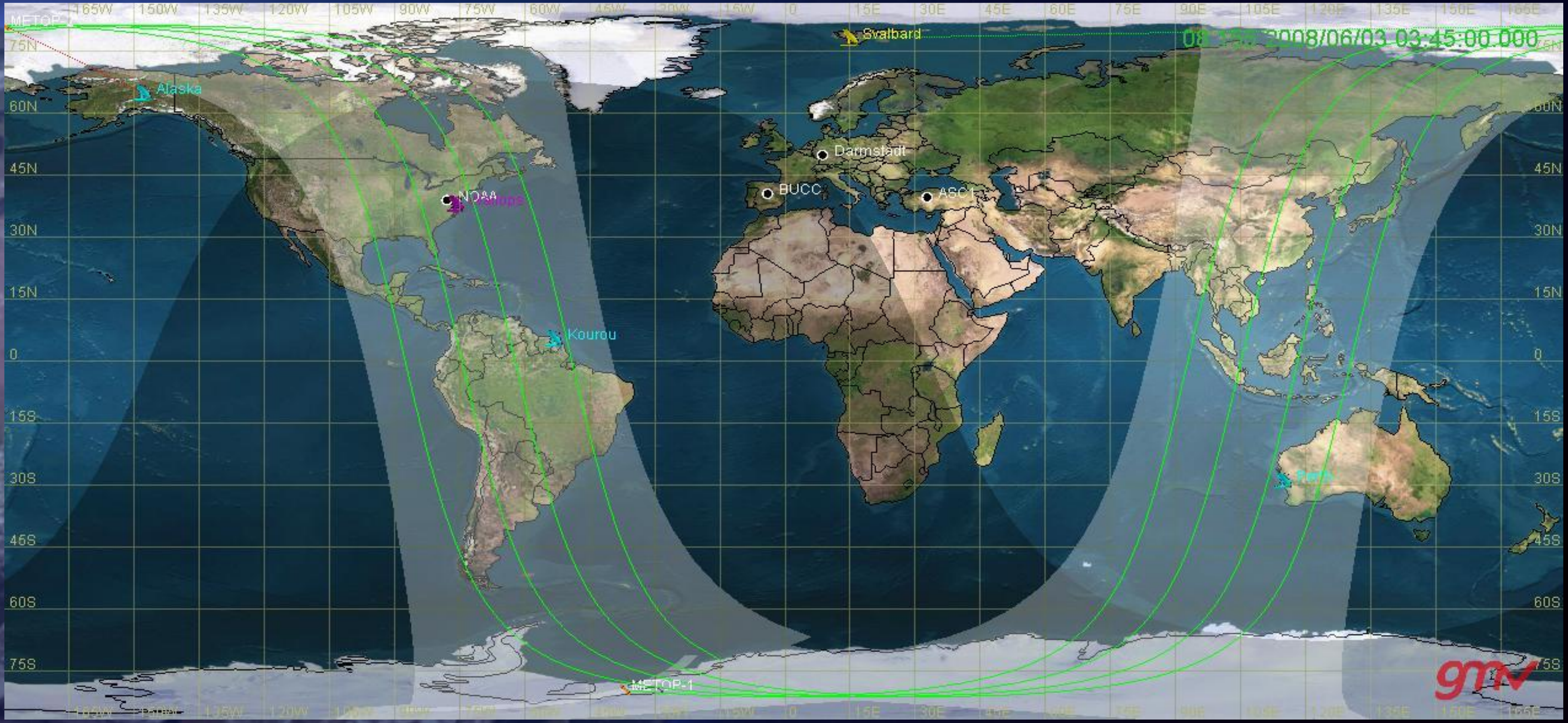
# Global coverage with GSO MetSat through international cooperation

- Geostationary MetSat satellites are particularly useful for detecting the development of weather and predicting their behaviour over the next few hours.
- They provide information on storms, clouds, winds, fog, rain, snow, incoming solar radiation, volcanic ash, dust, land and sea surface temperature and even fires.



# Why are MetSats so important for all this? Answer: Global coverage !

- Non-geostationary polar orbiting MetSat satellites (example Metop: Orbit height 830 km, 14 orbits/day, measurements twice over the same are at a swath width of ~2000 km)
    - Primary source of global climate observations and forecasts up to 10 days, e.g. providing vertical profiles of temperature and humidity through the atmosphere on a global basis.



# Constellation of the currently operational meteorological satellites of WIGOS


## GEOSTATIONARY METEROLOGICAL SATELLITES

| | | | |
|---|---|---|---|
| 1 | GOES-18 | 137° W | |
| 2 | GOES-14 | 108° W | (stand-by) |
| 3 | GOES-17 | 104,7° W | (stand-by) |
| 4 | GOES-16 | 75.2° W | |
| 5 | Electro-L N2 | 14.5° W | |
| 6 | Meteosat-12 | 0.3° W | |
| 7 | Meteosat-10 | 0° | |
| 8 | Meteosat-11 | 9.5° E | |
| 9 | Meteosat-9 | 45.5° E | |
| 10 | INSAT-3DR | 74° E | |
| 11 | Electro-L N3 | 76° E | |
| 12 | FY-2H | 79° E | |
| 13 | INSAT-3DS | 82° E | |
| 14 | GOES-19 | 89.5° E | (comissioning) |
| 15 | FY-2G | 99.5° E | |
| 16 | FY-4B | 105° E | |
| 17 | FY-4A | 123.5° E | |
| 18 | GEO-KOMPSAT-2A | 128.2° E | |
| 19 | Himawari-8 | 140.7° E | (stand-by) |
| 20 | Himawari-9 | 140.7° E | |
| 21 | Electro-L N4 | 165.8° E | |

## NON-GEOSTATIONARY METEROLOGICAL SATELLITES

### SUN-SYNCHRONOUS ORBIT

| | | | |
|---|---|---|---|
| 22 | DMSP-F18 | ECT 04:30 desc | Early Morning |
| 23 | FY-3E | ECT 05:40 desc | |
| 24 | DMSP-F17 | ECT 06:35 desc | |
| 25 | NOAA-15 | ECT 07:29 desc | |
| 26 | FY-3C | ECT 08:20 desc | Mid-Morning |
| 27 | NOAA-19 | ECT 08:22 desc | |
| 28 | Meteor-M N2-3 | ECT 09:00 desc | |
| 29 | Metop-B | ECT 09:30 desc | |
| 30 | Metop-C | ECT 09:30 desc | |
| 31 | FY-3F | ECT 10:00 desc | |
| 32 | NOAA-18 | ECT 10:34 desc | |
| 33 | SNPP | ECT 13:25 asc | Afternoon |
| 34 | NOAA-20 | ECT 13:25 asc | |
| 35 | NOAA-21 | ECT 13:30 asc | |
| 36 | FY-3D | ECT 13:40 asc | |
| 37 | Meteor-M N2-4 | ECT 15:00 asc (commissioning) | |

### DRIFTING ORBITS

| | | |
|---|---|---|
| 38 | Sentinel-6A | 66 ° incl |
| 39 | JASON-3 | 66 ° incl |
| 40 | GPM-core | 65 ° incl |
| 41 | FY-3G | 50° incl |
| 42 | COSMIC-2 | 24° incl |

### HIGHLY ELLIPTICAL ORBIT

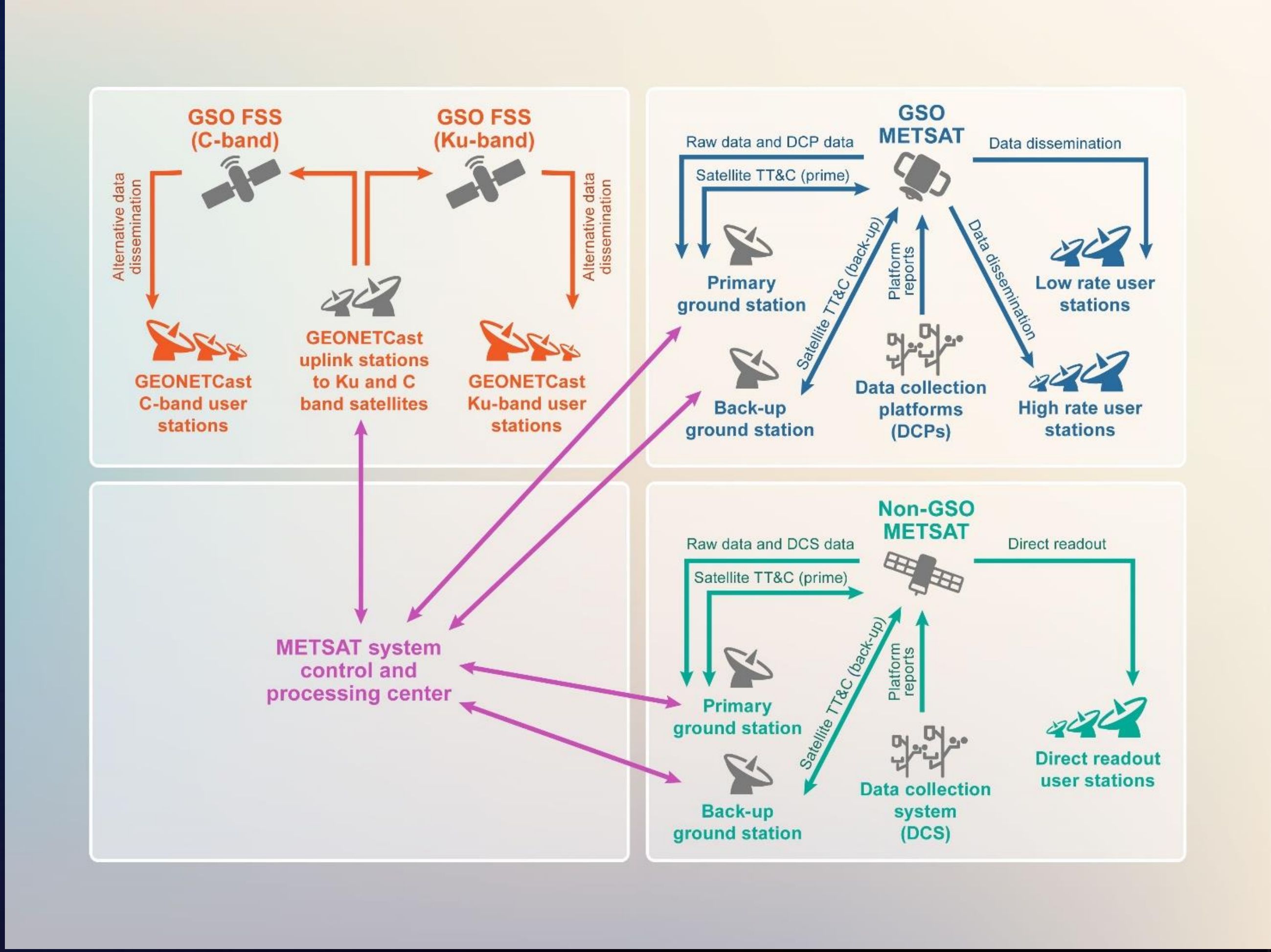
| | |
|---|---|
| 43 | Arctica-M N1 |
| 44 | Arctica-M N2 |

USA | Russia | EUROPE | India | China | Republic of Korea | Japan

# General telecommunication architecture of a MetSat system

Radio-frequencies are used for the following MetSat/EESS applications:

- telemetry, telecommand and ranging of the spacecraft
- transmissions of observation data from MetSat satellites to main reception stations;
- re-transmissions of pre-processed data to meteorological user stations through MetSat satellites;
- direct broadcast transmissions to meteorological user stations from MetSat satellites;
- alternative data dissemination to users (GEONETCast) via other satellite systems than MetSat (not in MetSat/EESS allocated frequency bands);
- transmissions from Data Collection Platforms through MetSat satellites;
- relay of Search and Rescue messages (COSPAS-SARSAT);
- orbit determination and radio occultation systems by exploitation of GPS signals;
- active and passive microwave sensing.



# Development and trends for next generation MetSat satellite systems

- Each operating agency of MetSat satellite systems has their next generation satellite systems under development to complement and finally gradually replace the existing satellites.
- Data continuity is ensured on instrument level, by providing successor instruments.
- Additional new instrument types cover the user requested additional/new observations of weather and climate variables (e.g. microwave sensing from GSO, lightning imager from GSO, ice cloud measurements from NGSO, exploiting frequency bands above 275 GHz).
- New instruments observe with increased measurement resolutions, higher instrument sensitivity, higher repetition rates, increased number of observation channel.
- Consequence from the evolution of the measurements is a significantly increased data volume which requires the use of higher frequency bands for the data downlinks to handle the data volumes.
- The data volume to be downlinked and distributed to the users from the new generation of MetSat/EESS satellites that are currently deployed will (have to) use X-Band (7450-7550 MHz, 7750-7900 MHz, 8025-8400 MHz) and/or Ka-Band 25.5-27 GHz).
- One trend is also the development of small satellite constellations with distinct instruments to improve latency of the data availability to the users.

# Overview of instrument types and missions on MetSat systems

## GSO MetSat:

- Visible imagers
- Infrared imagers
- Infrared sounders
- UV sounders

**First microwave sensors are planned also for next generation GSO MetSats !**

- Data Collection System
- Search and Rescue
- Further instruments (e.g. lightning imager)

## NGSO MetSat:

- Visible imagers
- Infrared imagers
- Infrared sounders
- UV sounders
- Active microwave sensors
- Passive microwave sensors
- Data Collection System
- Search and Rescue
- Further instruments (individual to different NGSO MetSat systems)

# ITU Radio Regulations (1)

**Status:**

- Mandatory intergovernmental treaty

**Concept:**

- Make spectrum and orbital positions allocations to avoid harmful interference between radio stations of different countries and to achieve efficient use

**Instruments:**

- Allocation table, technical limitations,
- pre-determined parameters, operational measures,
- coordination procedures

**Objectives:**

- International spectrum sharing
- International recognition of spectrum use
- Interoperability and roaming
- Global protection of passive bands

# ITU Radio Regulations (2)

**Radiocommunication service:**

A service involving the transmission, emission and/or reception of radio waves for specific telecommunication purposes (RR Article 1)

**Allocation:**

Entry in the Table of Frequency Allocations for the purpose of its use by one or more terrestrial or space radiocommunication services under specified conditions (RR Article 5)

**Shared frequency bands**

**Primary and secondary allocations**

**Passive bands (RR No. 5.340 "all emissions are prohibited) → Exceptional conditions!**

**29.9-34.2 GHz**

| Allocation to services | | |
|---|---|---|
| **Region 1** | **Region 2** | **Region 3** |
| **29.9-30** FIXED-SATELLITE (Earth-to-space) 5.484A 5.484B 5.516B 5.517B 5.527A 5.539<br>INTER-SATELLITE 5.521A<br>MOBILE-SATELLITE (Earth-to-space)<br>Earth exploration-satellite (Earth-to-space) 5.541 5.543<br>5.525 5.526 5.527 5.538 5.540 5.542 | | |
| **30-31** FIXED-SATELLITE (Earth-to-space) 5.338A<br>MOBILE-SATELLITE (Earth-to-space)<br>Standard frequency and time signal-satellite (space-to-Earth)<br>5.529A 5.542 | | |
| **31-31.3** FIXED 5.338A 5.543B<br>MOBILE<br>Standard frequency and time signal-satellite (space-to-Earth)<br>Space research 5.544 5.545<br>5.149 | | |
| **31.3-31.5** EARTH EXPLORATION-SATELLITE (passive)<br>RADIO ASTRONOMY<br>SPACE RESEARCH (passive)<br>5.340 | | |
| **31.5-31.8**<br>EARTH EXPLORATION-SATELLITE (passive)<br>RADIO ASTRONOMY<br>SPACE RESEARCH (passive)<br>Fixed<br>Mobile except aeronautical mobile<br>5.149 5.546 | **31.5-31.8**<br>EARTH EXPLORATION-SATELLITE (passive)<br>RADIO ASTRONOMY<br>SPACE RESEARCH (passive)<br>5.340 | **31.5-31.8**<br>EARTH EXPLORATION-SATELLITE (passive)<br>RADIO ASTRONOMY<br>SPACE RESEARCH (passive)<br>Fixed<br>Mobile except aeronautical mobile<br>5.149 5.546 |
| **31.8-32** FIXED 5.547A<br>RADIONAVIGATION<br>SPACE RESEARCH (deep space) (space-to-Earth)<br>5.547 5.547B 5.548 | | |

# Definition of MetSat in the ITU Radio Regulations

- MetSat is defined in No. 1.52 of the Radio Regulations (RR) as "an Earth exploration-satellite service (RR No. 1.51) for meteorological purposes".
- It allows the radiocommunication operation between earth stations and one or more space stations, which may include links between space stations, with links to provide:
  - Information relating to the characteristics of the Earth and its natural phenomena, including data relating to the state of the environment, obtained from active or passive sensors on Earth satellites;
  - Information collected from airborne or Earth-based platforms;
  - Information distributed to earth stations;
  - Feeder links necessary for the operation of MetSat satellites and its applications.

# Frequency allocations to SOS, EESS & MetSat in the Radio Regulations

| Space operation service | Earth Exploration-satellite service *) | Meteorological-satellite service |
|---|---|---|
| 137-138 MHz (s-E) (P) | | 137-138 MHz (s-E) (P) |
| 400.15-401 MHz (s-E) (s) | | 400.15-401 MHz (s-E) (P) |
| 401-402 MHz (s-E) (P) | 401-402 MHz (E-s) (P) | 401-402 MHz (E-s) (P) |
| | 402-403 MHz (E-s) (P) | 402-403 MHz (E-s) (P) |
| | 460-470 MHz (s-E) (may be used under FN 5.289) | 460-470 MHz (s-E) (s) |
| 1525-1535 MHz (s-E) (P) | 1525-1535 MHz (s) | |
| | 1690-1710 MHz (s-E) (may be used under FN 5.289) | 1675-1710 MHz (s-E) (P) |
| 2025-2110 MHz (E-s) (s-s) (P) | 2025-2110 MHz (E-s) (s-s) (P) | |
| 2200-2290 MHz (s-E) (s-s) (P) | 2200-2290 MHz (s-E) (s-s) (P) | |
| | 7190-7250 MHz (E-s) (P) | |
| | | 7450-7550 MHz (s-E) (GSO) (P) |
| | | 7750-7900 MHz (s-E) (NGSO) (P) |
| | 8025-8400 MHz (s-E) (P) | 8175-8215 MHz (E-s) (P) |
| | 13.75-14 GHz (s) | |
| | 18-18.3 GHz (R2) / 18.1-18.4 GHz (R1&3) (s-E) (P) | |
| | 25.5-27 GHz (s-E) (P) | |
| | 28.5-30 GHz (E-s) (s) | |
| | 37.5-40 GHz (s-E) (s) | |
| | 40-40.5 GHz (E-s) (P) & (s-E) (s) | |
| | 65-66 GHz (P) | |

*) Not including active or passive allocations to the EESS.

# Overview of bands and their applications most commonly used by current & planned MetSat systems

| | Communications |
|---|---|
| Up- and downlink for GSO and NGSO MetSat Data Collection Systems (DCS) | 399.9 – 400.05 MHz<br>400.1 – 403 MHz<br>460 – 470 MHz |
| Search and Rescue messages (COSPAS-SARSAT) | 406 – 406.1 MHz<br>1544 – 1545 MHz |
| Telemetry, telecommand and ranging of the spacecraft | 2025 – 2110 MHz<br>2200 – 2290 MHz<br>7190 – 7250 MHz |
| Downlink of meteorological data to dedicated Earth stations and broadcast directly to the users. Band selection depends on the bandwidth of the downlink required. | 137 – 138 MHz<br>1675 – 1710 MHz<br>7450 – 7550 MHz<br>7750 – 7900 MHz<br>8025 – 8400 MHz<br>18 – 18.3 GHz (R2)<br>18.1 – 18.4 (R1&3)<br>25.5 – 27 GHz |
| Data distribution via commercial sats (GEONETCast) | 3800 – 4200 MHz<br>10.7 – 12.5 GHz |

| Passive Sensing | |
|---|---|
| 10.6 – 10.68 GHz | Shared |
| 10.68 – 10.7 GHz | RR 5.340 |
| 18.6 – 18.8 GHz | RR 5.340 |
| 23.6 – 24 GHz | RR 5.340 |
| 31.3 – 31.5 GHz | RR 5.340 |
| 31.5 – 31.8 GHz | shared |
| 36 – 37 GHz | shared |
| 50.2 – 50.4 GHz | RR 5.340 |
| 52.6 – 54.25 GHz | RR 5.340 |
| 54.25 – 59.3 GHz | shared |
| 86 – 92 GHz | RR 5.340 |
| 114.25 – 116 GHz | RR 5.340 |
| 116 – 122.25 GHz | shared |
| 155.5 – 158.5 GHz | shared |
| 164 – 167 GHz | RR 5.340 |
| 174.8 – 182 GHz | shared |
| 182 – 185 GHz | RR 5.340 |
| 185 – 190 GHz | shared |
| 190 – 191.8 GHz | RR 5.340 |
| 226 – 231.5 GHz | RR 5.340 |
| 235 – 238 GHz | RR 5.340 |
| 239.2 – 242.2 GHz | shared |
| 244.2 – 247.2 GHz | shared |
| 313 – 356 GHz | RR 5.565 |
| 439 – 467 GHz | RR 5.565 |
| 657 – 692 GHz | RR 5.565 |

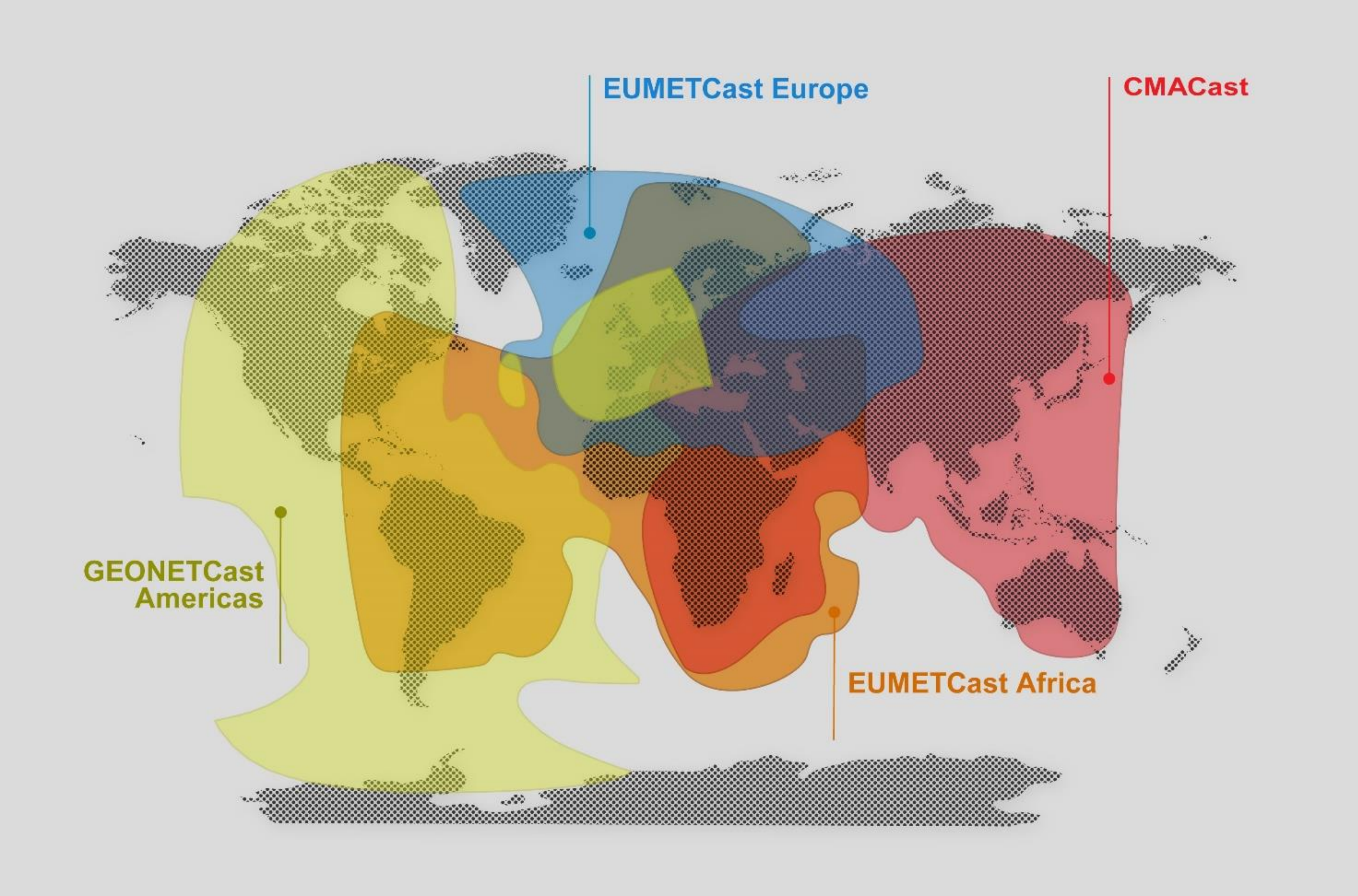
Allocations added at WRC-23 (AI 1.14)

| Active Sensing |
|---|
| 5150 – 5250 MHz |
| 5250 – 5350 MHz |
| 5350 – 5460 MHz |
| 5360 – 5470 MHz |
| 5470 – 5570 MHz |
| 13.4 – 13.75 GHz |
| 35.5 – 36 GHz |

| Other Instruments |
|---|
| 1164 – 1215 MHz |
| 1215 – 1240 MHz |
| 1559 – 1610 MHz |

**RR Footnote 5.340:**
**All emissions are prohibited in the following frequency bands…**

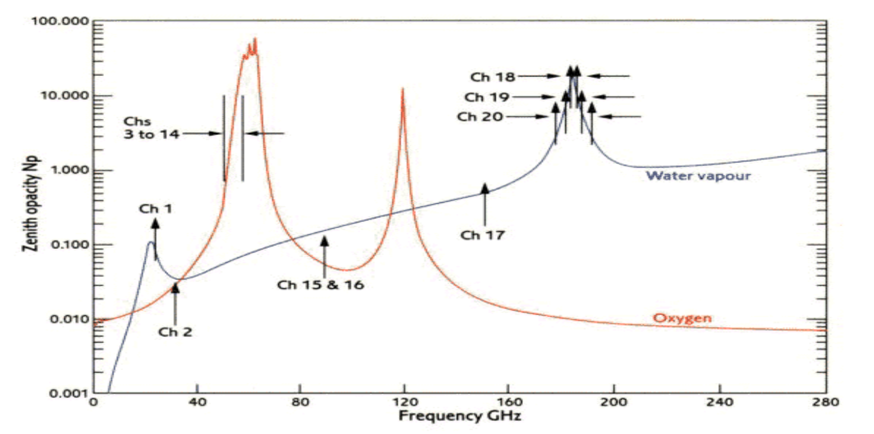
# GEONETCast

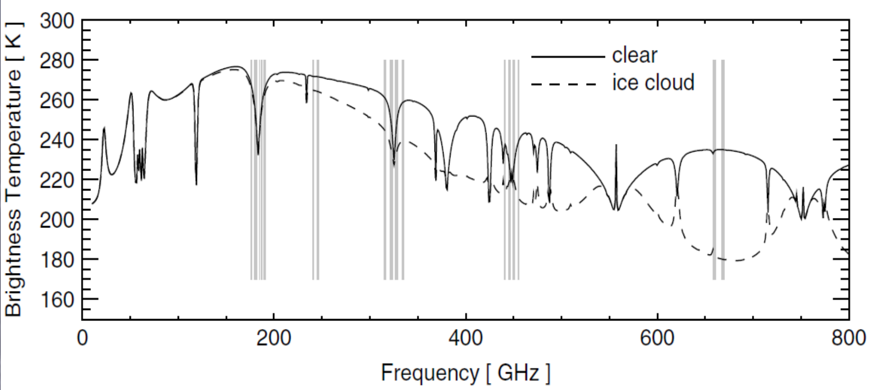


EUMETCast Europe
CMACast
GEONETCast Americas
EUMETCast Africa

# Passive Microwave Sensing (EESS (passive)) (1)

- Frequency bands used for passive microwave sensing (Radio Regulations: EESS (passive)) are determined by the fundamental properties of the Earth and its atmosphere.

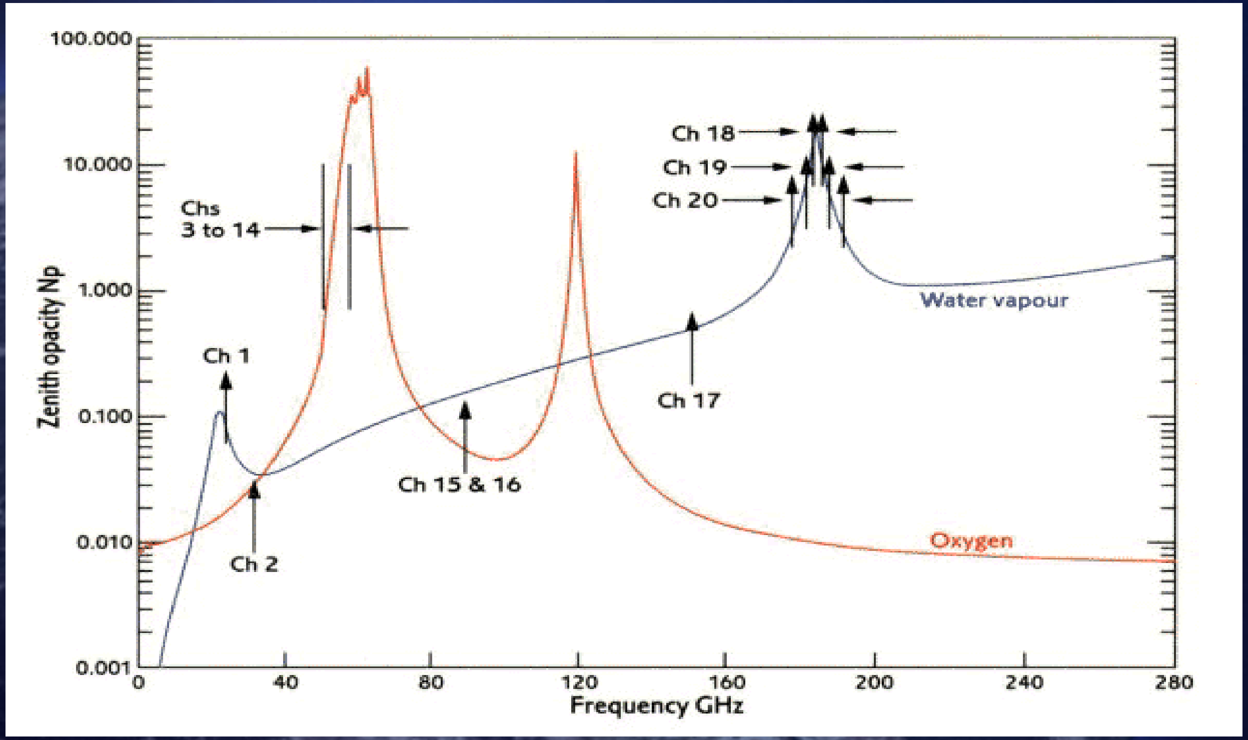



- No amount of engineering and/or funding can change these properties that are given by nature !!!.
- In the RR, due regard is given to this fact by footnote 5.340 ("…all emissions are prohibited.") and specific limitations to active services in Resolution 750.

# Passive Microwave Sensing (EESS (passive)) (2)

- Passive sensors can determine vertical variation and horizontal distribution of temperature and water vapour in the atmosphere, which are two key atmospheric variables. Together with several other physical parameters (e.g. ice, liquid water, and sea state) they determine the condition of the planet.




- There are bands where absorption caused by different atmospheric gases is much higher, for example **oxygen close to 60 GHz and 118 GHz** and **water vapour at 24 GHz and 183 GHz**.

- These absorption peaks are fixed by molecular physics and are **indispensable natural resources** for passive sensing.

# What is measured in the different passive bands? (1)

- **Below 10 GHz**, the atmosphere is almost completely transparent, even in the presence of clouds. This allows sensors operating below 10 GHz to directly sense the planet's surface. For example Soil moisture and ocean salinity is measured at 1.4 GHz and sea surface temperature at 6/7 GHz.

- **At 10 GHz,** clouds and water vapour remain largely transparent, but heavy rain does attenuate, providing unique information about rainfall (other techniques are indirect).

- **At 18 GHz**, the dielectric properties of seawater are such that energy collected by the passive sensors becomes almost independent of the sea surface temperature, but the wind induced ripples and waves change the emissivity, so wind information can be determined.

- **Around 24 GHz**, there is a weak water absorption line and by measuring this line, the total column water vapour can be determined. The 24 GHz band is strongly sensitive to total column water vapour and weakly sensitive to cloud liquid water.

- **At 31 GHz**, liquid water attenuation provides liquid water content of clouds.
  - Although 24 GHz is referred to as a water vapour channel and 31 GHz as a cloud channel, in reality the loss of data from one channel also diminishes the value of both.

# What is measured in the different passive bands? (2)

- Oxygen absorbs energy between 50 and 60 GHz in several individual narrow bands (lines). Passive sensors operating in these bands provide temperature vertical profile information, showing how temperature changes at different atmospheric heights (vertical temperature profile). A large number of channels is needed across this oxygen absorption spectral line complex to provide vertical profile information.

- There is also an important 118 GHz oxygen absorption line. The short wavelength allows for narrow sensor fields of view to detect small scale features of extreme weather events such as hurricanes/typhoons.

- At 183 GHz is the most important water vapour spectral line. This line is sampled progressively further from the centre frequency to gain profile information. The effects of clouds are even stronger at 183 GHz than at 50 GHz so additional channels are needed to provide cloud information, in particular at 89 GHz, 150/165 GHz and 229 GHz.

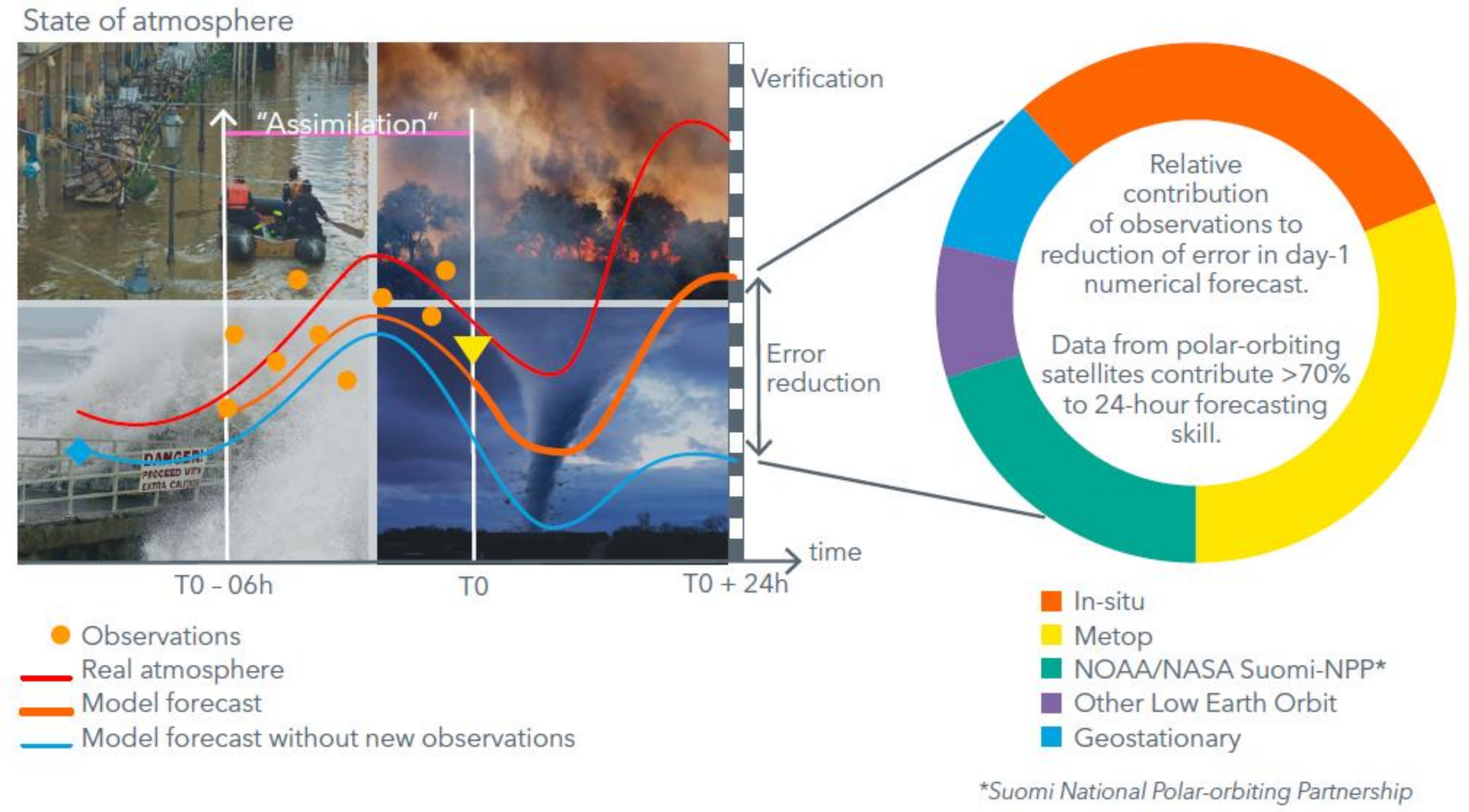
- For determining cloud-ice content, measurements in a set of frequency channels are needed, i.e. 183 GHz, 243 GHz, 325 GHz, 448 GHz and 664 GHz to retrieve all relevant atmospheric parameters.

# What is measured in the different passive bands? (3)

**Bands being actively used or prepared for by NWP centres (Slide from ECMWF presentation)**

| *Frequency GHz* | *Instruments* | *Application area* |
|---|---|---|
| 1.4-1.427P | SMOS (ESA), SMAP (NASA), Aquarius (NASA) , CIMR (ESA) | Soil moisture, salinity, thin sea ice |
| 6.425-7.25 | AMSR-2 (JAXA) , CIMR (ESA) | SST |
| 10.6-10.68p 10.68-10.7P | AMSR-2 (JAXA), GMI (NASA), MWRI (CMA) , CIMR (ESA) | Heavy Precipitation |
| 18.6-18.8p | AMSR-2 (JAXA), GMI (NASA), AMR (NOAA), MWRI (CMA) , CIMR (ESA) , MWI (EUMETSAT) | Ocean near surface wind, |
| 23.6-24P | AMSU-A (NOAA/EUMETSAT), ATMS (NOAA), SSMIS (DOD), GMI (NASA), AMR (NOAA), MTVZA-GY (Roscosmos), MWRI (CMA), MWS+I (EUMETSAT), AMSR-2 (JAXA) | Total column water vapour |
| 31.3-31.5P 31.5-31.8p | AMSU-A (NOAA/EUMETSAT), ATMS (NOAA), GMI (NASA), MTVZA-GY (Roscosmos), MWS+I (EUMETSAT) | Total column cloud liquid |
| 36-37 | SSMIS (DOD), GMI (NASA), AMSR-2 (JAXA), MWRI (CMA), CIMR (ESA) | Liquid water path and cloud detection on GMI |
| 50.2-50.4P 52.6-54.25P 54.25-59.3p 59.3-59.5 60.40- 61.15 63-63.5 | AMSU-A (NOAA/EUMETSAT), ATMS (NOAA), SSMIS (DOD), MWTS-2 (CMA), MTVZA-GY (Roscosmos), MWS (EUMETSAT) | Temperature profile |
| 86-92P | AMSU-A (NOAA/EUMETSAT), ATMS (NOAA), SSMIS (DOD), MWHS-2 (CMA), MTVZA-GY (Roscosmos), MWRI (CMA), MWS (EUMETSAT), AMSR-2 (JAXA) | Precipitation |
| 100-102P 109.5-111.8P 114.25-116P 116-122.25p | MWHS-2 (CMA), TROPICS (NASA), MWI (EUMETSAT) | Temperature profile, cloud |
| 148.5-151.5P 155.5-158.5p 164-167P | ATMS (NOAA), GMI (NASA), MHS (EUMETSAT), MWHS-2 (CMA), MTVZA-GY (Roscosmos), SSMIS (DOD) , MWS+I (EUMETSAT) | Precipitation, water vapour |
| 174.8-182.0p 182.0-185.0P 185.0-190.0p 190.0-191.8P | AMSU-B (NOAA), MHS (EUMETSAT), ATMS (NOAA), SSMIS (DOD), MWHS-2 (CMA), GMI (NASA), SAPHIR (CNES-ISRO), TROPICS (NASA), MTVZA-GY (Roscosmos), MWS+I (EUMETSAT) | Water vapour |
| 200-209P 226-231.5P 239.2-242.2P 245.2-247.2P 313-356 439-467 657-692 | TROPICS (NASA), MWS (EUMETSAT) | Ice cloud |

# Improvement of forecast skills due to meteorological satellites (1)

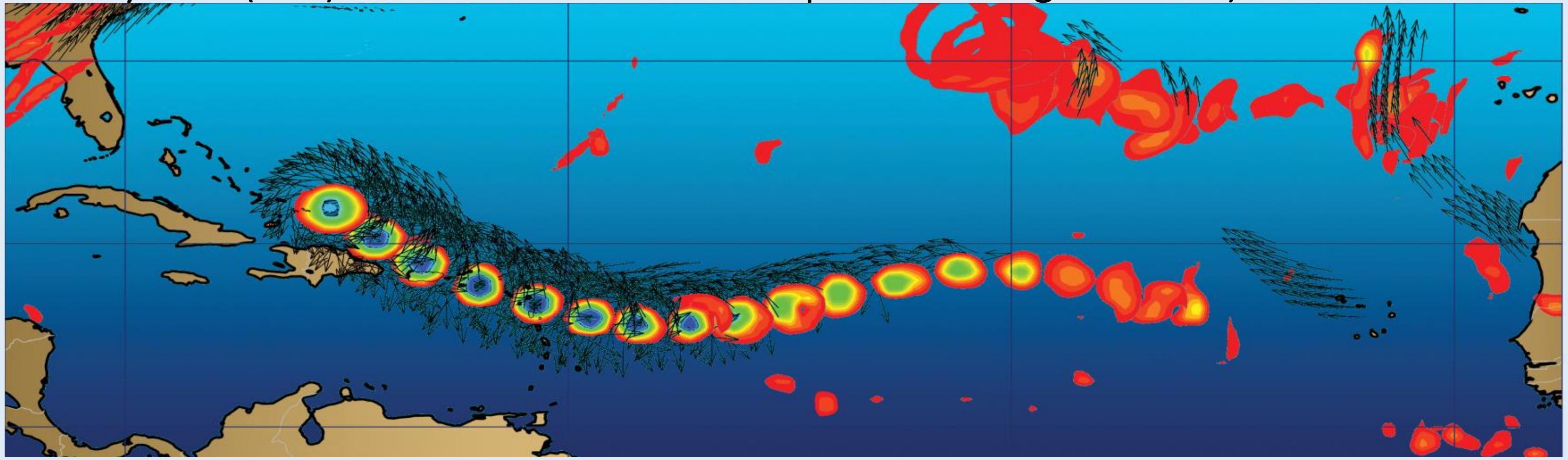


# Improvement of forecast skills due to meteorological satellites (2)

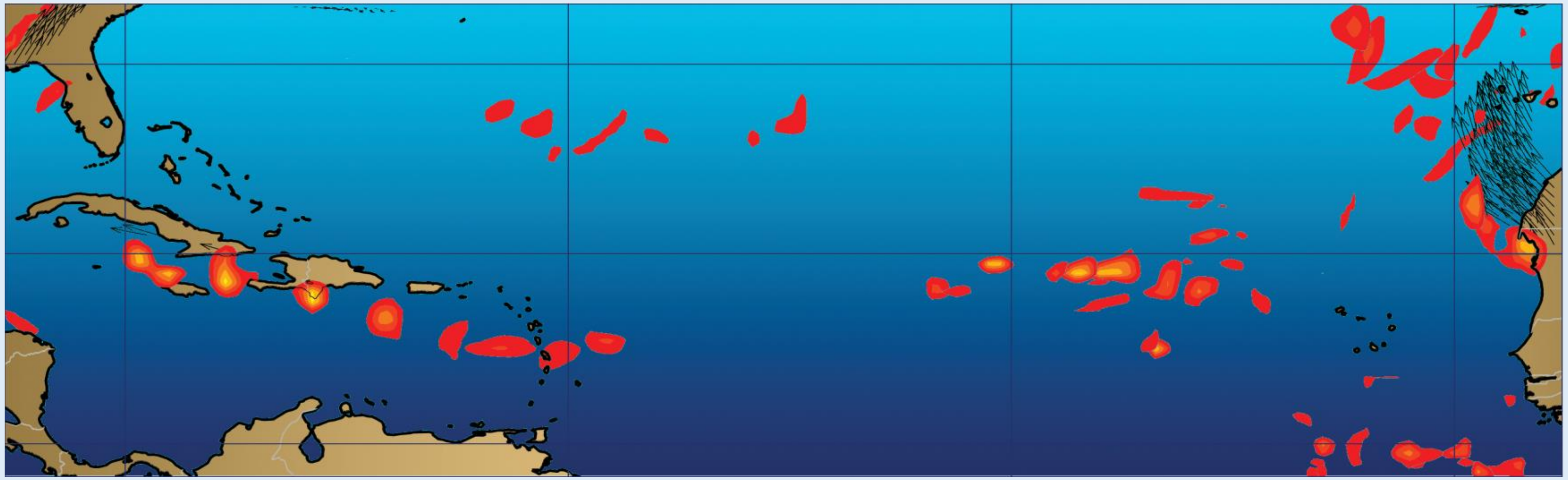
## Contribution of meteorological satellites to forecasting

(Example: Initial Joint Polar System (IJPS) of NOAA and EUMETSAT polar-orbiting satellites)

The initial conditions, largely determined by satellite observations (top right, red), were essential for the ECMWF to forecast the development and trajectory of Hurricane Irma four days in advance (Source: ECMWF).



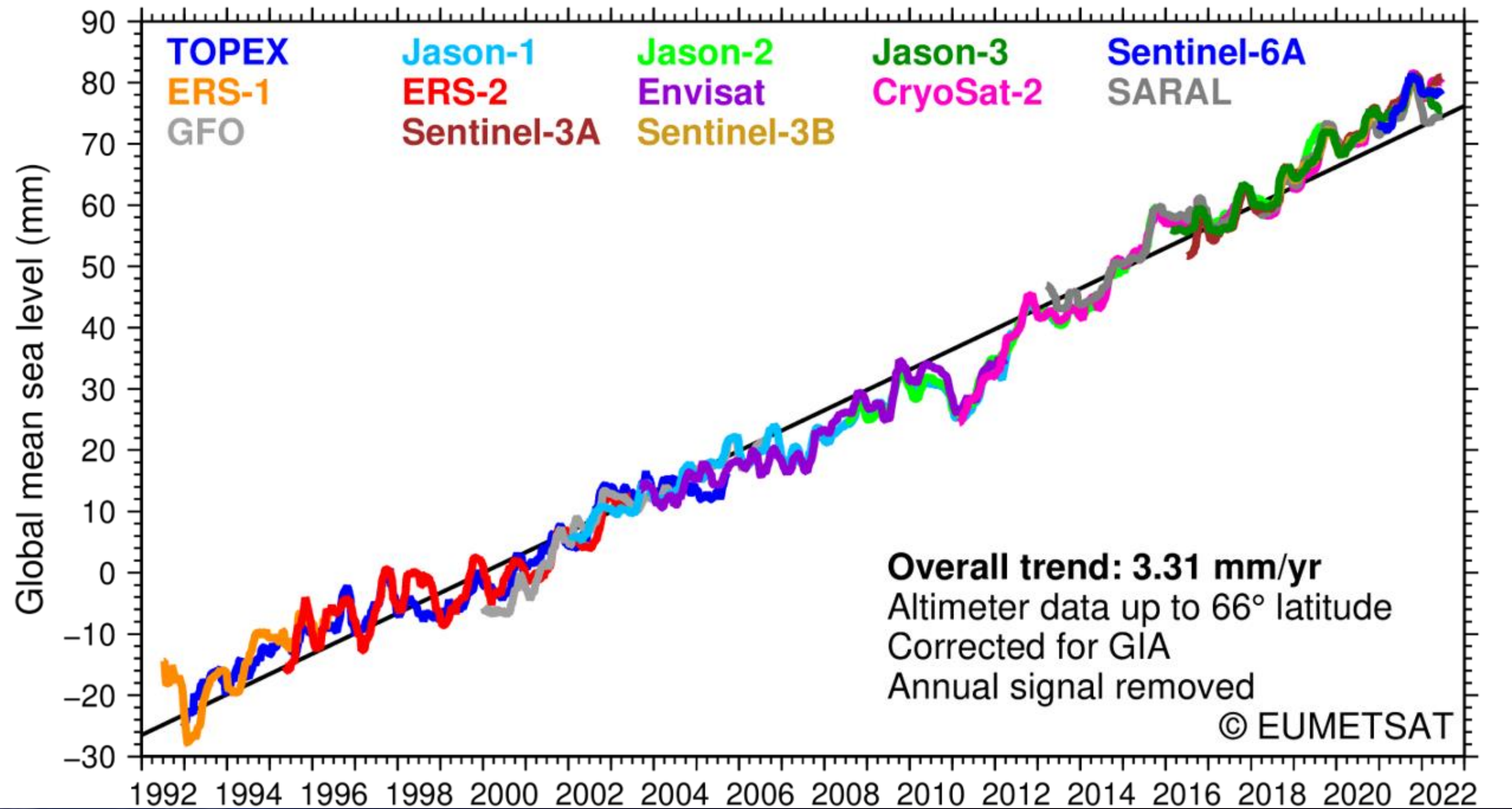
Without satellite observations the model would have missed the initial development of Irma (Source: ECMWF).



# Sea level rise observed by 12 satellites over a period of 28 years

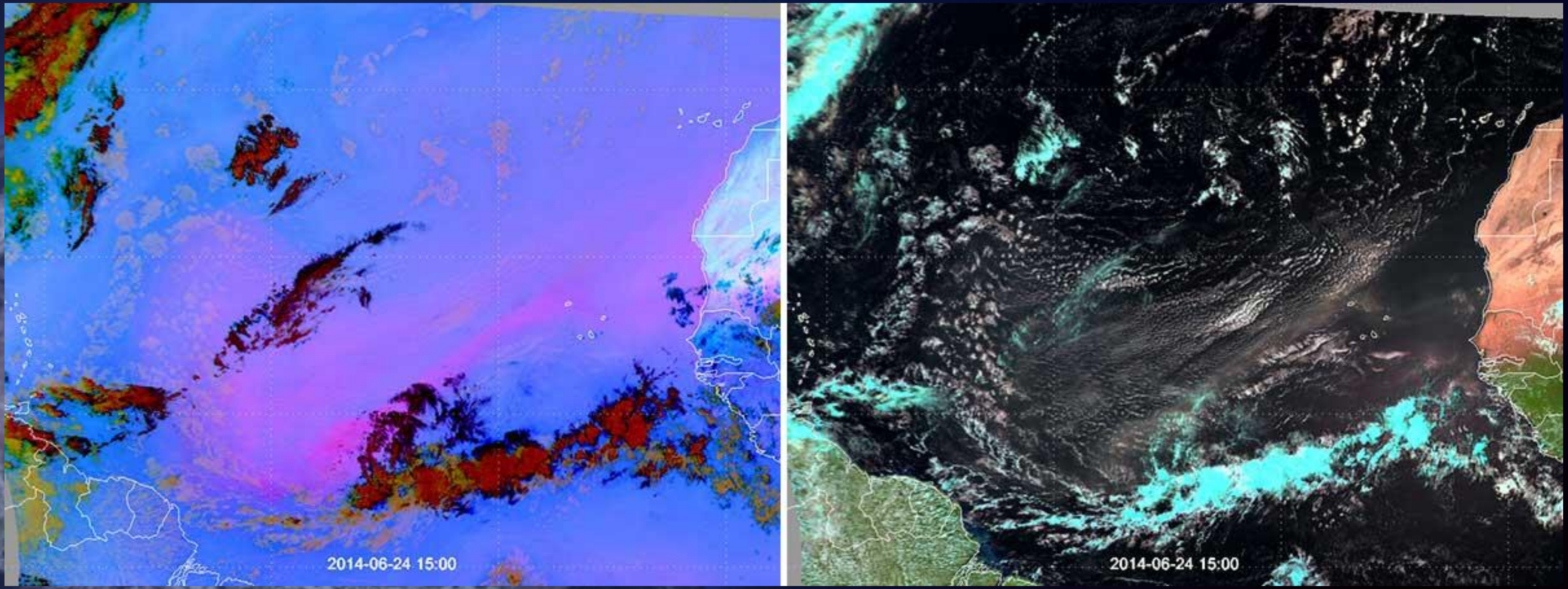
**Monitoring of the oceans from space provides information about ocean currents, ocean surface winds, sea state, sea ice, sea surface temperature and ocean colour. Those data ingested into weather & ocean prediction models provide crucial information for safety at sea, operations of marine infrastructure, fisheries, sustainable use of marine resources and the protection of vital marine and coastal ecosystems.**

- **Mean sea level rise is a sensitive indicator of climate change.**
- **Thus, measuring continuously over decades the sea level rise with active and passive microwave sensors is essential.**



# Examples of MetSat observations: Forecasting dust

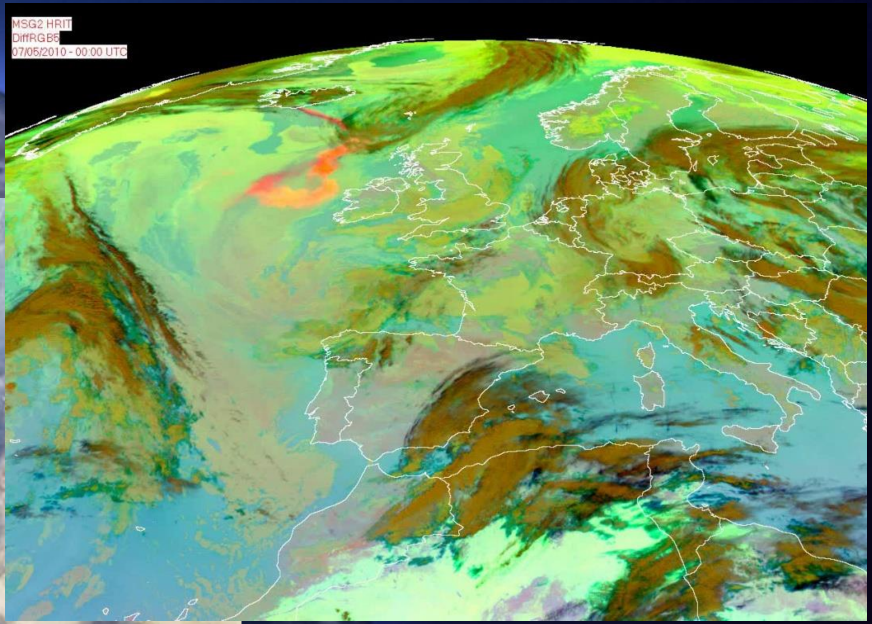
**Million of tons of dust are transported from the Sahara across the Atlantic every summer. In June 2014, as the FIFA World Cup kicked off in Brazil, Saharan dust travelled from West Africa to the host country.**

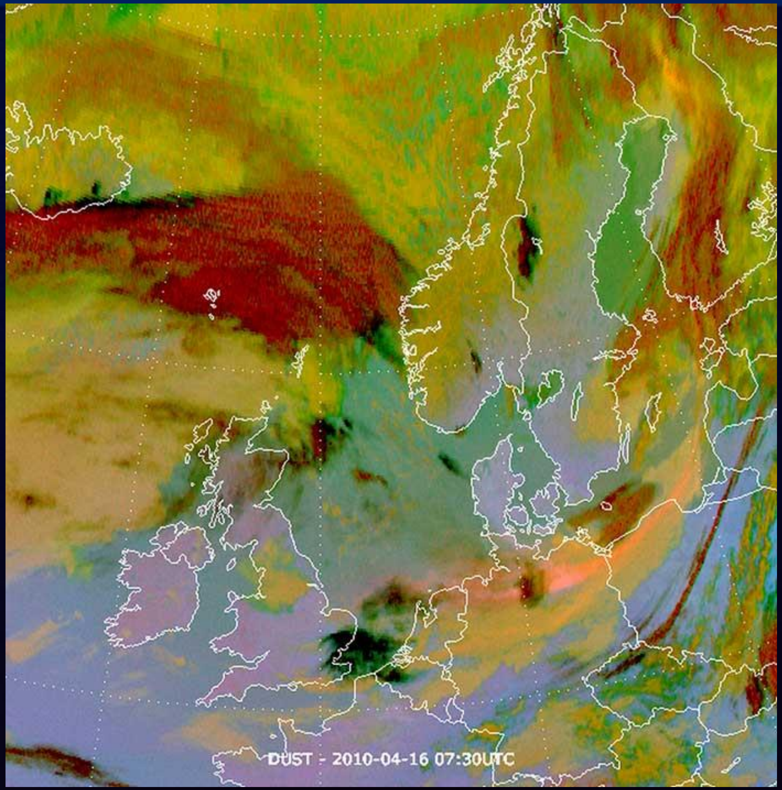



**When comparing the Dust RGB and the Natural Colour RGB from the same time, the dust can be clearly seen (as pink) on the Dust RGB, but not the Natural Colour RGB.**

# Examples of MetSat observations: Volcanic ash

**When the Eyjafjallajökull volcano in Iceland erupted in 7 – 11 May 2010, satellite imagery proved to be instrumental in helping track the movement of the large ash plume (peach colour in the images).**

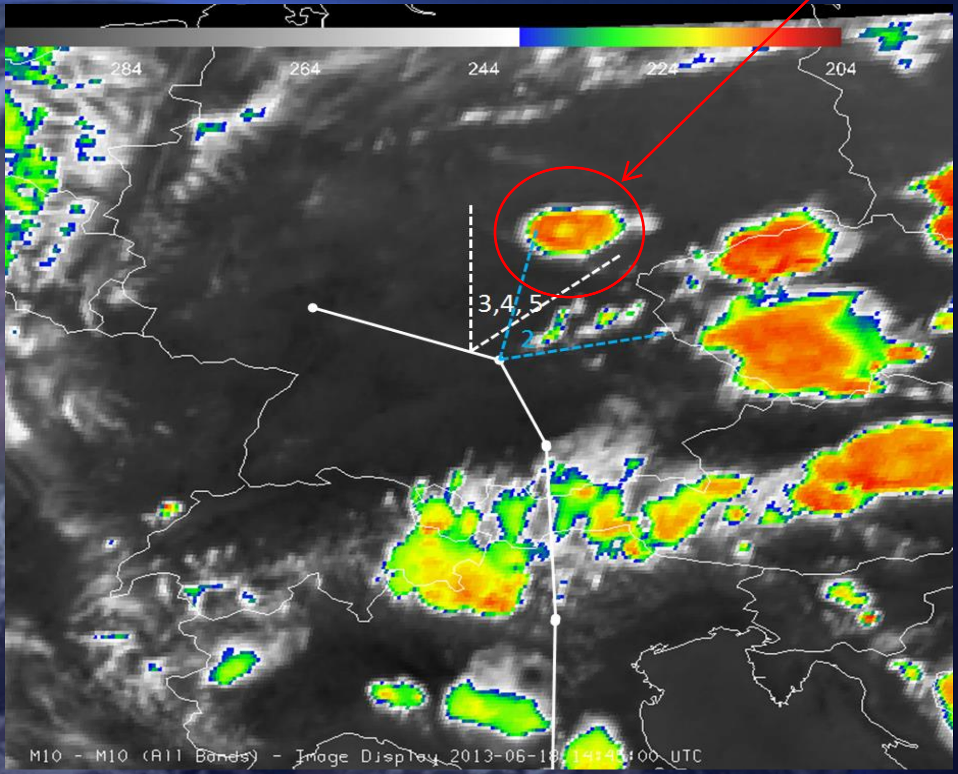


# Examples of MetSat observations: Extreme weather over Europe

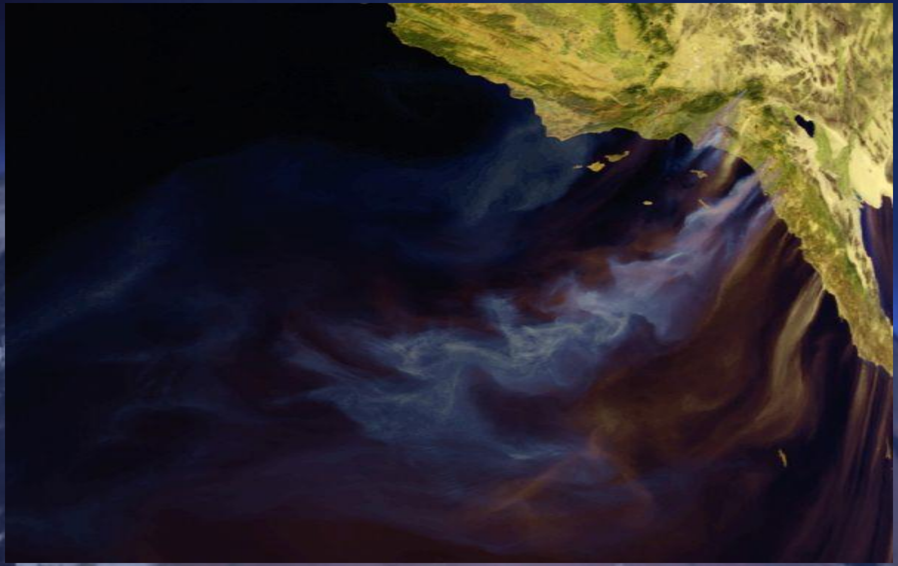
On the left picture extreme weather over Europe was observed via MetSat satellite. At the same this extreme weather was observed by a passenger on a flight from Rome to Frankfurt at a height of 8000m.

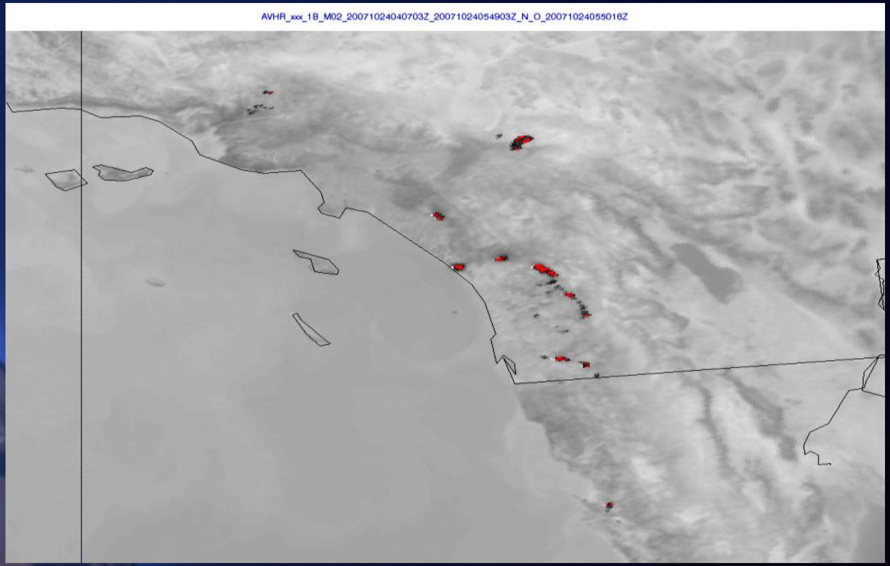
Erfurt, Germany




# Examples of MetSat observations: California fires

**The Metop-A AVHRR image (RGB Composite NIR1.6, VIS0.8, VIS0.6) on the right shows fires in California on 22 Oct 2007 when large smoke plumes were visible over the Pacific Ocean.**

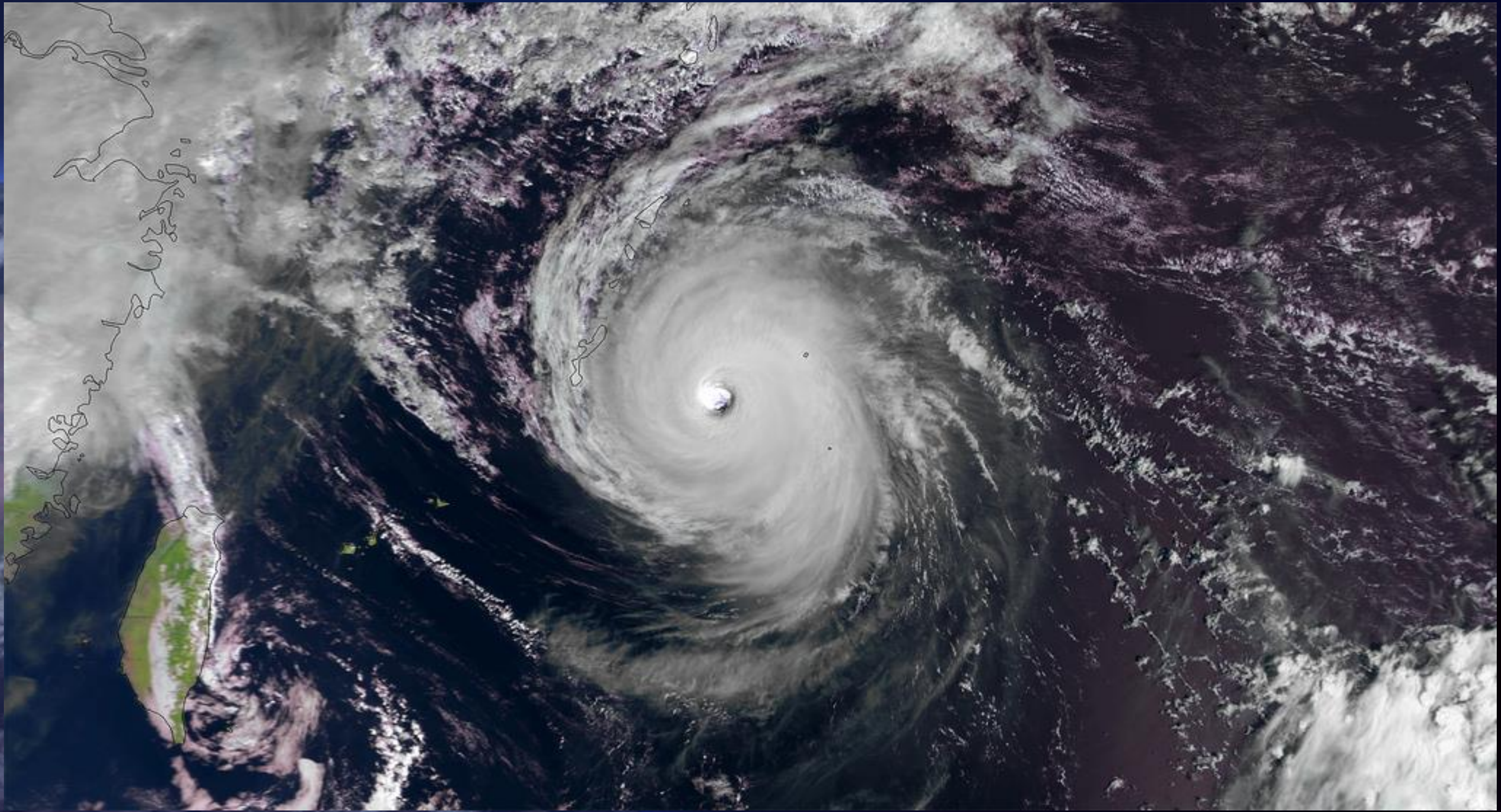





**For comparison: Smoke cloud seen from ground.**

# Examples of MetSat observations: Typhoon Danas

**Typhoon Danas approaching Okinawa, in the Pacific, as captured by the AVHRR instrument onboard EUMETSAT's Metop-B satellite (00:55 UTC)**



# Examples of MetSat observations: Hurricane Katrina

**GOES 1-km visible image of Hurricane Katrina a day before the 29 August 2005 landfall just east of New Orleans**

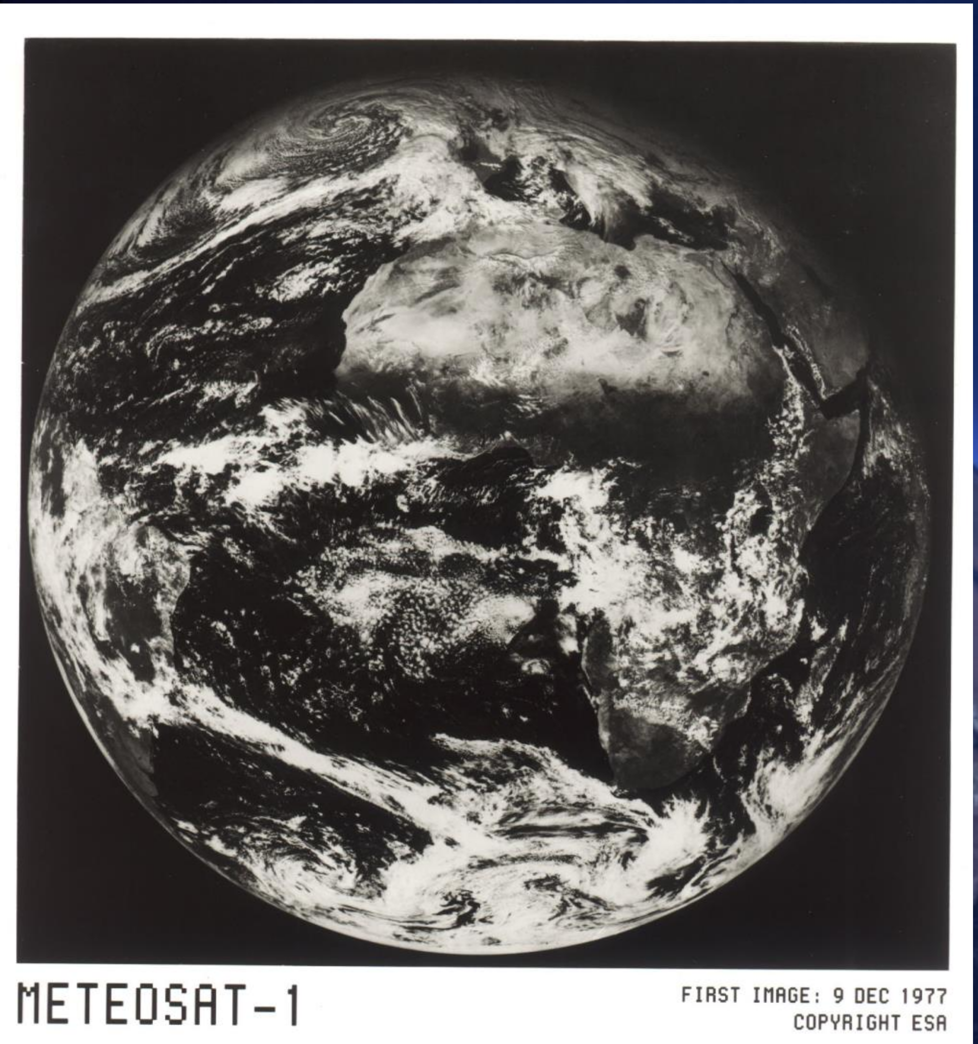
# A little bit of history ! (1)

First weather satellite launched from Cape Canaveral, FL

- Satellite Weight: 122 kg
- Payload: Two TV cameras, two video recorders, and the power, communications, and other systems needed

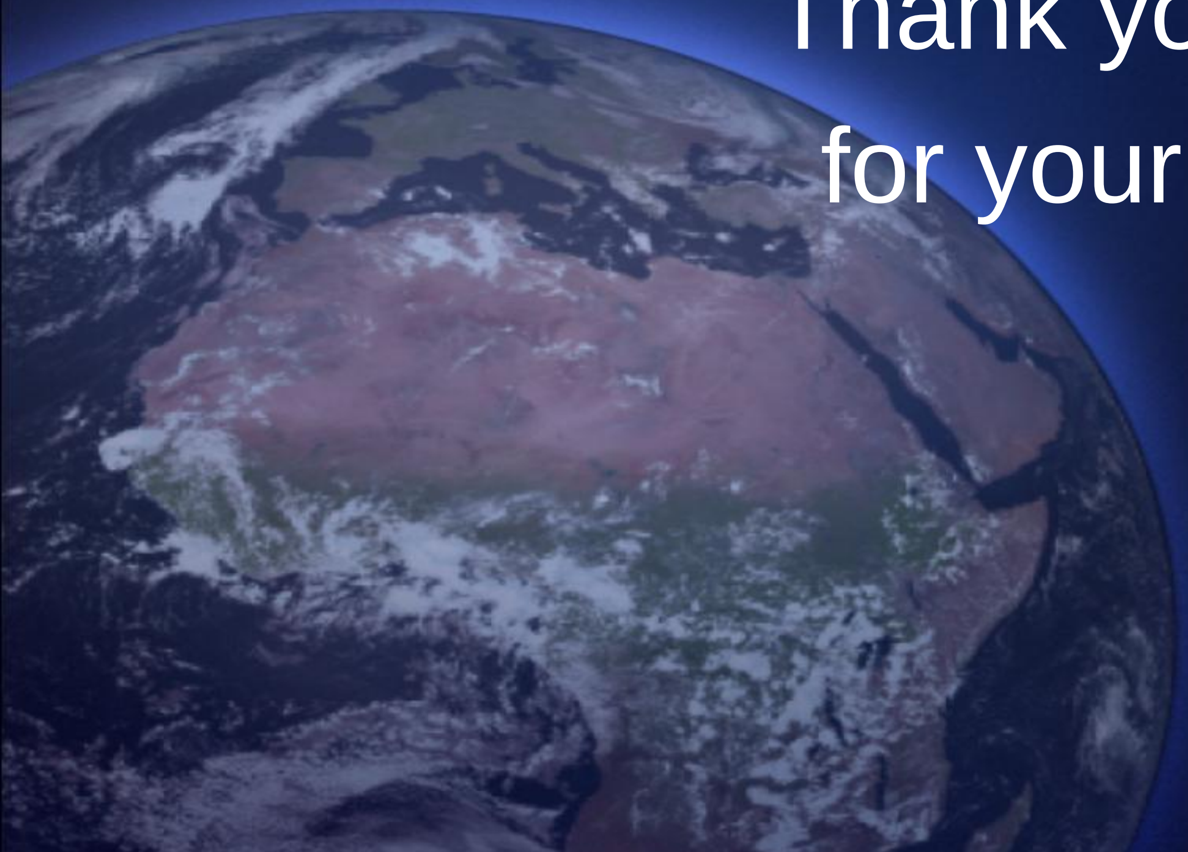
First view of cloud formations as they developed and moved across the continent

# A little bit of history ! (2)




- With the launch of the first Meteosat satellite on 23 November 1977, Europe gained the ability to gather weather data over its own territory with its own satellite.
- Meteosat began as a research programme for a single satellite by the European Space Research Organisation, a predecessor of the European Space Agency (ESA).
- Once the satellite was in orbit, the immense value of the images and data it provided led to the move from a research to an operational mission requiring a dedicated organisation to conduct it.
- In anticipation of the founding of EUMETSAT, ESA launched the Meteosat Operational Programme (MOP) in March 1983.

# Questions?



Thank you very much
for your attention !!!