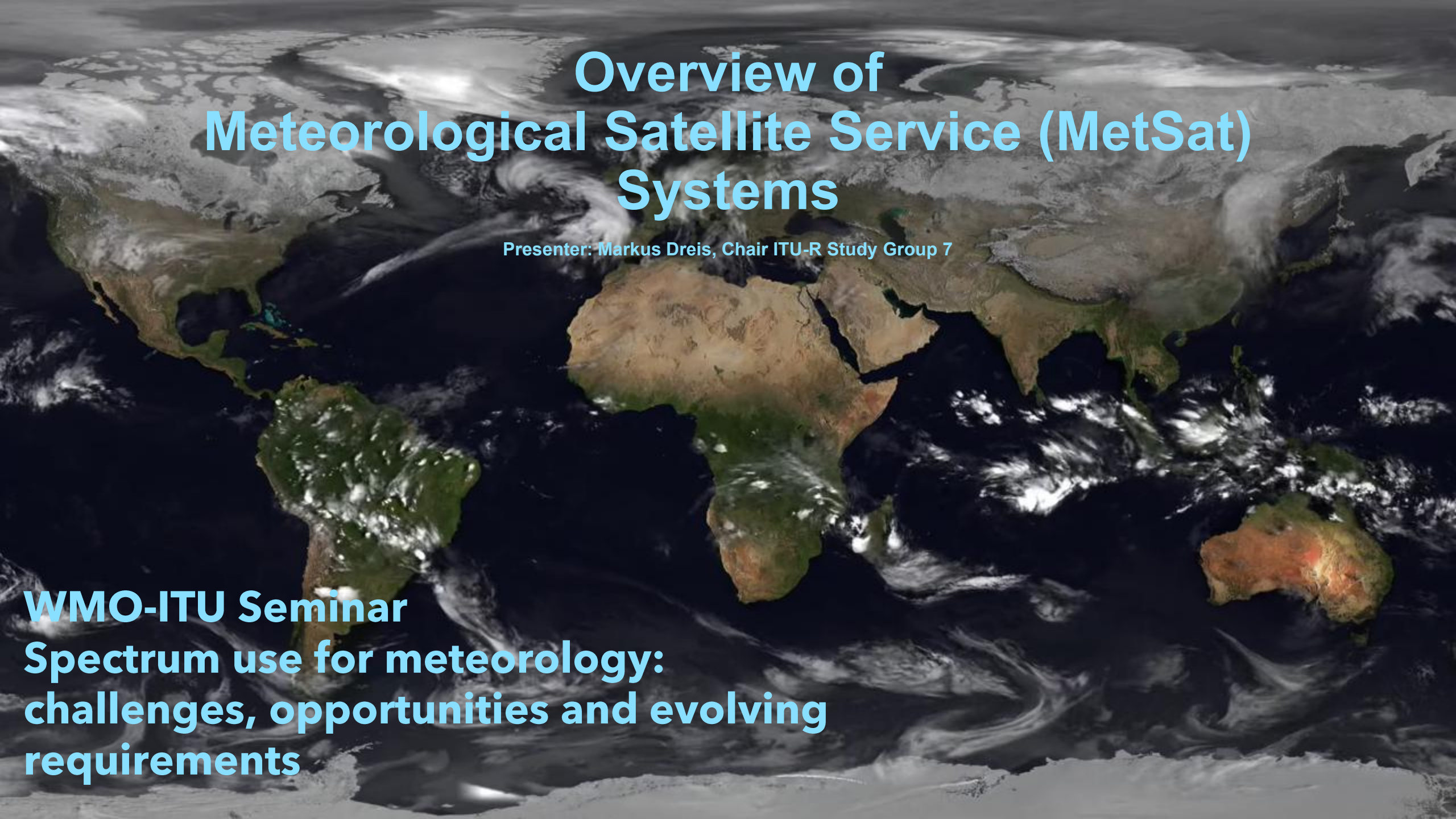


A satellite view of Earth from space, showing a wide expanse of white clouds swirling over the continents. The landmasses are visible in shades of green and brown, contrasting with the dark blue of the oceans. The perspective is from a high altitude, looking down at the planet.

Overview of Meteorological Satellite Service (MetSat) Systems

Presenter: Markus Dreis, Chair ITU-R Study Group 7

WMO-ITU Seminar
Spectrum use for meteorology:
challenges, opportunities and evolving
requirements

The mission of MetSat 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, continuously over decades.
- ... to provide the space-based component of the WMO Integrated Global Observing System (WIGOS) for the measurement of meteorological and environmental 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.

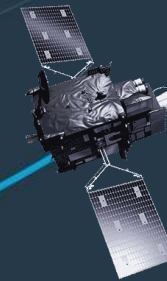
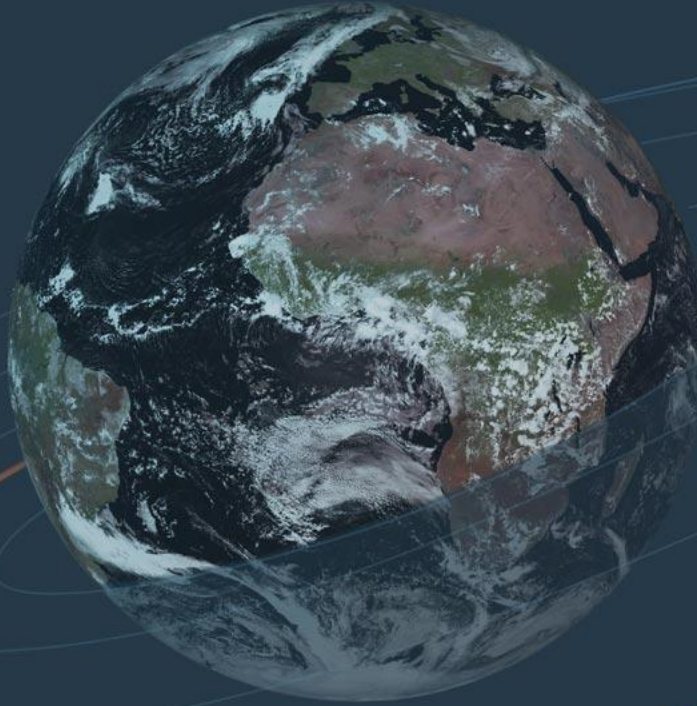
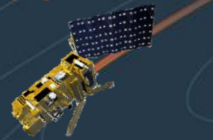
➤ **Distributing Data**

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

To fulfil the mission objectives of MetSat it requires...

**Low-Earth orbit at
650-850 km altitude**

Critical for
forecasts
up to 10 days in
advance



**Geostationary orbit
at 36000km altitude**

Vital for forecasts up
to a few hours ahead

Definition of EESS & MetSat in the Radio Regulations (RR)

1.51 Earth exploration-satellite service (EESS): A radiocommunication service between earth stations and one or more space stations, which may include links between space stations, in which:

- information relating to the characteristics of the Earth and its natural phenomena, including data relating to the state of the environment, is obtained from active sensors or passive sensors on Earth satellites;
- similar information is collected from airborne or Earth-based platforms;
- such information may be distributed to earth stations within the system concerned;
- platform interrogation may be included.
- This service may also include feeder links necessary for its operation.

1.52 Meteorological-satellite service (MetSat): An earth exploration-satellite service for meteorological purposes.

Translation of the RR definition for EESS & MetSat

- EESS and MetSat systems are used to gather data about the Earth's land, sea, and atmosphere for the purpose of studying and monitoring the Earth's climate and environment, amongst many other related scientific applications.
 - MetSats are used particularly for weather-related purposes.
 - Active sensors are radar-like measuring instruments in the EESS (active) which obtain information by transmitting radio waves and then receiving their reflected energy.
 - Passive sensors are very sensitive receivers in the EESS (passive) which measure the electromagnetic energy emitted, absorbed or scattered by the Earth's surface or atmosphere. In practice, they are instruments which measure the natural noise floor at discrete resonance frequencies described by the laws of physics.
- In addition to the data collected by the MetSat satellites, data may also be collected from airborne or ground-based platforms to supplement and calibrate the satellite data, the so-called Data Collection System.
- All of this collected data must also be transmitted to Earth stations or to other platforms for additional processing and distribution.

Translation of Rec. ITU-R SA.1020-0 general architecture into operational MetSat

recommends:

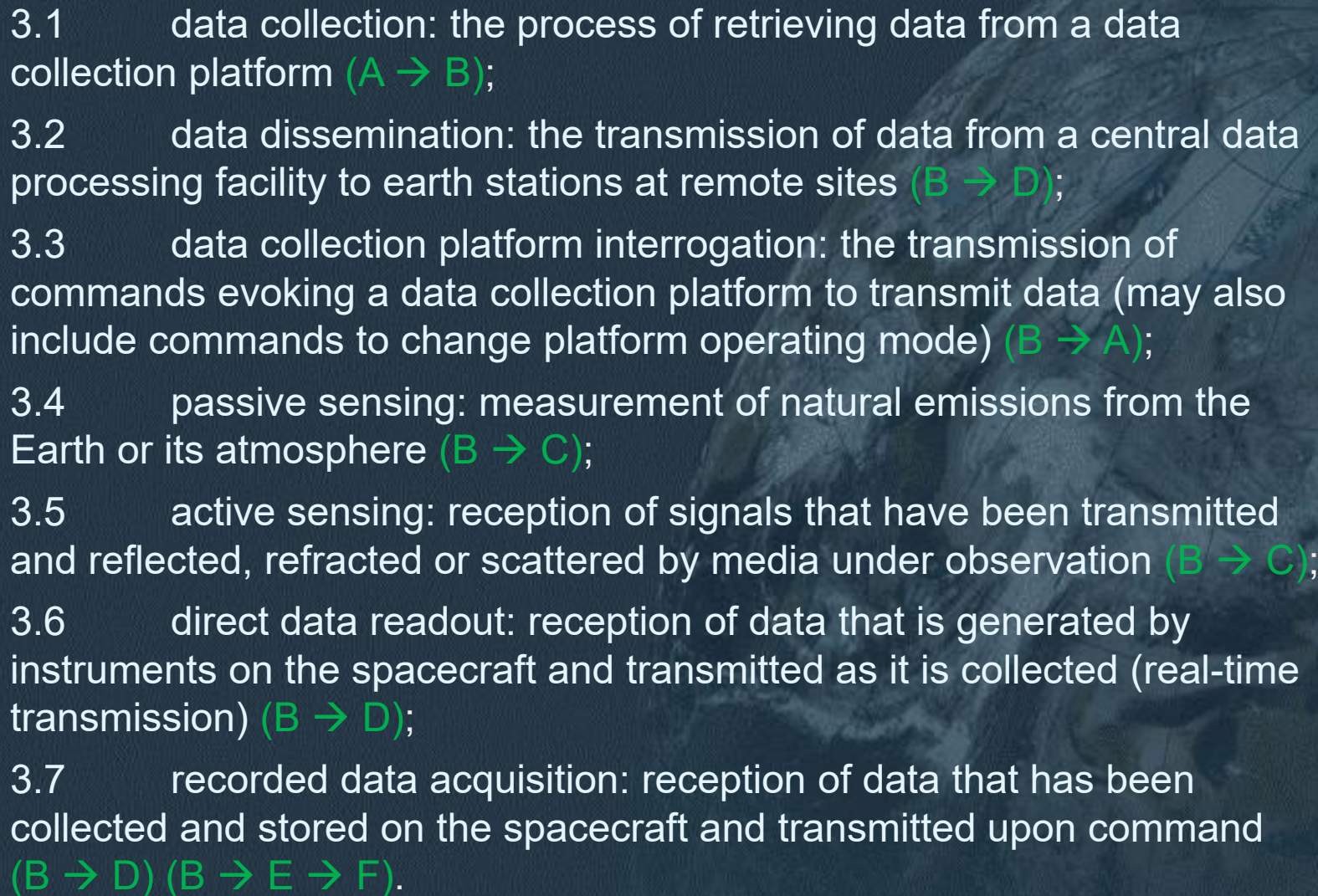
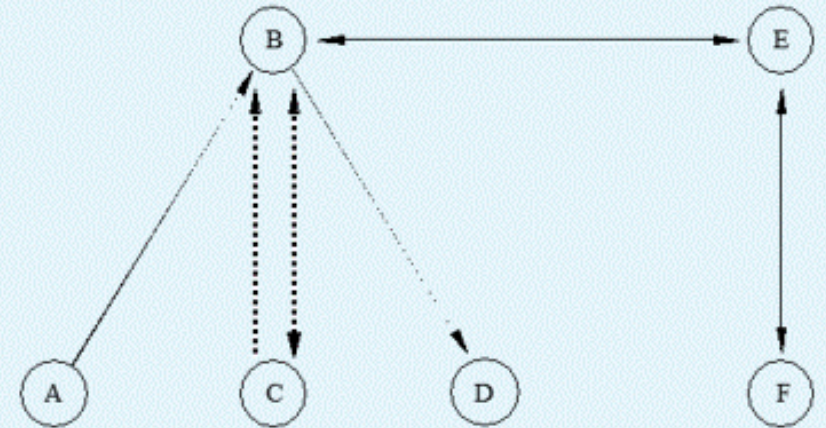
- 
- 3.1 data collection: the process of retrieving data from a data collection platform (A → B);
 - 3.2 data dissemination: the transmission of data from a central data processing facility to earth stations at remote sites (B → D);
 - 3.3 data collection platform interrogation: the transmission of commands evoking a data collection platform to transmit data (may also include commands to change platform operating mode) (B → A);
 - 3.4 passive sensing: measurement of natural emissions from the Earth or its atmosphere (B → C);
 - 3.5 active sensing: reception of signals that have been transmitted and reflected, refracted or scattered by media under observation (B → C);
 - 3.6 direct data readout: reception of data that is generated by instruments on the spacecraft and transmitted as it is collected (real-time transmission) (B → D);
 - 3.7 recorded data acquisition: reception of data that has been collected and stored on the spacecraft and transmitted upon command (B → D) (B → E → F).

FIGURE 1
Hypothetical reference system

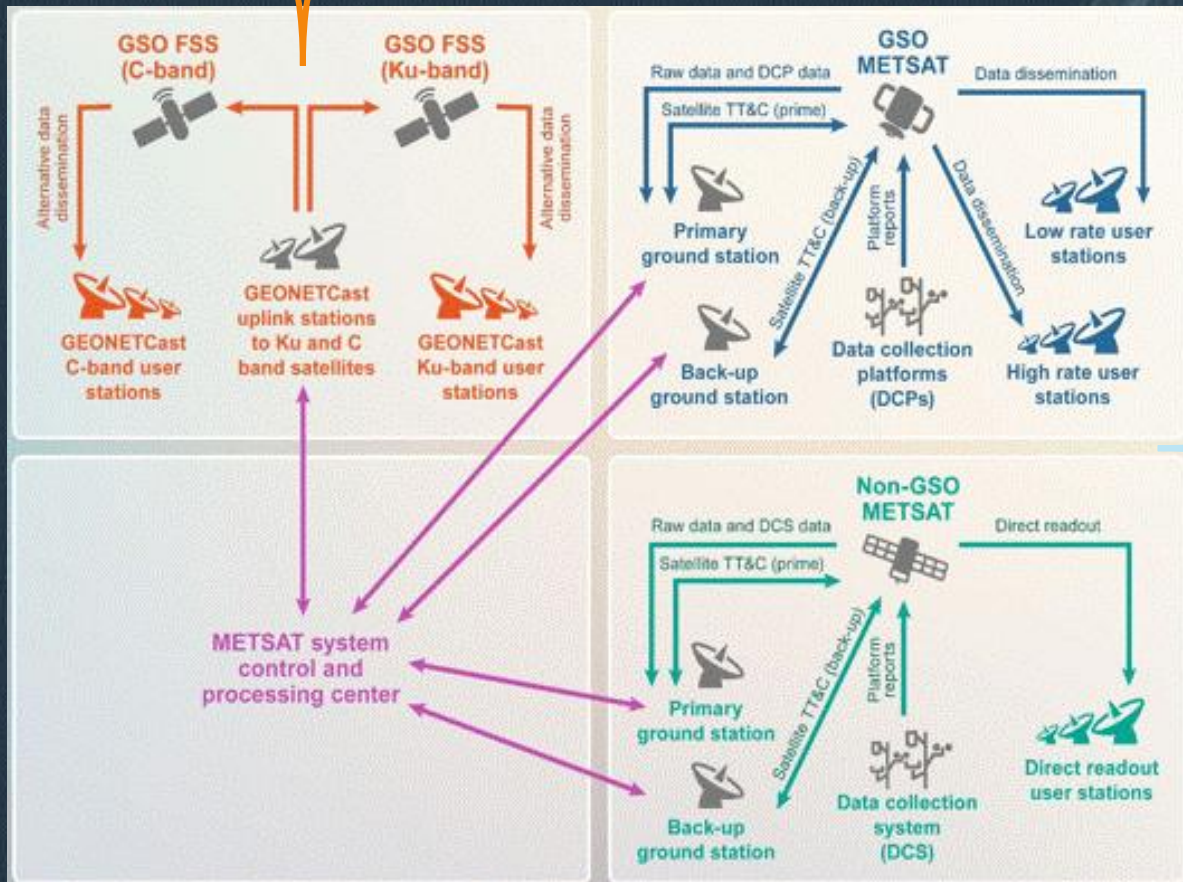


D01

- A: transmitting earth station (data collection, data dissemination, data collection platform interrogation, tracking or command)
- B: satellite, including any active and passive sensors, transponders and data handling or processing sub-systems
- C: media being remotely observed
- D: receiving earth station (interrogation received by a data collection platform, data collection, data dissemination, direct data readout, recorded data acquisition or tracking)
- E: data relay satellite
- F: earth station serving data relay satellite

EESS & MetSat Radiocommunication Architecture

Alternative data dissemination to users (GEONETCast) via other satellite systems than MetSat (not in MetSat/EESS allocated frequency bands)



- 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;
- 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

Overview of instrument types & 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)

Frequency allocations to SOS, EESS & MetSat in the RR

Space operation service	Earth Exploration-satellite service (EESS) (not including active and passive sensor EESS allocations)	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) (FN 5.290)
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)	
7125-7155 MHz (E-s)	7190-7250 MHz (E-s) (P) (FN 5.460A, 5.460B)	
7190-7235 MHz (E-s)		7450-7550 MHz (s-E) (GSO) (P)
Note: Since MetSat is a sub-class of EESS, those allocations can also be used for the operation of MetSat satellites and their applications. Example: 8025-8400 MHz and 25.5-27.0 GHz for the downlink from MetSat satellites.		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)	

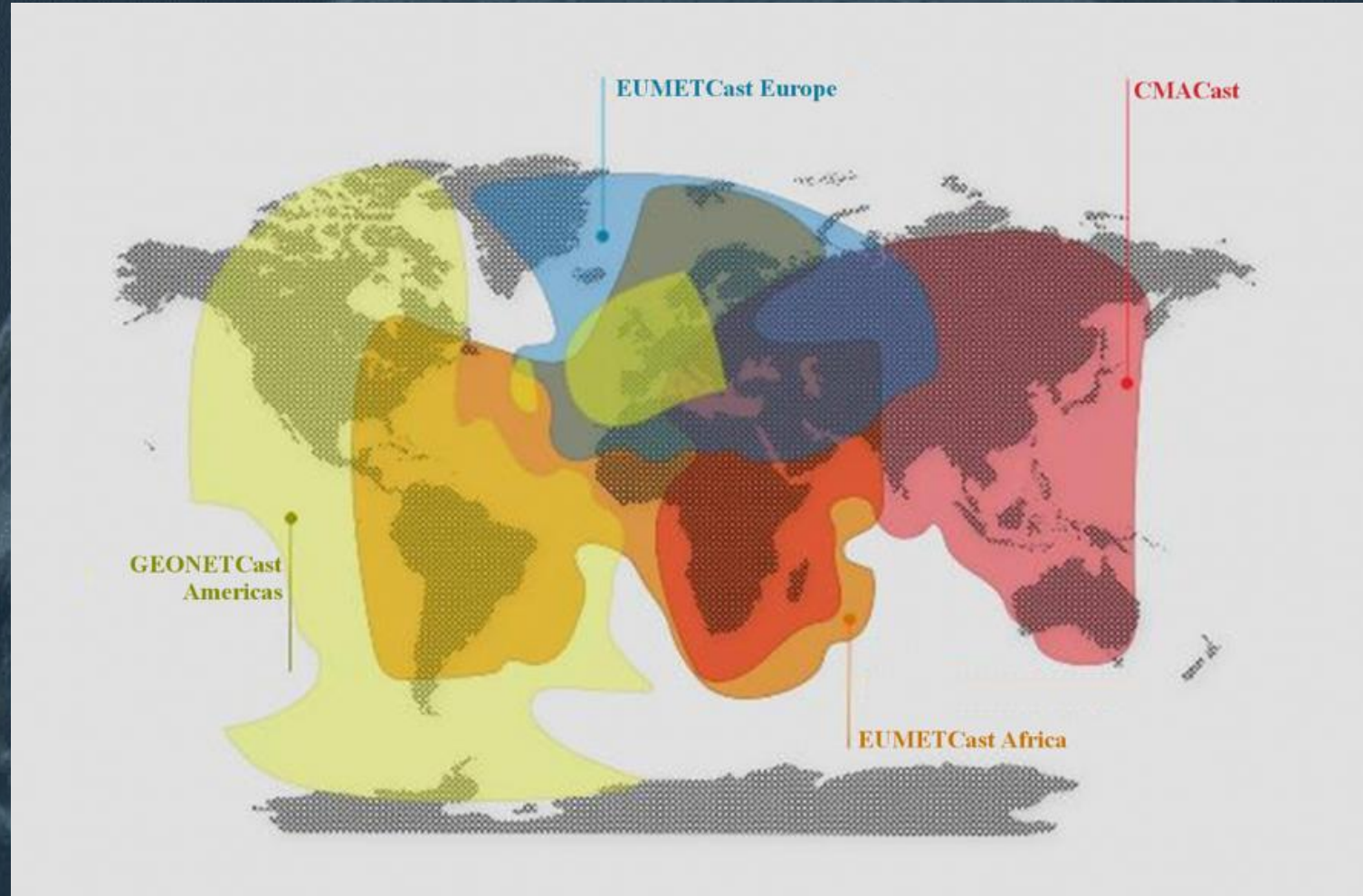
MetSat data downlinks and dissemination to the users

- The following frequency bands allocated to EESS or MetSat are used by today's (in operation or planned) GSO and NGSO MetSat systems to downlink the instrument data either to
 - the main Earth stations of the MetSat operator for processing and distribution/dissemination to the user by various means, or
 - directly to the user's Earth stations, called „direct read-out“.
- Which band is used is mainly driven by the datarate (bandwidth) required.

Earth Exploration-satellite service (EESS) (not including active and passive sensor EESS allocations)	Meteorological-satellite service
	1675-1710 MHz (s-E) (P)
	7450-7550 MHz (s-E) (GSO) (P)
	7750-7900 MHz (s-E) (NGSO) (P)
8025-8400 MHz (s-E) (P)	
18-18.3 GHz (R2) / 18.1-18.4 GHz (R1&3) (s-E) (P)	
25.5-27 GHz (s-E) (P)	

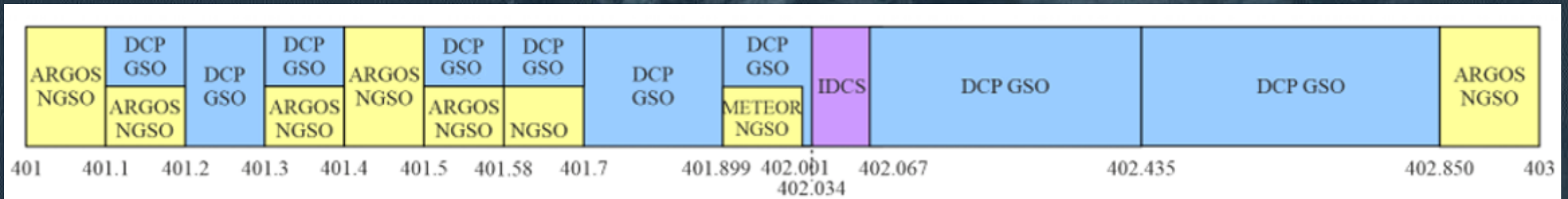
Alternative data dissemination mechanism - GEONETCast

- Global Earth Observation System of Systems (GEOSS) initiative, coordinated by the intergovernmental Group on Earth Observation (GEO)
- Using existing global commercial satellite infrastructure in C-band (3800-4200 MHz) and Ku-band (10.7-11.7 GHz)
- Based upon Digital Video Broadcast (DVB) technology providing complementary services to a common user community.



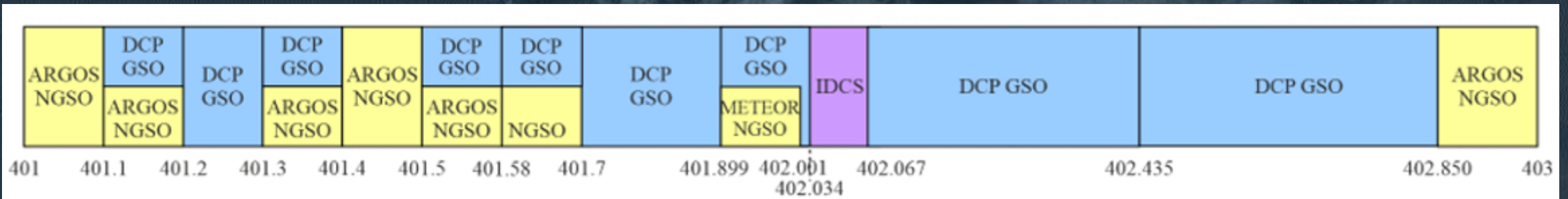
Data Collection Systems (DCS) on GSO MetSat

- DCS on GSO MetSat are for the collection of basic meteorological and other environmental data from remote Data Collection Platforms (DCPs), using the band 401-403 MHz.
- DCPs are transmitting in sequential mode with dedicated transmitting time slots.
- Transmission rates are very small, ranging from 100 bit/s up to 300/1200 bit/s for high rate DCPs.
- Advantage: Autonomous operation at very remote locations.
- Magnitude: In the case of the GOES-R series satellites, in 2024 there were approximately 30 000 GOES high rate DCPs in operation, sending up to 1 000 000 messages per day, delivering more than 6 million observations into the WIGOS daily.
- Coordination of limited spectrum resource through the Coordination Group for Meteorological Satellites (CGMS) – Recommendation ITU-R SA.2045 outlines the basic general partitioning of the band 401-403 MHz.



Data Collection Systems (DCS) on NGSO MetSat

- DCS on non-GSO MetSat satellites provide a variety of information used principally by governmental agencies but also to a limited extent by commercial entities.
 - Examples: Argos and Brazilian DCS.
 - Argos and the Brazilian DCS are using different satellites on complementary orbits, but are compatible and have established a data exchange in 2001.
- Data acquired include a number of environmental parameters for oceans, rivers, lakes, land and atmosphere related to physical, chemical and biological processes. It also includes animal tracking data.
- Different to DCPs on GSO MetSat, there are also platforms known as PMT (Platform Messaging Transceiver) which can be interrogated by the satellite using the 460 470 MHz band.
- DCS on NGSO MetSat use the yellow parts in the basic partitioning plan.



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

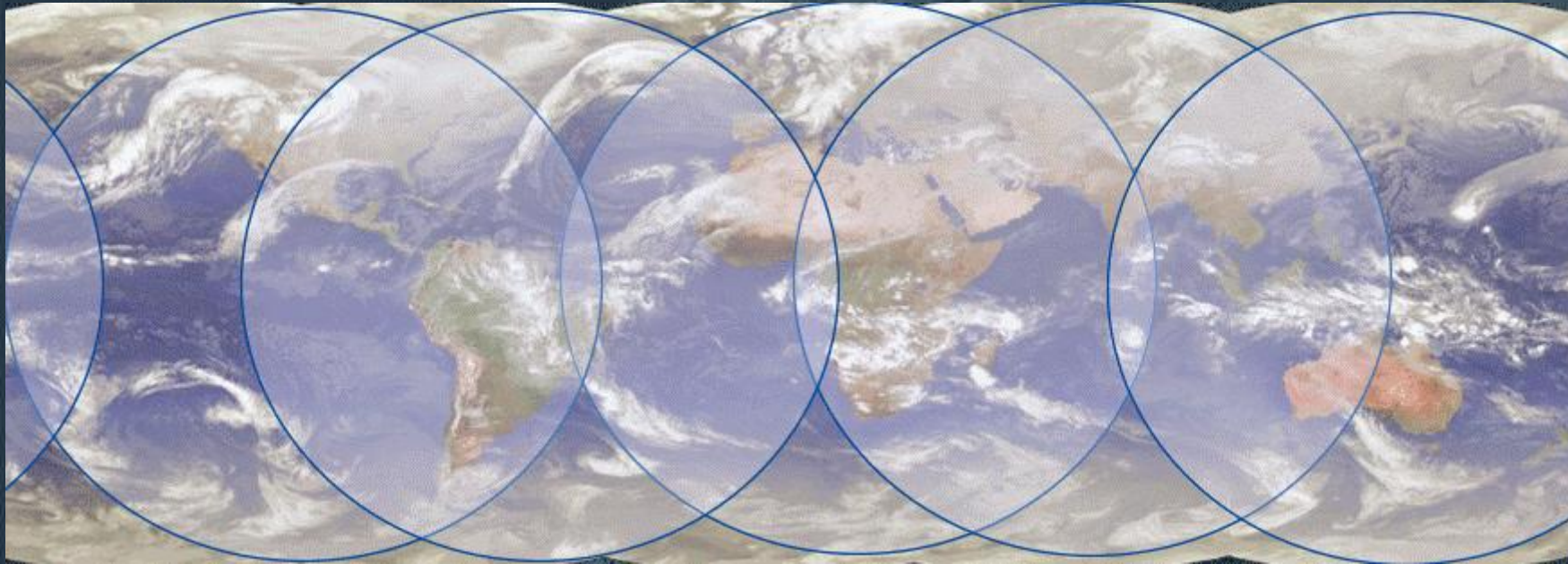
- The development and operation of MetSat satellites and their instruments is usually based on **public investments**.
- In turn, the **data** from the instruments (to a significant extent from active and passive microwave sensors) **go back (non-profit) to the benefit of society** and are used to develop 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 (NWP) products. These forecasts cover different sized geographic areas from the whole globe down to small areas.

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.



USA



Europe



Russia



India



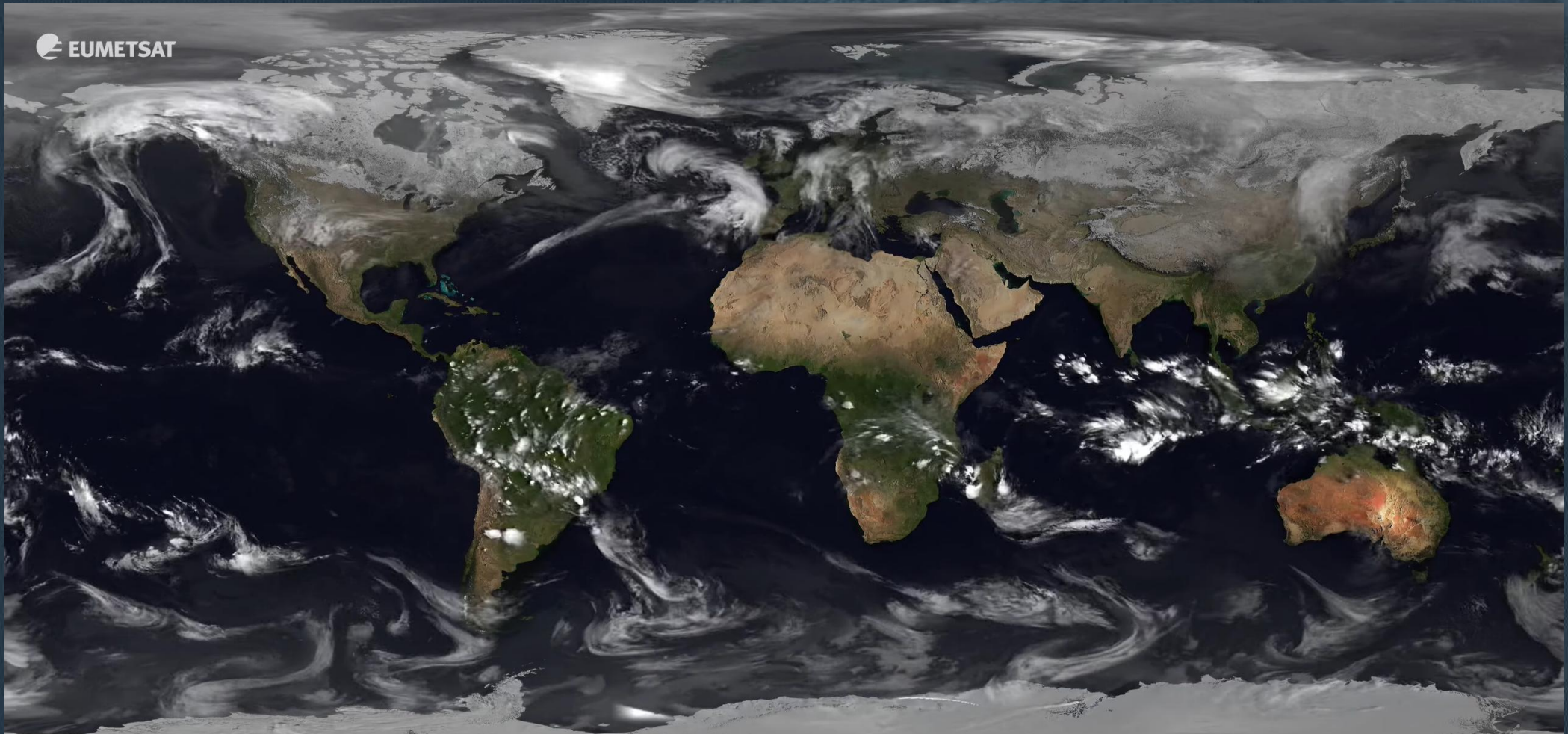
China



Japan

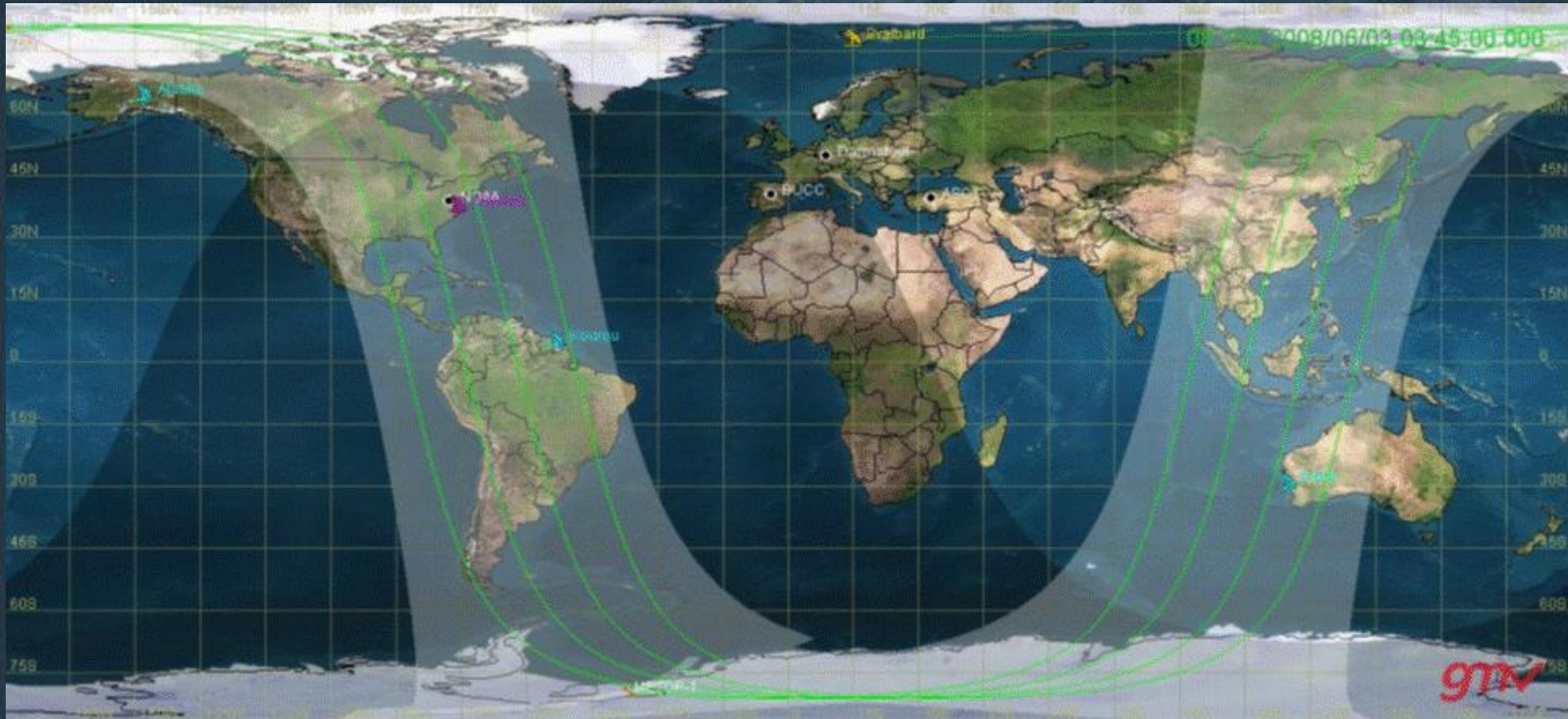
Global weather

This image was captured by the imaging instruments on board geostationary weather satellites from Europe, US, China, and Japan. It shows infrared (IR 10.8) cloud data superimposed over NASA's Blue Marble Next Generation ground maps.



Global coverage by non-geostationary MetSat satellites

- 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



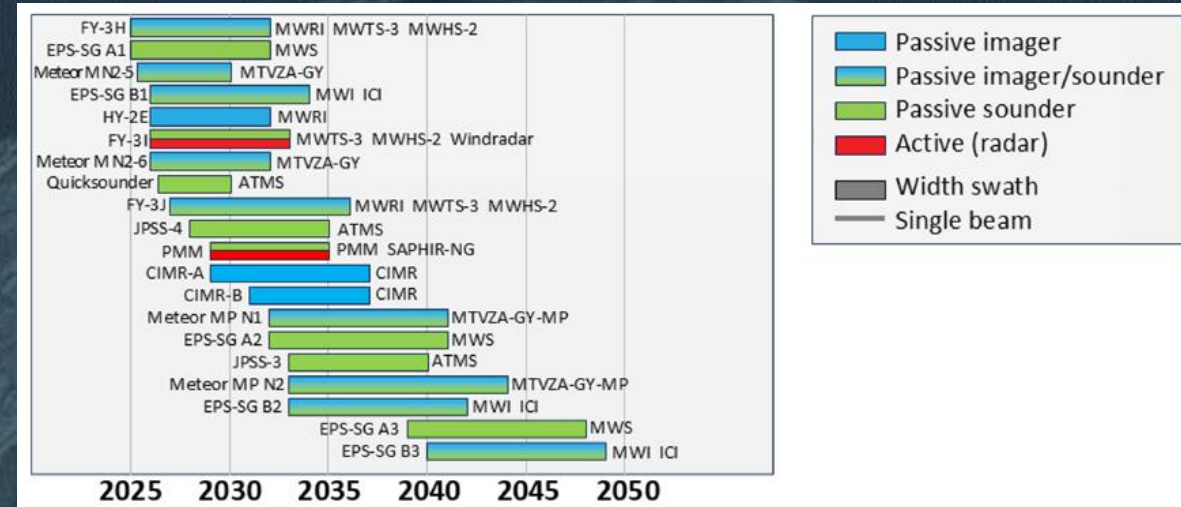
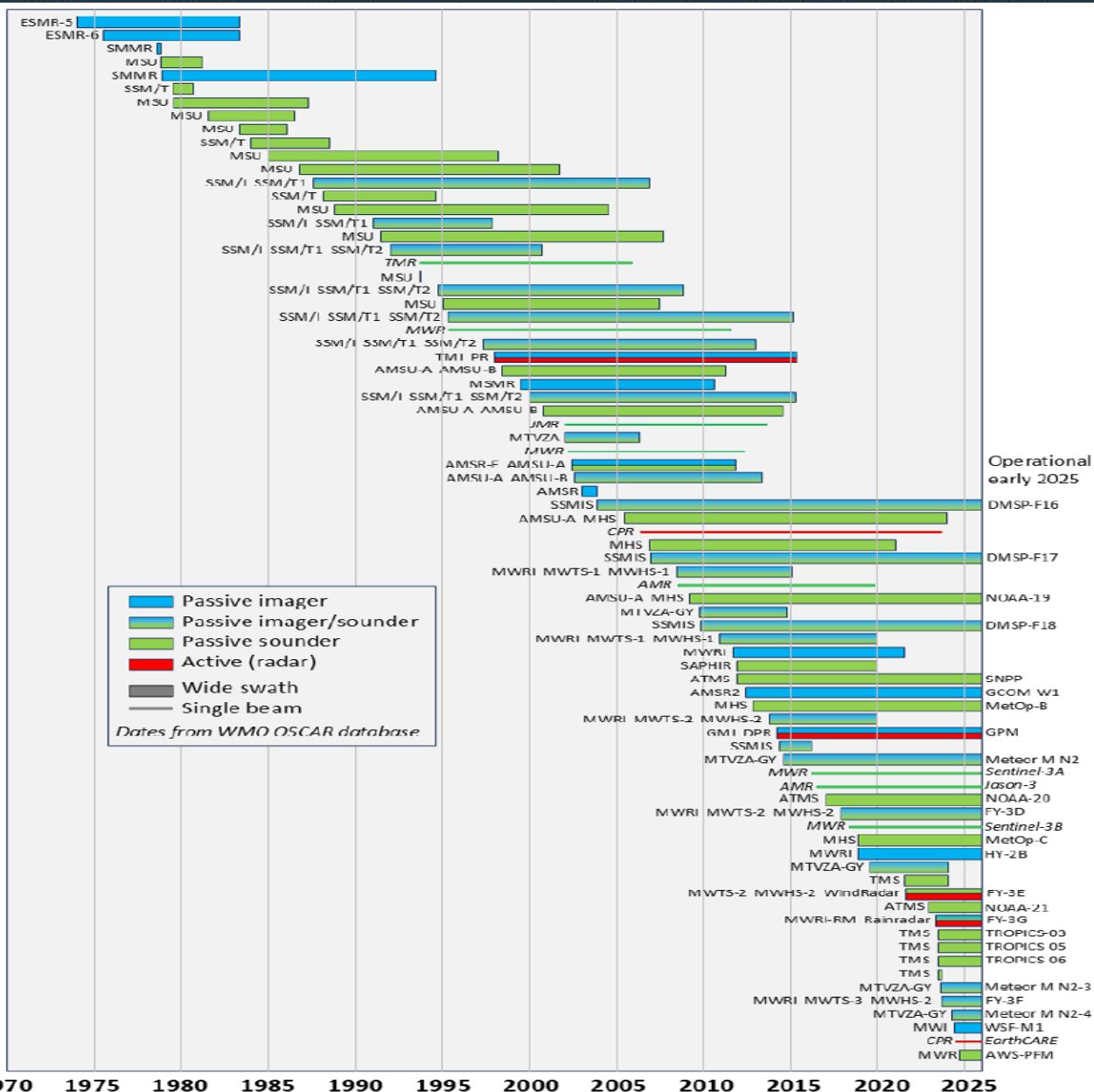
Constellation of the currently operational MetSat of WIGOS



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

NON-GEOSTATIONARY METEROLOGICAL SATELLITES		
SUN-SYNCHRONOUS ORBIT		
23	DMSP-F18	ECT 04:30 desc
24	FY-3E	ECT 05:40 desc
25	WSF-M1	ECT 06:00 desc
26	DMSP-F17	ECT 06:35 desc
27	Meteor-M N2-3	ECT 09:00 desc
28	Metop-B	ECT 09:30 desc
29	Metop-C	ECT 09:30 desc
30	Metop-SGA1	ECT 09:30 desc
31	FY-3F	ECT 10:00 desc
32	SNPP	ECT 13:25 asc
33	NOAA-20	ECT 13:25 asc
34	NOAA-21	ECT 13:30 asc
35	GCOM-W	ECT 13:30 asc
36	GOSAT-GW	ECT 13:30 asc
37	FY-3D	ECT 13:40 asc
38	Meteor-M N2-4	ECT 15:00 asc
DRIFTING ORBITS		
39	Sentinel-6A	66° incl
40	Sentinel-6B	66° incl
41	JASON-3	66° incl
42	GPM-core	65° incl
43	FY-3G	50° incl
44	COSMIC-2	24° incl
HIGHLY ELLIPTICAL ORBIT		
45	Arctica-M N1	
46	Arctica-M N2	

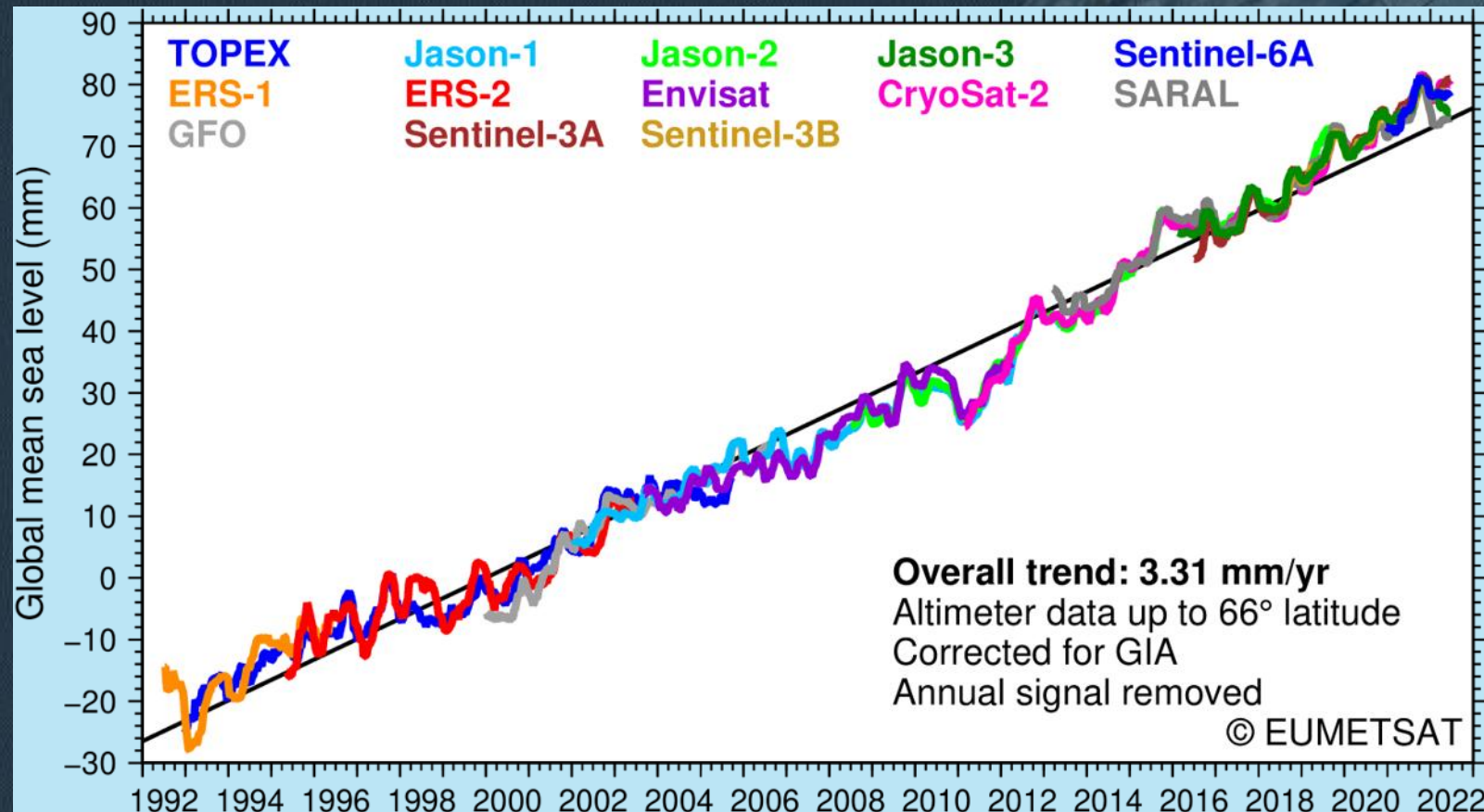
Continuity in the measurements is key!



The two figures respectively show the timelines of past, current and future satellite missions carrying cross-track (sounding) and conically scanning (imaging) multi-channel microwave radiometers used for precipitation retrieval and providing analysis-ready data to the users on a global basis.

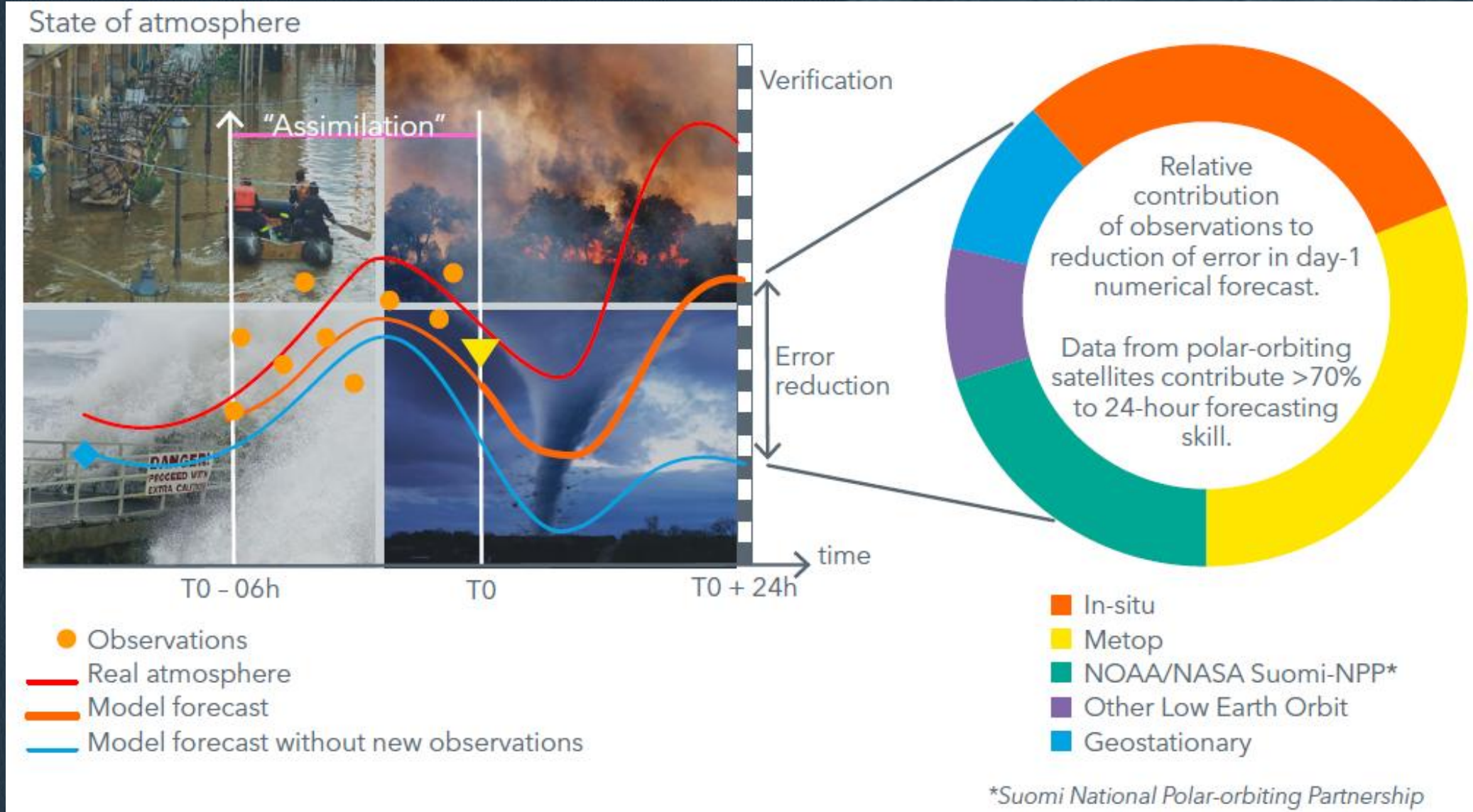
Sea level rise observed by 12 satellites over a period of 30 years

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.

Improvement of forecast skills due to MetSat (1/2)

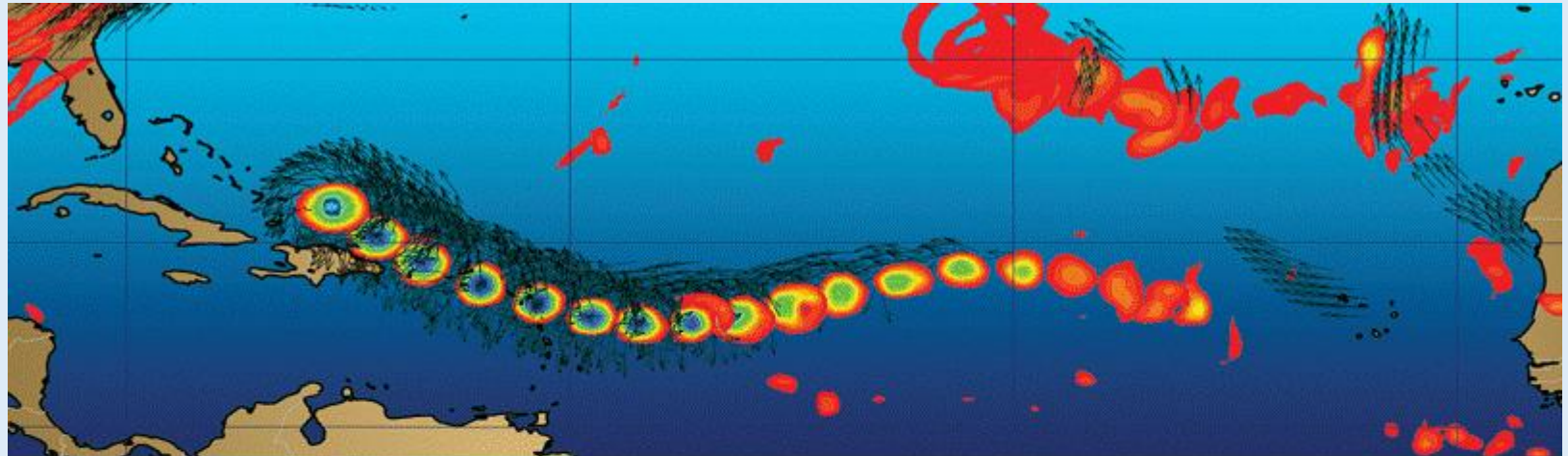


Improvement of forecast skills due to MetSat (2/2)

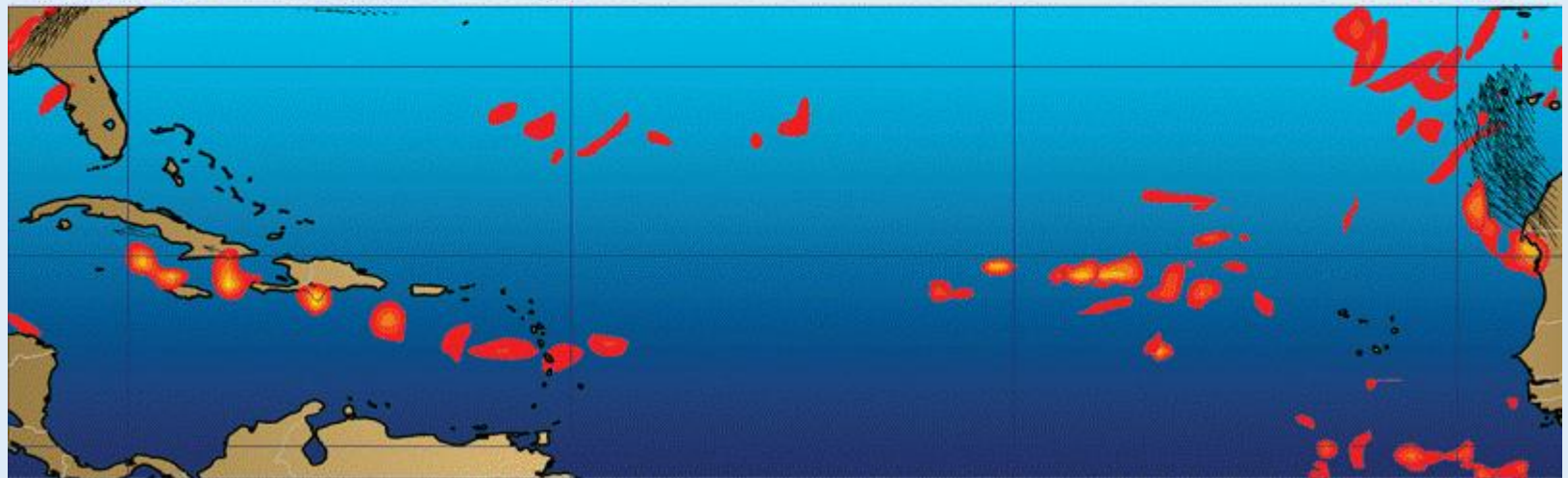
Contribution of meteorological satellites to forecasting

(Example: Initial Joint Polar System (IIPS) 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).



A little bit of history !

First weather satellite launched from Cape Canaveral, FL

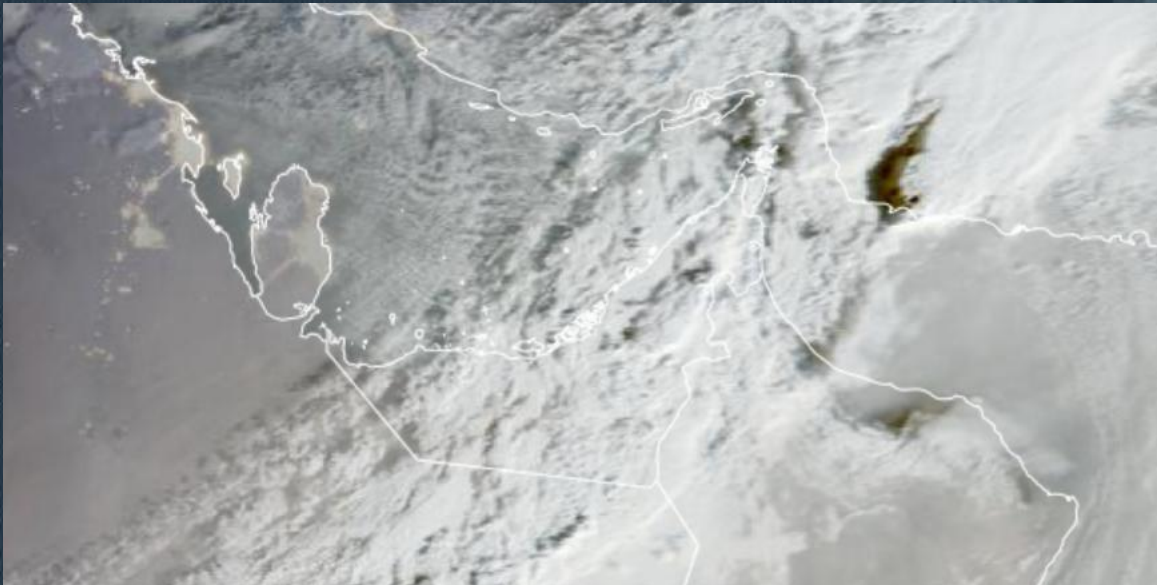
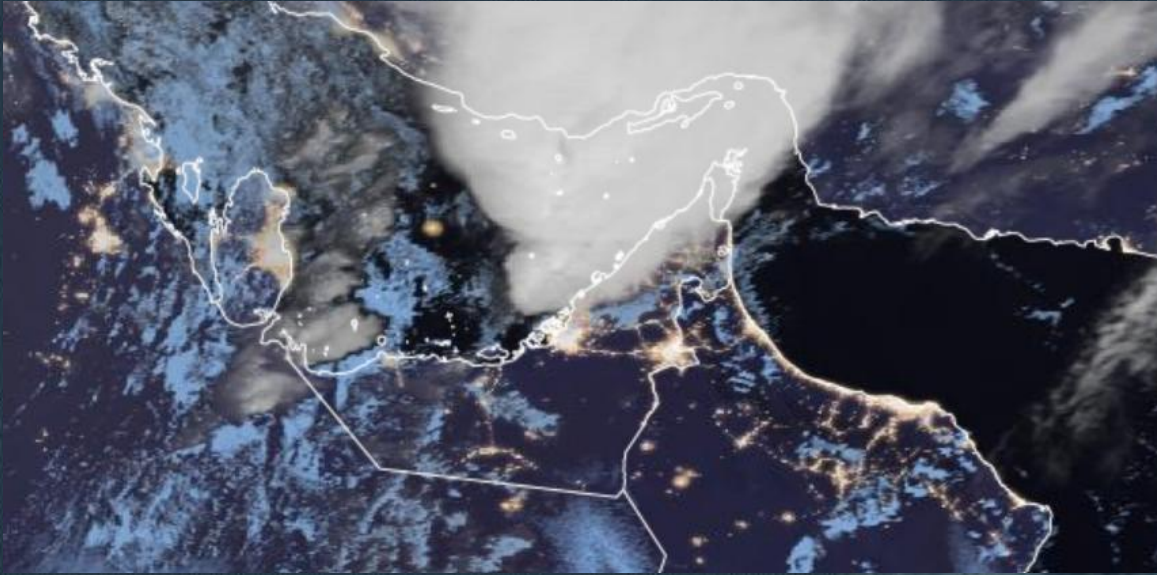
- Satellite Weight: 122 kg
- Payload: Two TV cameras, two video recorders, and the power, communications, and other systems needed

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

FIRST TELEVISION PICTURE FROM SPACE
TIROS I SATELLITE
APRIL 1, 1960



Example: Heavy rain over the United Arab Emirates

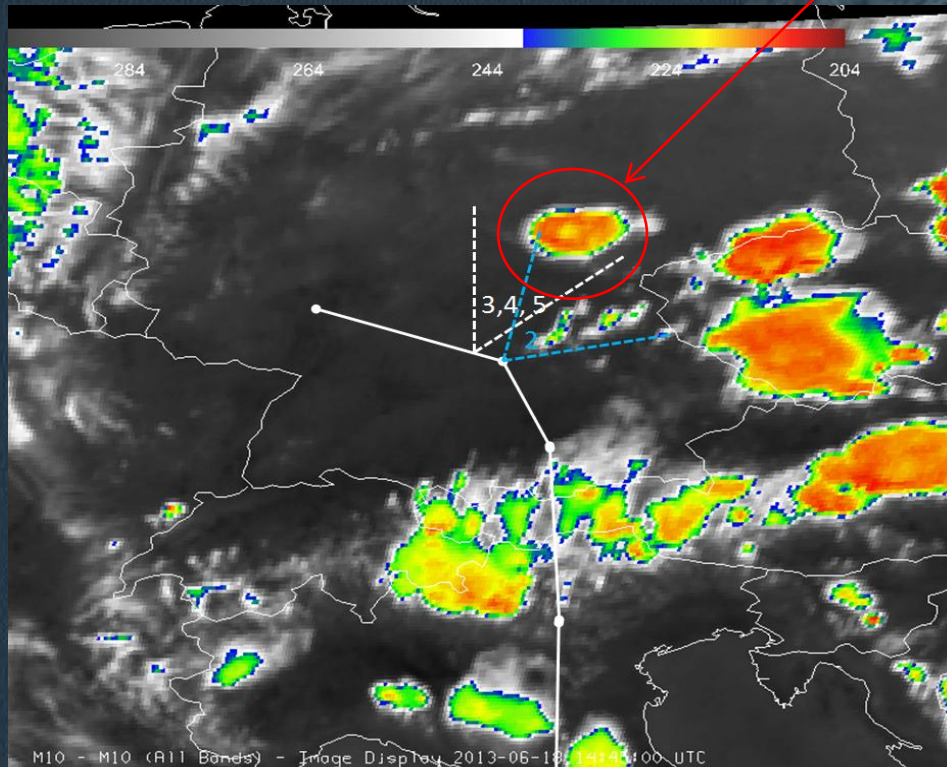


- Heavy rain over the United Arab Emirates on Thursday 18 Dec 2025 at 17:00 UTC (upper picture) and Friday 19 Dec 2025 at 4:00 UTC - as seen from Meteosat-12 geostationary weather satellite 36,000km above the Earth.
- Heaviest rain since beginning of weather records in UAE 76 years ago.
- The National Center of Meteorology had warned of rainfall across the country from Thursday to Friday, 18-19 Dec 2025, including in Dubai and the capital Abu Dhabi.

Example: Extreme weather over Europe

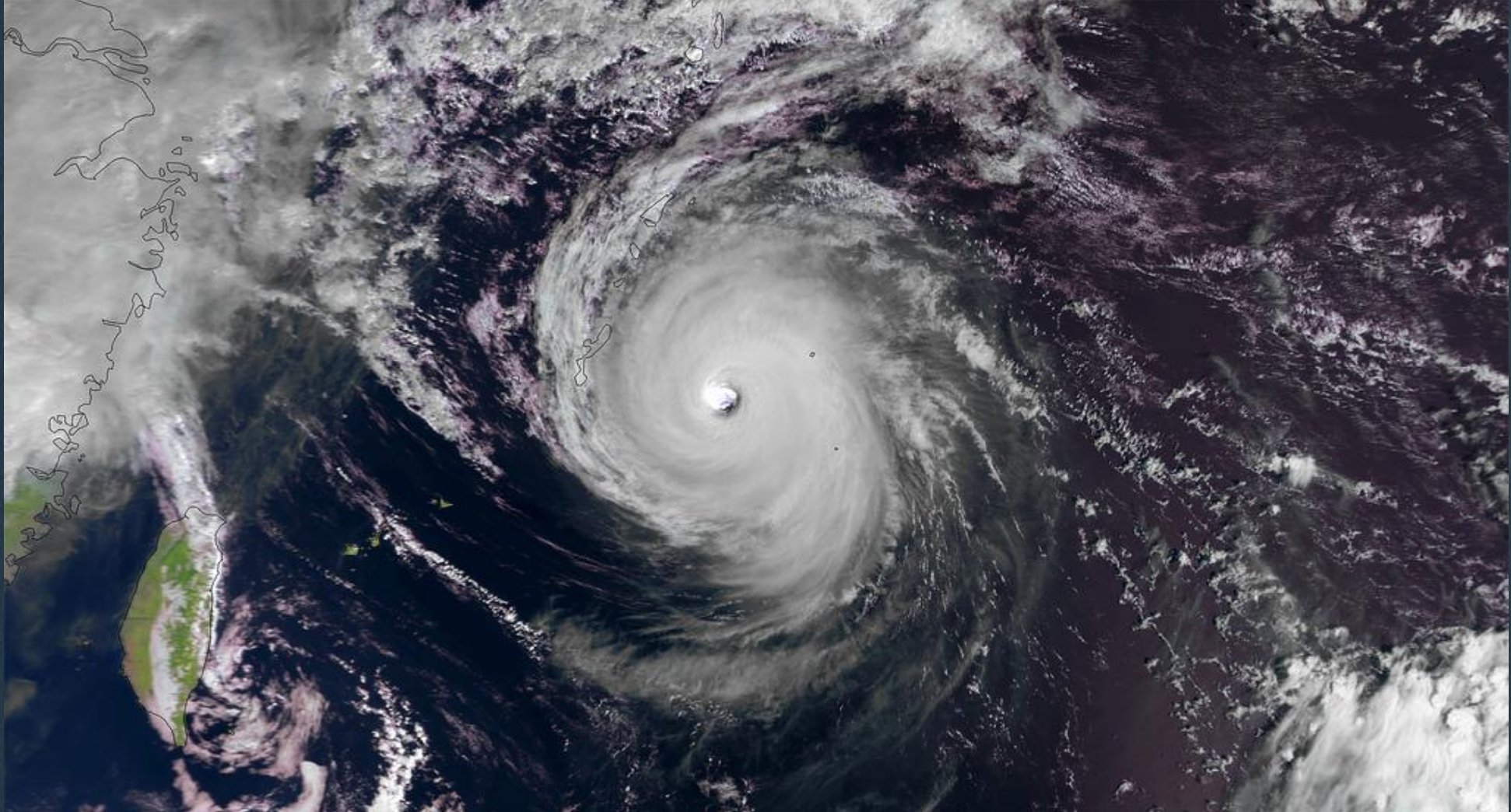
On the left picture extreme weather over Europe was observed via a MetSat satellite. At the same time this extreme weather was observed by a passenger on a flight from Rome to Frankfurt at a height of 8000m.

Erfurt, Germany



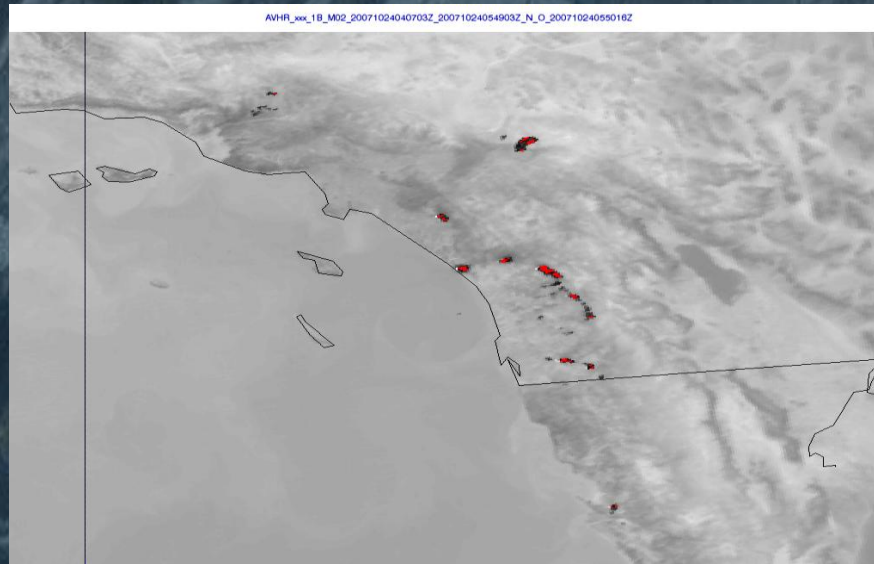
Example: Typhoon Danas

Typhoon Danas approaching Okinawa, in the Pacific, as captured by the AVHRR instrument onboard EUMETSAT's Metop-B satellite



Example: California fires

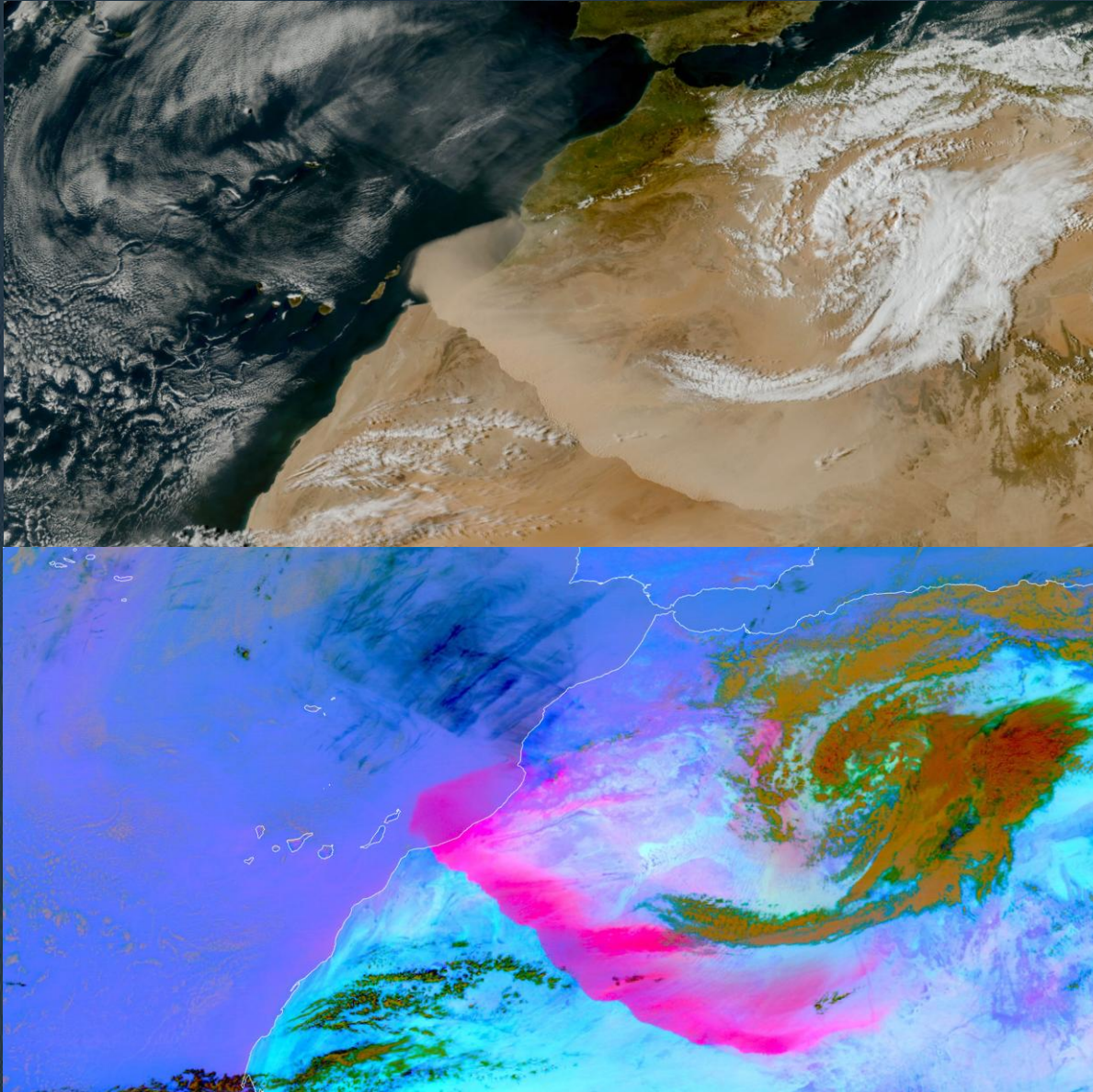
The Metop-A AVHRR image (RGB Composite NIR1.6, VIS0.8, VIS0.6) on the right it shows fires in California when large smoke plumes were visible over the Pacific Ocean.



For comparison: Smoke cloud seen from ground.



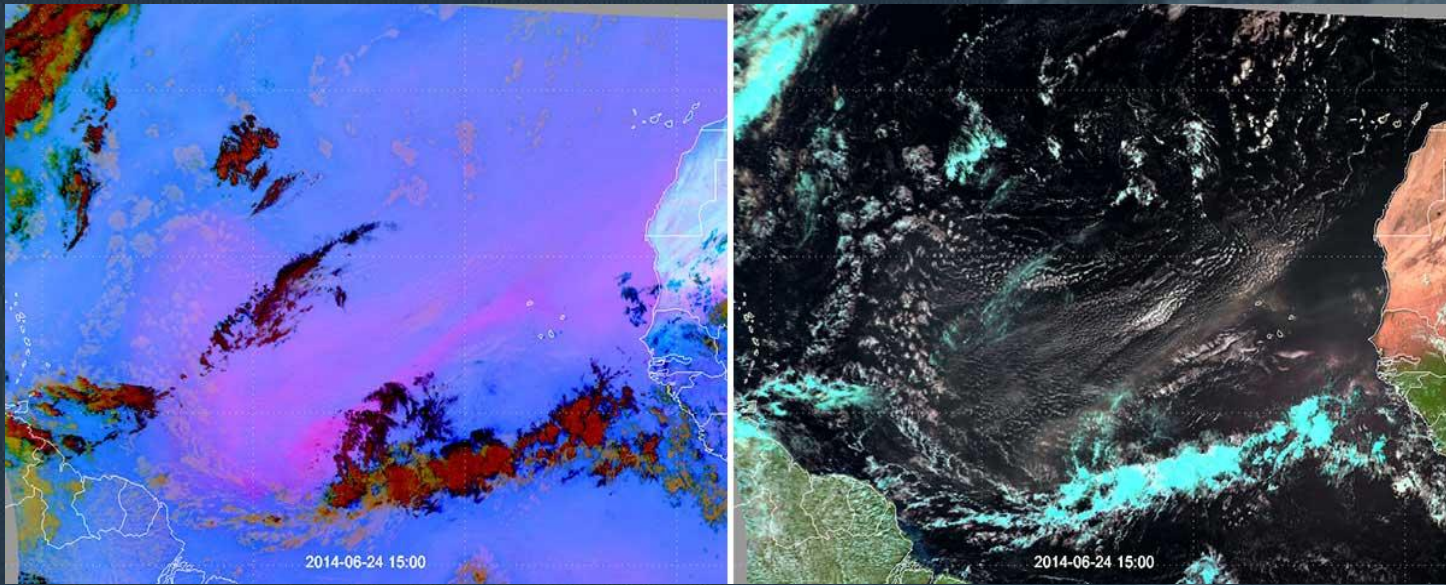
Example: Sahara dust storm



- Massive Saharan dust/sand storm on 30 March 2026 as seen from the Meteosat-12 satellite.
- This phenomenon is called Haboob.
- Desert sand/dust particles are lifted into the atmosphere by gusts of surface wind and can be transported and deposited thousands of kilometres away.
- When dust travels over populated areas, it can reduce air quality and impact health by causing respiratory problems and cause flight delays.

Example: Forecasting dust

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

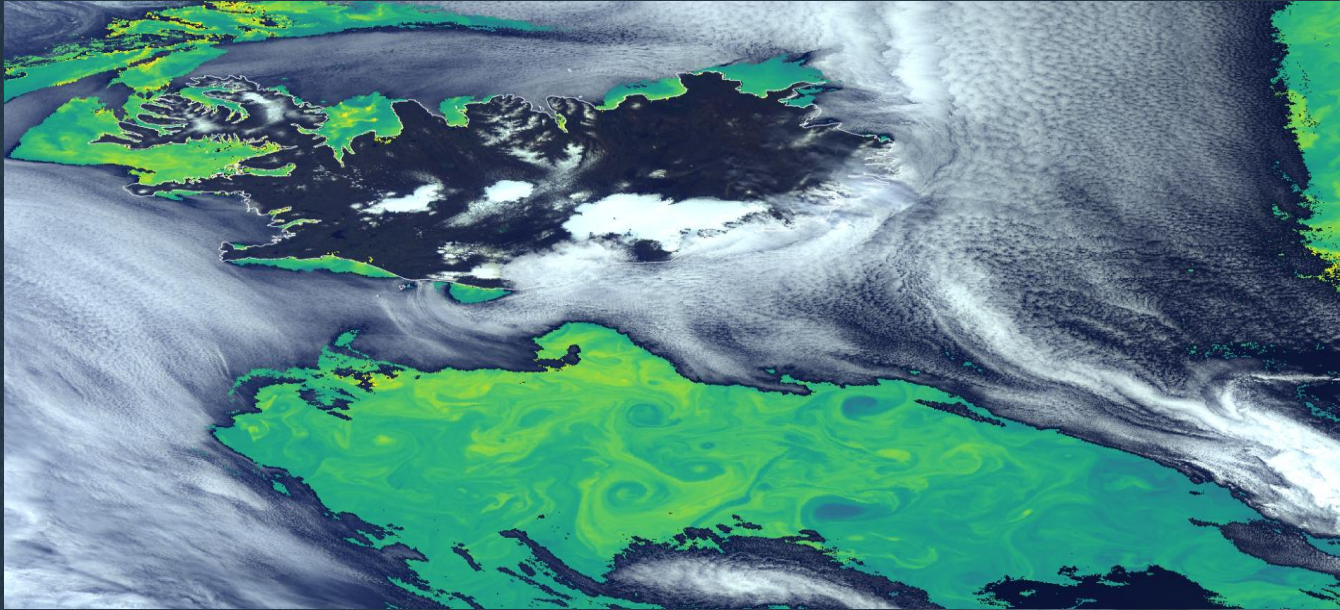


When comparing the Dust RGB and the Natural Colour RGB from the same time, the dust can be clearly seen (as pink) on the Dust RGB, but not the Natural Colour RGB.



Saharan dust moving across the Mediterranean Sea and passing over the Balearic Islands on 18 June 2024 as seen from the Sentinel-3 satellite.

Example: Phytoplankton swirls



The image on top features intricate phytoplankton swirls south of Iceland on 21 May 2025 as seen by a Copernicus Sentinel-3 satellite.

What looks at first like a painted texture is in fact the fingerprint of mesoscale circulation and biological response shaped by interacting physical and biological processes.



The bottom image shows probable phytoplankton swirls in the southern Black Sea on 25 May 2026.

The bloom (cyan colour in the image) is most likely caused by coccolithophores, which are microscopic single-celled plant-like organisms that live in large numbers throughout the upper layers of the ocean.

Example: Global sea ice - 2024

The image uses the global sea ice concentration measurements of the AMSR-2 instrument on the Japanese GCOM-W1 satellite, also known as "SHIZUKU".

In September 2024 the year's minimum sea ice concentration is reached in the Arctic while at the same time the maximum is reached in Antarctica.



Keeping an eye on Earth



Thank you very much for your attention !!!