



The global satellite observing system and its future evolution

Niels Bormann, Stephen English

1. The WMO Integrated Global Observing System (WIGOS)
2. New operational missions:
 - EPS-SG, MTG, Sentinels, Copernicus expansion missions
3. Guiding the evolution of the observing system with data assimilation
4. Future trends:
 - Small satellites, commercial programmes, etc

Niels.Bormann@ecmwf.int



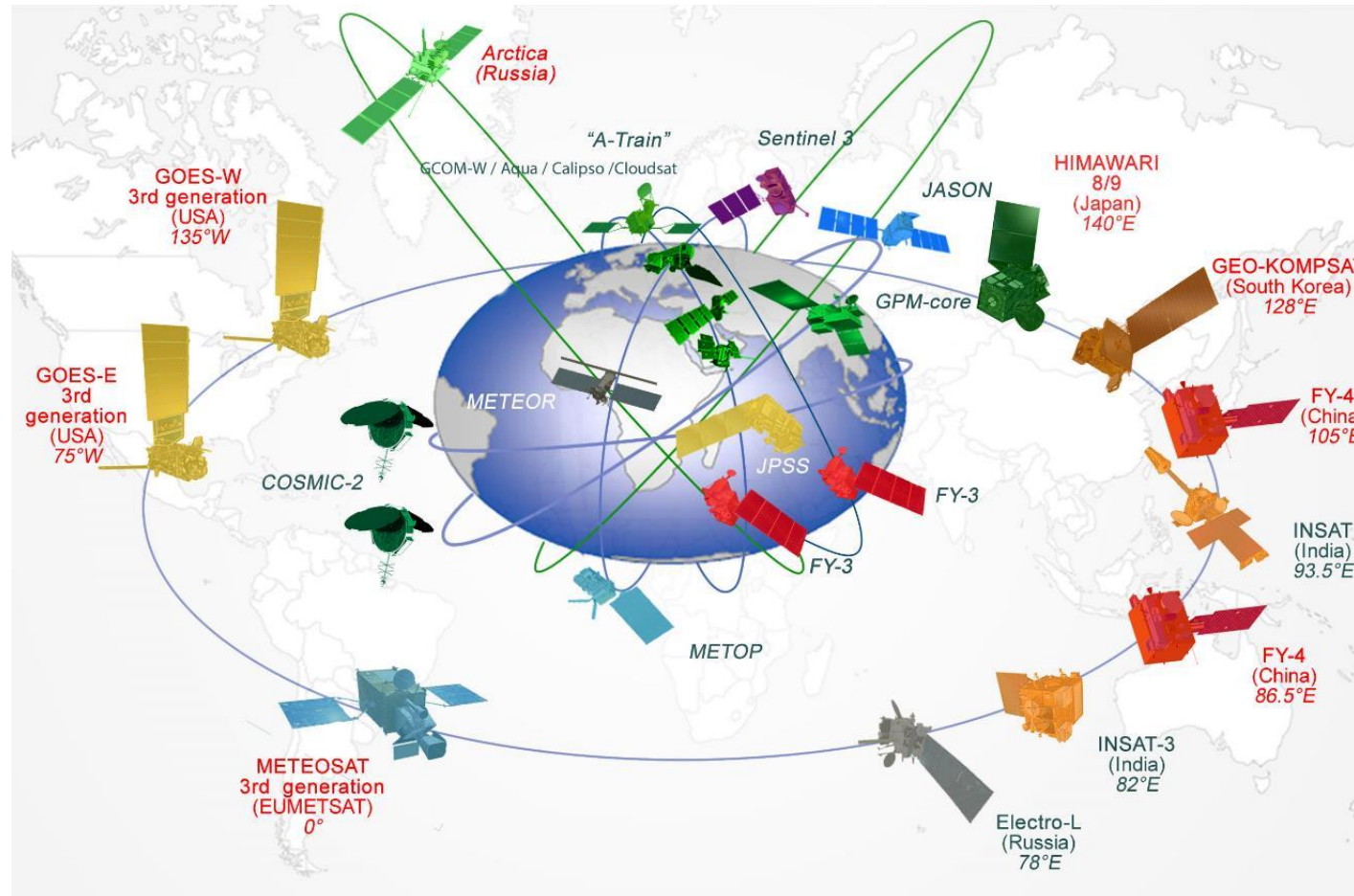
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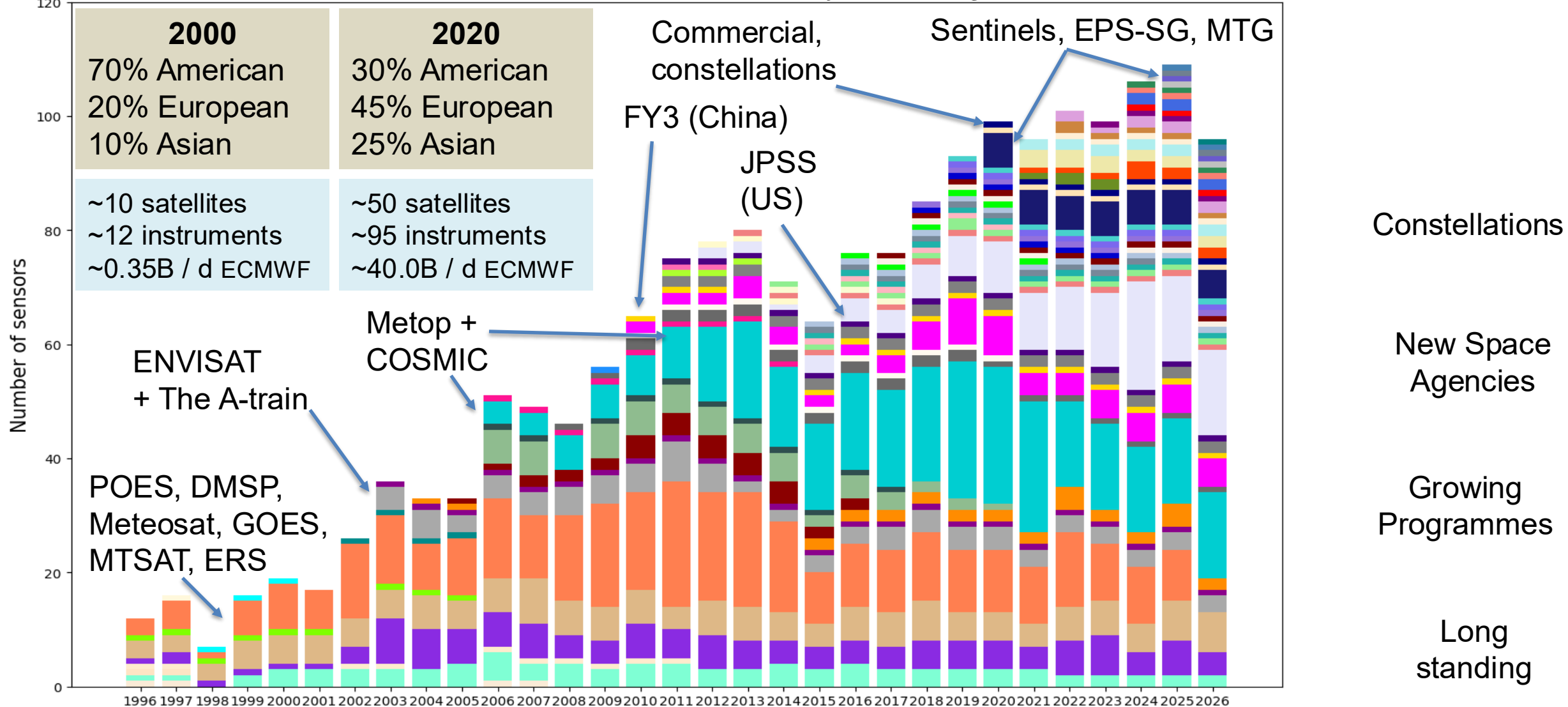
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WIGOS: WMO Integrated Global Observing System



In 2026 there are ~200 active satellites supporting weather, climate, earth system and space weather and another ~100 doing relevant Earth Observation

Number of satellite instruments monitored operationally at ECMWF

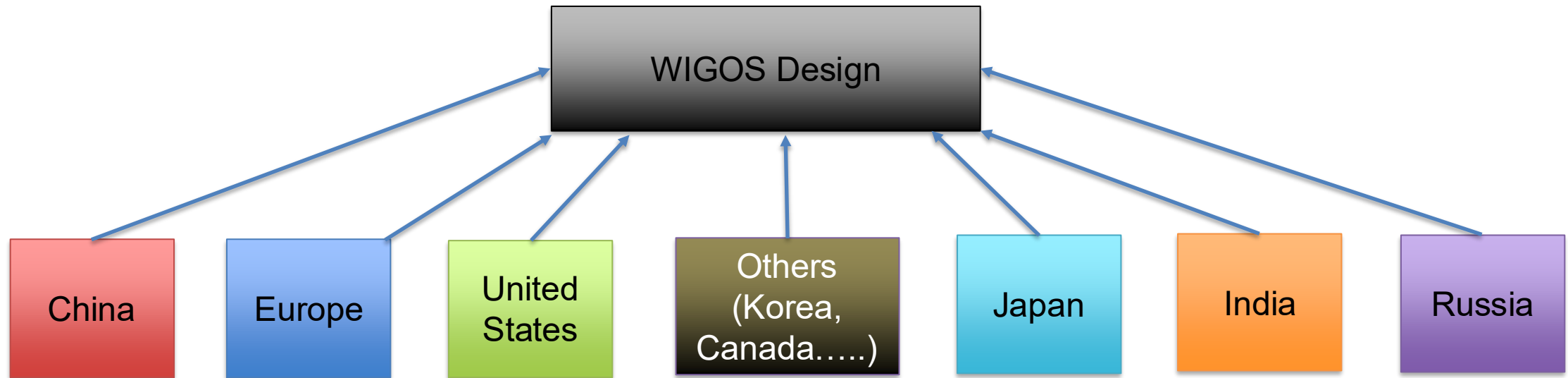


- | | | | | | | | | |
|----------------|----------------|----------------|-----------------|------------|------------|----------|-----------|----------|
| Mixed | GEO-KOMPSAT-2A | GRACE | Aeolus | COMS-1 | SAC-C | FY2 | TERRA | SCAT |
| YAM-8 | PlanetIQ | SPIRE-Lemur-3U | SARAL | JASON | C-NOFS | TRMM | ENVISAT | METEOSAT |
| Metop-D | Sentinel-6A | PAZ | CRYOSAT | GRACE-B | AURA | METOP | AQUA | GOES |
| FY-4B | GRACE-D | COSMIC2 | MEGHA-TROPIQUES | GCOM | TerraSAR-X | GRACE-A | QuickSCAT | ERS-2 |
| AWS | GRACE-C | Leo-Geo | TanDEM-X | OceanSat-2 | FY3 | COSMIC | RTOVS | ERS |
| Sentinel-3B | SMAP | KOMPSAT-5 | INSAT-3D | JPSS | CORIORIS | MTSAT | GMS-5 | DMSP |
| Sentinel-3A | Sentinel | Sentinel-5P | GPM | SMOS | QuikSCAT | HIMAWARI | POES | CHAMP |
| GEO-KOMPSAT-2B | HY2 | | | | | | | |

Graph by Mohamed Dahoui

WMO Coordination and WIGOS

WMO is striving towards a coordinated global observing system
(**WMO Integrated Global Observing System – WIGOS**)



Trying to make sure national efforts are complementary
Surface and space components

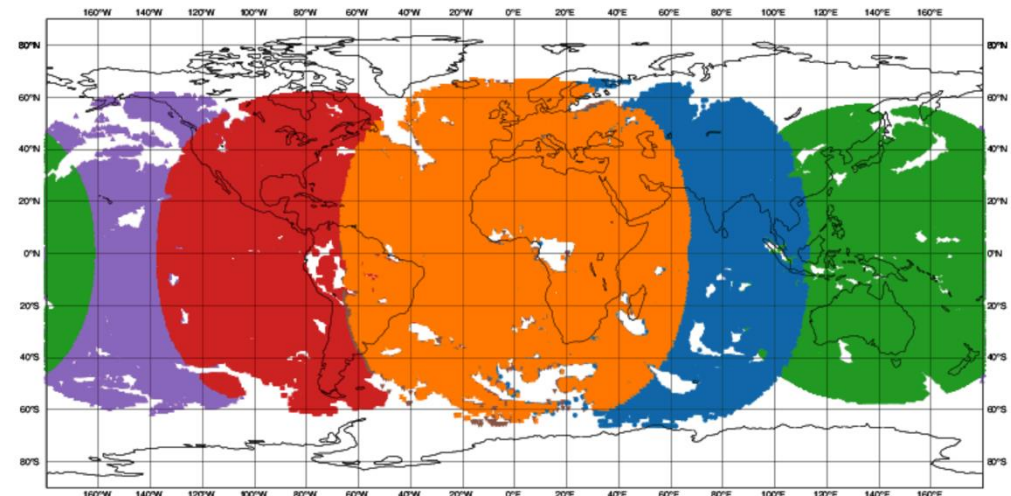
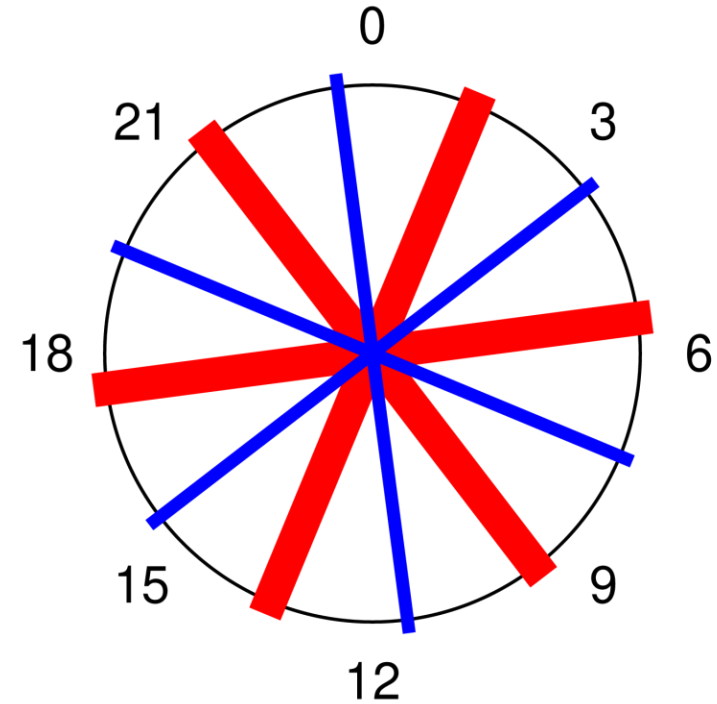
WIGOS Vision and CGMS baseline

WIGOS Vision:

- Expresses a comprehensive vision for the evolution of the global observing system
- Coordinated by WMO
- <https://community.wmo.int/vision2040> (soon to be updated)

Coordination Group for Meteorological Satellites (CGMS):

- International group of space agencies
- Aims to coordinate contributions from different countries/agencies
- Separate from WMO – but in consultation with WMO
- Establishes “CGMS baseline” of maintained commitments
- Key elements:
 - 3 orbit backbone, complemented by other polar sats
 - At least 5 geostationary satellites
 - At least 14600 radio occultations per day
 - Etc
- <https://cgms-info.org/wp-content/uploads/2025/06/CGMS-Baseline-v7.pdf>



Gap Analysis and Rolling Review of Requirements

- Gap Analysis

- Performed annually by WMO to identify gaps in commitments vs the WIGOS Vision

Earth Observation	Orbit	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	Orbits or Satellites	WIGOS Vis.
Backbone system with specified orbital configuration and measurement approaches (Subcomponent 1)														
<i>Geostationary core constellation with a minimum of five satellites providing complete Earth coverage</i>														
VIS/IR Imagery	GEO	6	6	6	6	6	6	6	6	5	5	4	Orbits	≥5 satellites
IR Sounding	GEO	2	2	2	2	2	2	2	4	4	4	4	Orbits	≥5 satellites
Lightning	GEO	4	4	4	4	4	4	4	4	4	4	5	Orbits	≥5 satellites
UV/VIS/NIR Sounder	GEO	2	2	2	2	2	1	1	1	1	1	1	Orbits	≥5 satellites
Earth Observation	Orbit	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	Orbits or Satellites	WIGOS Vis.
Backbone system with specified orbital configuration and measurement approaches (Subcomponent 1)														
<i>Sun-synchronous core constellation satellites in three orbital planes (morning, afternoon, early morning)</i>														
IR Sounding	LEO	3	3	3	3	3	3	3	3	3	3	2	Orbits	3 SSO
MW Sounding	LEO	3	3	3	3	3	3	3	3	3	3	3	Orbits	3 SSO
VIS/IR Imagery	LEO	3	3	3	3	3	3	3	3	3	3	2	Orbits	3 SSO
Day/Night VIS Imagery	LEO	2	2	2	2	2	2	2	2	2	2	1	Orbits	3 SSO
MW Imager	LEO	3	3	3	3	3	3	3	3	3	3	2	Orbits	3 SSO
Scatterometers	LEO	4	4	4	4	4	3	2	2	2	2	3	Orbits	3 SSO

Definition of colours for orbital coverage	
5/6 GEO	Green
3/4 GEO	Yellow
1/2 GEO	Orange
No GEO	Red

Definition of colours for orbital coverage	
3 LEO orbits covered	Green
2 LEO orbits covered	Yellow
1 LEO orbit covered	Orange
No LEO coverage	Red

- WMO Rolling Review of Requirements (RRR)

- Supports high-level design of WIGOS
- Compiles observation requirements and capabilities, based on expert knowledge and impact studies
- Application areas: Atmosphere, Ocean, Hydrology and Terrestrial, Cryosphere, Space Weather, Integrated Earth System

Tools to support WIGOS evolution: OSCAR

WMO Space provide detailed support for satellite data from <https://space.oscar.wmo.int>

OSCAR lists what exists, what is planned, what it can do, how this compares to requirements

The screenshot shows the top of the OSCAR website. On the left is the WMO logo. In the center, the text reads "OSCAR Observing Systems Capability Analysis and Review Tool". On the right is a "Login" button. Below this is a navigation bar with tabs for "Home", "Observation Requirements", "Space-based Capabilities", "Surface-based Capabilities", and "Analysis". Under "Space-based Capabilities", there are sub-links for "Overview", "Programmes", "Satellites", "Instruments", "Frequencies", "Agencies", "Satellite Status", and "Gap Analyses". A search bar labeled "Quick Search..." is on the right.

Space-based Capabilities (OSCAR/Space)

This section contains details of environmental satellite missions, instruments and other related information. It also provides expert assessments on the relevance of instruments for fulfilling some WMO pre-defined capabilities (see [list of mission types](#)) and the measurement of particular physical variables (see [See Gap analyses by variable or by type of mission](#))

The OSCAR/Space section is managed by the WMO Space Programme Office. See the [WMO Space Programme website](#) for more information.

How to get started with OSCAR/Space ?

→ Using the "Quick Search"

The "quick search" is present on every page at the right end of the menu bar. Please type e.g. the name of a satellite, instrument or variable. The system will then automatically suggest some items, which you can directly select in the drop down menu.

→ Using the top menu

From the top menu, you can select the full tables of satellites, instruments, programmes etc. These tables can then be sorted and filtered according to your criteria.

From any page, you can use the hyperlinks to navigate between your items of interest. The quick search and top menu are available from all pages.

For support and feedback please use the [helpdesk form](#).

OSCAR/Space Version 2.9 released

OSCAR/Space Version 2.9 was released. Please see the release notes via the link [here](#).

Satellite status updates

Launch	Operator	Satellite	Payload
18 Feb 2025		BlackSky-Gen3-1	Blacksky Imager
04 Feb 2025		WorldView Legion-5	Spaceview-NG
04 Feb 2025		WorldView Legion-6	Spaceview-NG
25 Dec 2024		Resurs-P5	Geoton-L1, GSA, ShMSA-VR, ShMSA-VR
21 Dec 2024		StriX-2	X-SAR
21 Dec 2024		Tomorrow-S3	TMS
21 Dec 2024		Tomorrow-S4	TMS
05 Dec 2024		PROBA-3C	

Additional related information

- Information and links relating data access are integrated in OSCAR. Access to low-level data is described on the [Data access page](#). Satellite imagery and derived products can be accessed through the [Product Access Guide](#). An overview of [related software and processing tools](#) is also available.
- [WMO-CGMS Virtual Laboratory for education and training in satellite meteorology](#) (VLab), a global network of specialized training centres provides valuable information in the area of training and education.



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Instrument: IASI-NG

Instrument details

Acronym	IASI-NG		
Full name	Infrared Atmospheric Sounder Interferometer - New Generation		
Purpose	Temperature/humidity sounding, ozone profile and total-column or profiles of green-house gases (C2H2, C2H4, C2H6, CFC-11, CFC-12, CH3OH, CH4, CO, H2CO2, HCN, HNO2, HNO3, N2O, NH3, PAN, SO2)		
Short description	16,921 channels, range 645-2760 cm ⁻¹ (3.62-15.50 μm) split in 12 bands [see detailed characteristics below]. Spectral resolution 0.125 cm ⁻¹ (unapodised) Monitoring and calibration information here		
Background	Evolution of IASI on Metop A, Metop-B, Metop-C		
Scanning Technique	Cross-track: 16 steps of 100 km (14 earth-viewing FOV's, one for cold space, one for blackbody) step-and-dwell scanned, for a swath of 2000 km. Along-track: one scan line every 100 km every 16 s.		
Resolution	4 x 4 12-km IFOV's regularly spread within the 100 x 100 km ² FOV (average sampling distance: 24 km).		
Coverage / Cycle	Near-global coverage twice/day		
Mass	360 kg	Power	500 W
		Data Rate	6 Mbps

Providing Agency	CNES
Instrument Maturity	Backed by strong heritage
Utilization Period:	2025 to 2047
Last update:	2024-09-23

Satellites this instrument is flying on

Note: a red tag indicates satellites no longer operational, a green tag indicates operational satellites, a blue tag indicates future satellites

- [EPS Second Generation](#) (EUMETSAT)
 - [Metop-SG-A1](#) (see instrument status) 2025 - 2033
 - [Metop-SG-A2](#) (see instrument status) 2032 - 2040
 - [Metop-SG-A3](#) (see instrument status) 2039 - 2047

Instrument classification

- Earth observation instrument
 - Passive optical radiometer or spectrometer
 - Cross-nadir infrared sounder, possibly including VIS channels

WIGOS Subcomponents

- Subcomponent 1
 - IR hyperspectral sounders [in SSO]
 - IR hyperspectral sounder [in SSO]

Mission objectives

Primary mission objectives

- Atmospheric temperature
- Height of the top of PBL
- Height of the tropopause
- Integrated Water Vapour (I WV)
- O3 Total Column
- Specific humidity
- Temperature of the tropopause

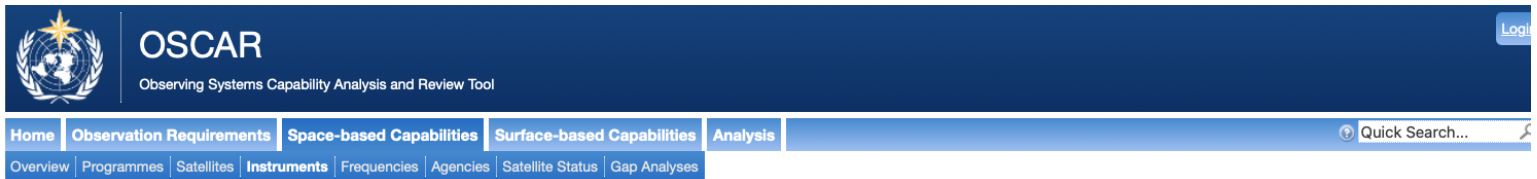
Detailed characteristics

Band	Wavelength	Wavenumber	NEΔT after apodisation
IAS-1	15.50 μm	645 cm ⁻¹	0.39 K @ 280 K
	15.27 μm	655 cm ⁻¹	0.26 K @ 280 K
	15.08 μm	663 cm ⁻¹	0.225 K @ 280 K
	14.49 μm	690 cm ⁻¹	0.225 K @ 280 K
IAS-2	12.99-14.49 μm	690-770 cm ⁻¹	0.130 K @ 280 K
IAS-3	10.00-12.99 μm	770-1000 cm ⁻¹	0.130 K @ 280 K
IAS-4	9.35-10.00 μm	1000-1070 cm ⁻¹	0.195 K @ 280 K
IAS-5	8.70-10.00 μm	1070-1150 cm ⁻¹	0.195 K @ 280 K
IAS-6	6.06-8.70 μm	1150-1650 cm ⁻¹	0.130 K @ 280 K
IAS-7	4.76-6.06 μm	1650-2100 cm ⁻¹	0.449 K @ 280 K
IAS-8	4.59-4.76 μm	2100-2180 cm ⁻¹	0.156 K @ 280 K
IAS-9	4.44-4.59 μm	2180-2250 cm ⁻¹	0.26 K @ 280 K
IAS-10	4.13-4.44 μm	2250-2420 cm ⁻¹	0.26 K @ 280 K
IAS-11	4.13 μm	2420 cm ⁻¹	0.26 K @ 280 K
	4.08 μm	2450 cm ⁻¹	0.26 K @ 280 K
	3.85 μm	2600 cm ⁻¹	0.65 K @ 280 K
IAS-12	3.70 μm	2700 cm ⁻¹	1.138 K @ 280 K
	3.62 μm	2760 cm ⁻¹	1.43 K @ 280 K

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OSCAR is super-useful for looking up instrument capabilities!

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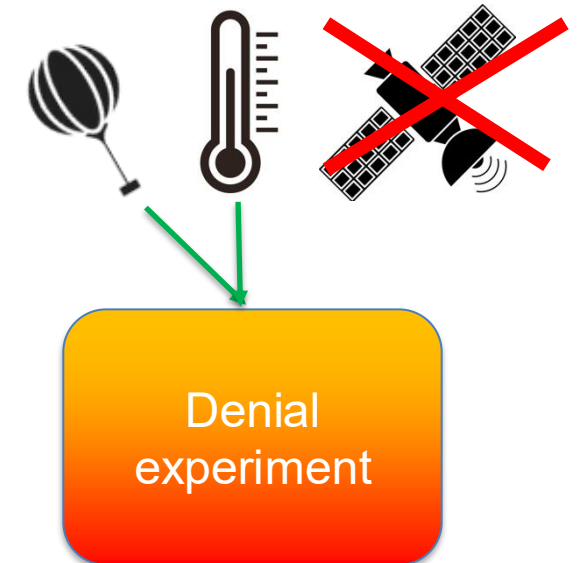
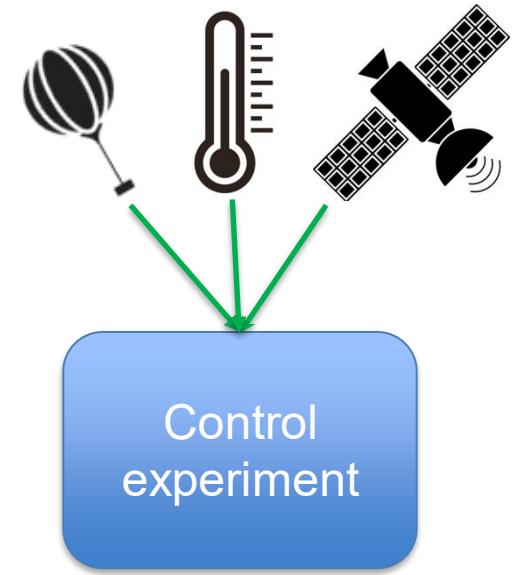
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	13.60 μm	735 cm ⁻¹	0.130 K @ 280 K
	13.50 μm	741 cm ⁻¹	0.195 K @ 280 K
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Impact assessments at NWP centres

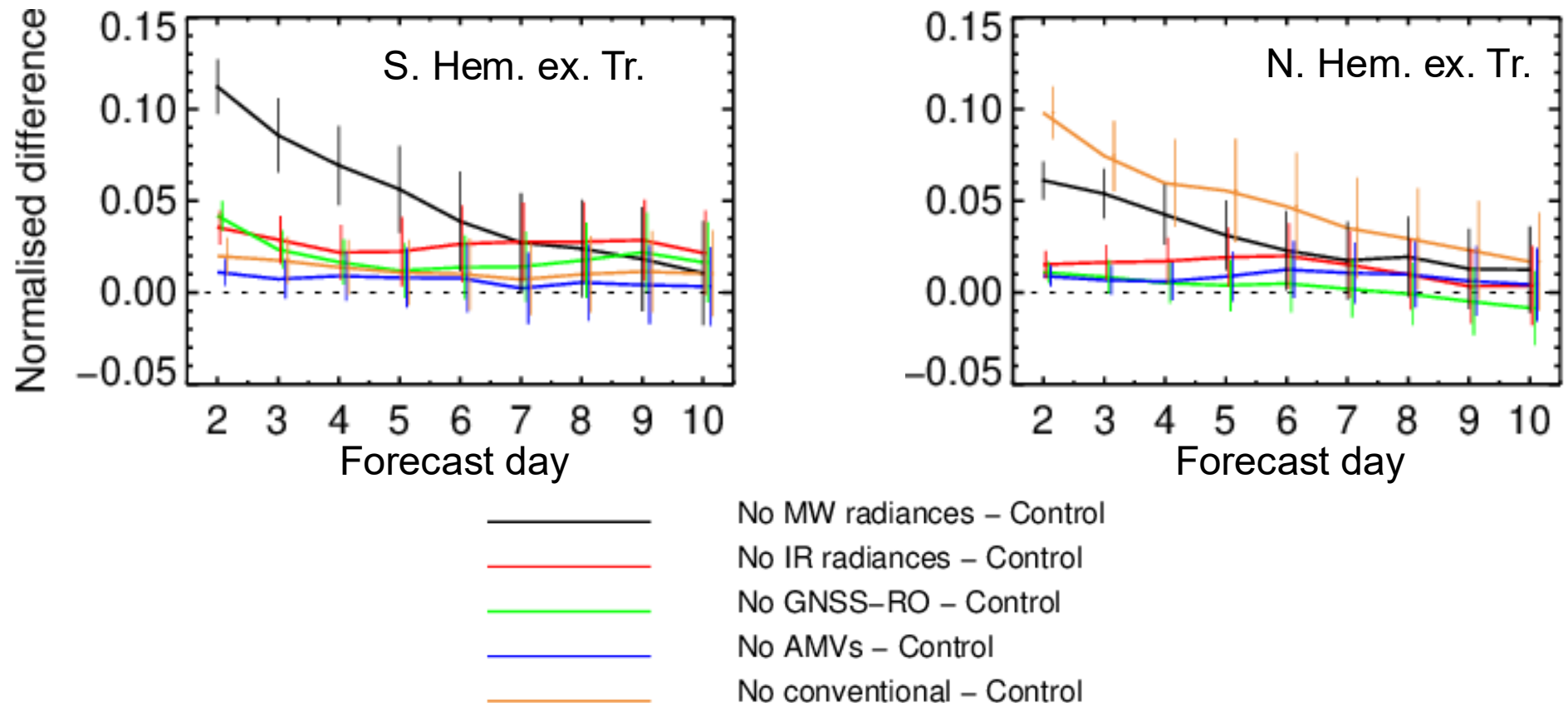
- NWP centres regularly evaluate the contributions of the global observing system, to inform the evolution of WIGOS.
- Reviewed in 4-yearly **WMO Workshops on the Impact of Various Observing Systems on Numerical Weather Prediction and Earth System Prediction.**
- One tool: Observing System Experiments (OSEs)



Example: Observing System Experiments at ECMWF

- June – Aug 2022 & Dec – Feb 2023
- TCO399 (~28 km) resolution
- Control: All operationally used observations

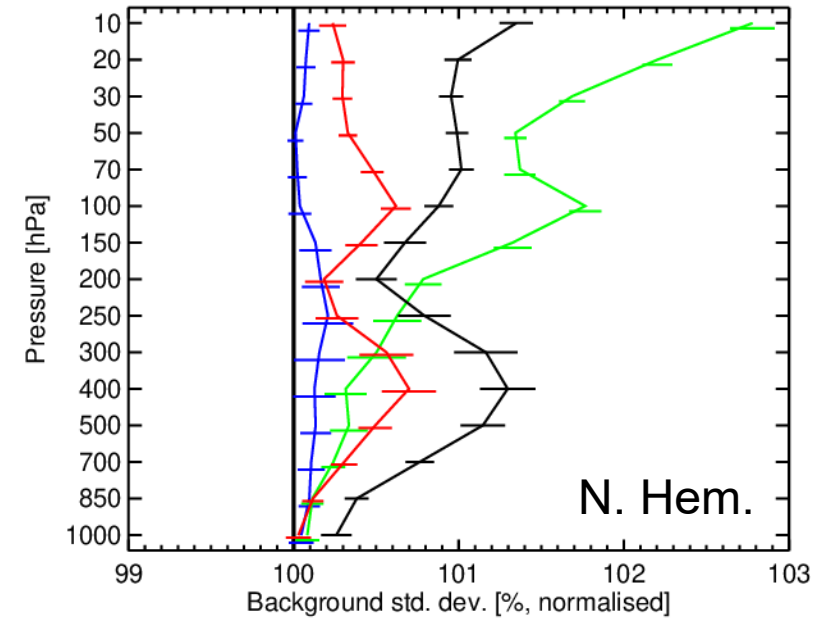
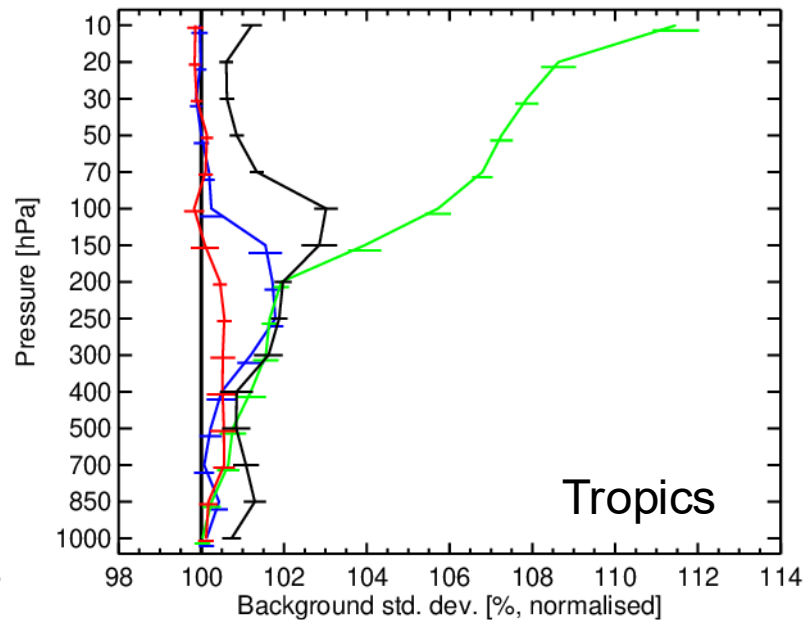
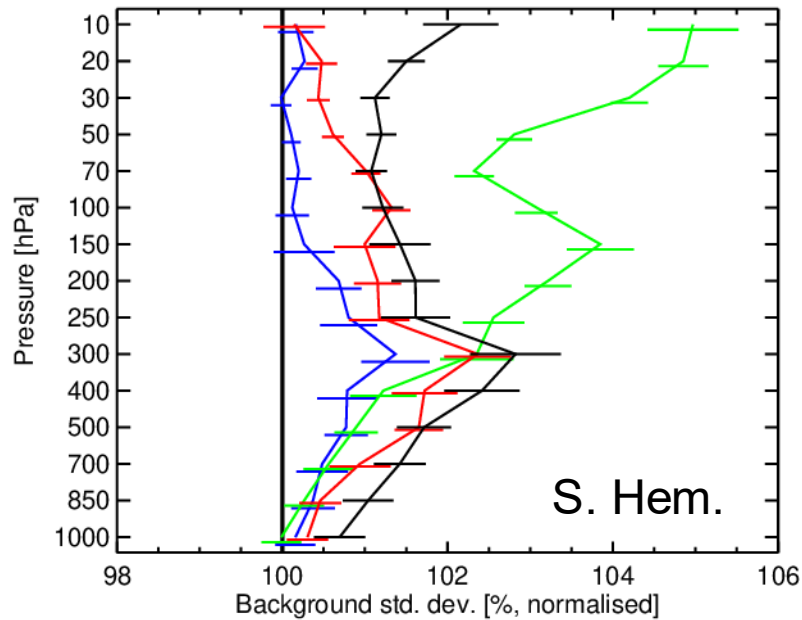
Normalised difference in Stdev of forecast error for Z 500 hPa, verified vs operations



Example: Observing System Experiments at ECMWF

Short-range impact on wind from in-situ observations:
Normalised stdev of background departures

Different observing systems provide complementary impact.



- No MW radiances
 - No IR radiances
 - No GNSS-RO
 - No AMVs
- 100% = Control

Frequency management and why this is critical to NWP

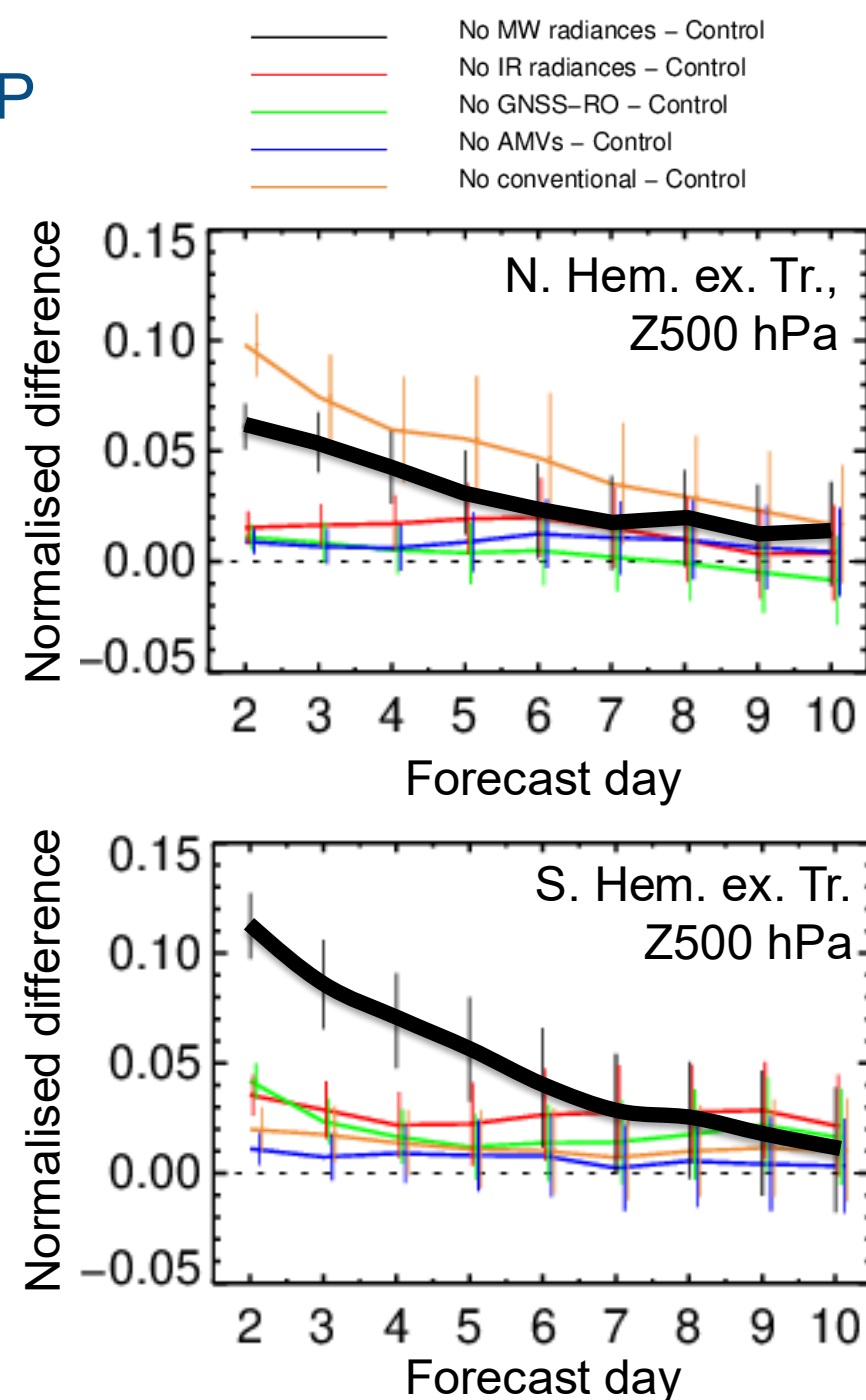
- **Passive microwave are leading contributors to current NWP skill:**

- 50-60 GHz and 176-190 GHz provide largest direct impact
- 18.7, 23.8, 31.4, 37, 89, 166 have lower direct impact but support the use of 50-60 and 176-190 GHz
- 1.4, 6.8, 10.7, 209, 229 important for emerging applications
- Active bands, notably radar, also suffer interference.

- **Satellite up + down link + control frequencies and data dissemination e.g. 400-406 MHz for radiosondes.**

- **Spectrum allocations discussed at World Radiocommunication Conferences (WRD)**

- WMO provides and coordinates input for Earth Observations
- Other fora to coordinate responses:
 - Committee on Radio Frequencies (CORF), USA
 - European Scientists on Spectrum for Earth Observation (ESSEO), Europe



March ~ **The Guardian**

5G signal could jam satellites that help with weather forecasting

New mobile system to be launched this year 'will put lives at risk'



Mixing 5G and weather forecasting could skew forecasts, warn experts

Global 5G wireless networks threaten weather forecasts

nature
International journal of science

16 APRIL 2019

OPINION CONTRIBUTOR — 07/01/19 06:30 PM EDT
BY CONTRIBUTORS ARE THEIR OWN

PHYSICS TODAY

NOAA warns of threat to weather forecasts from 5G spectrum

Why we need to protect weather prediction from radio frequency interference



THE Sun
NEWS WEBSITE OF THE YEAR

FOGGY OUTLOOK UK weather forecasts could get even WORSE as 5G 'risks' confusing satellite networks' accuracy of forecasts could drop

- Recent posts
- Why we need to protect weather prediction from radio frequency interference
 - ECMWF over the Moon

ITU News MAGAZINE

Monitoring our changing planet

Critical spectrum for Earth observation from space

Le Point Tech & Net

Les prévisions météo menacées par la 5G ?

The importance of sensing for WRC-19



"For these numerical weather prediction applications, radio-frequency spectrum is crucial for satellite weather observations as well as communications."

Stephen English
Head of the Earth System Assimilation Section, European Centre for Medium-Range Weather Forecasts (ECMWF)



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The history that led to Meteosat Third Generation (MTG)

Europe

Rest of the World

1957 1960 1970 1980 1990 2000 2010 2020 2030



1977
Meteosat-1
MVIRI = 3
channel
imager
(research)

1989
Meteosat-4
MVIRI = 3
channel
imager
(operational)

2005
MSG-1
SEVIRI
=12 channel
imager

2023-5
MTG-I1
FCI
LI
MTG-S1
IRS
Sentinel-4

1975
USA
GOES-1
VISSR

1994
USA
GOES-8
IMAGER
SOUNDER

2006
Japan
Himawari-6
IMAGER

2014
Japan
Himawari-8
AHI

2016
USA
GOES-16
ABI
GLM

India and South Korea have also developed similar programmes e.g. INSAT-3D 2013, GEOKOMPSAT 2018

2016
China
FY-4A
GIIRS
LMI
AGRI

Meteosat Third Generation (MTG)

Pair of satellites in geostationary orbit:

- **MTG-I – “Imager satellite”**: 1st launched Dec 2022
- **MTG-S – “Sounder satellite”**: 1st launched July 2025

Updated counterparts to Meteosat Second Generation

SEVIRI → FCI 16 channel visible/infrared imager

European rapid scan 2.5 minutes, full disk 10 minutes

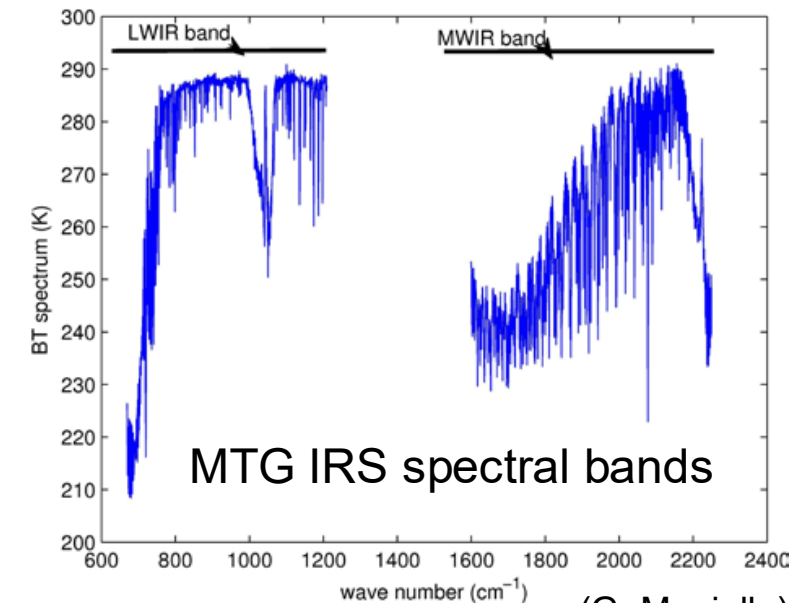
New instruments

LI: Lightning imager (777.4nm)

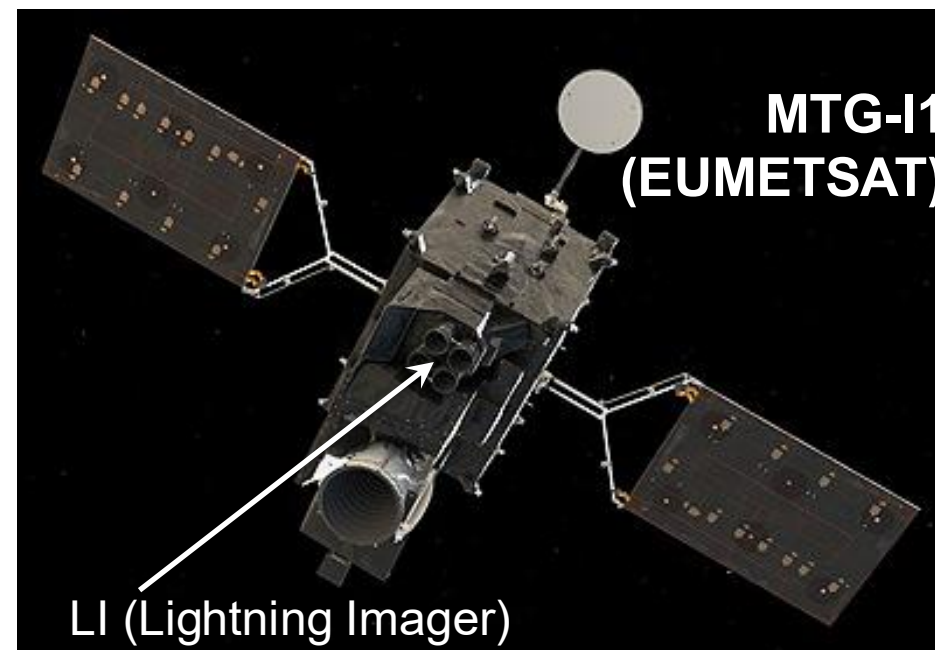
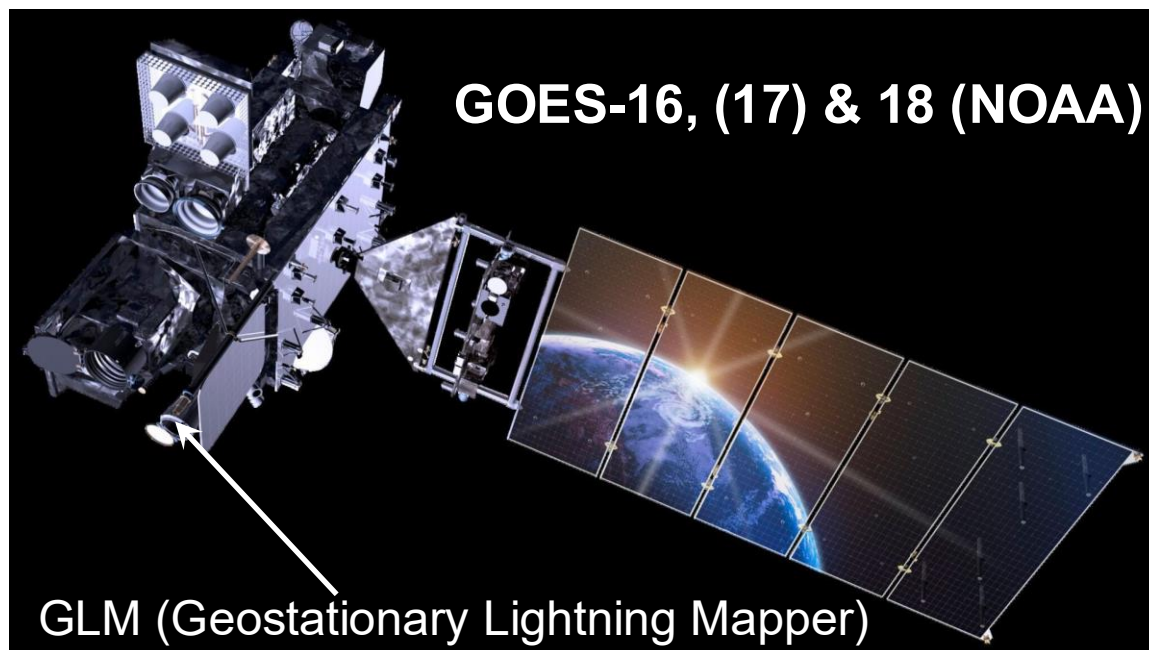
IRS: IR interferometer

IR spectra over Europe every 30 min; elsewhere ½ - 6 hourly (variable)

Sentinel-4: Ultraviolet, Visible and Near IR sounder



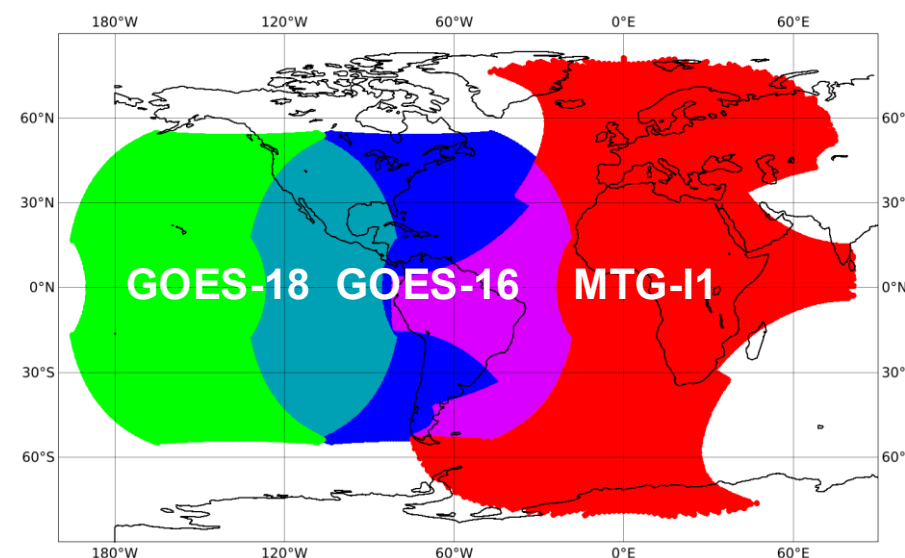
Lightning observations from geostationary satellites



Both instruments measure the optical signature of lightning pulses in the 777.4-nm oxygen line (in which emission from lightning is maximum).

Single camera on GOES; 4 slightly overlapping cameras on MTG.

Continuous monitoring, 8-km / 4.5-km resolution (nadir).



The history that led to European Polar System (EPS) – Second Generation (SG)

Europe

US research satellites in 1960s and 1970s led to what we have now

We are approaching a new leap forward (EPS-SG, FY-5, Post-JPSS)

2007
Metop
MHS
IASI
ASCAT
GRAS
GOME-2

HIRS/4
AMSU-A
AVHRR

2025/6
Metop-SG
MWS
MWI
ICI
IASI-NG
SCA
RO
MetImage
3MI
Sentinel-5

1957 1960 1970 1980 1990 2000 2010 2020 2030



Rest of the World

1964
NIMBUS-1
HRIR
APT
ACVS

1968
NIMBUS-B
SIRS

1972
NIMBUS-5
ITPR
NEMS
ESMR

NOAA-2
VTPR
VHRR

1979
TOVS
HIRS/2
MSU
AVHRR

SSU

FOR MEDIUM-RANGE WEATHER FORECASTS

1998
ATOVS
HIRS/4
AMSU-A
AVHRR

AMSU-B

2003
A-train
AIRS
MODIS
MLS
CloudSat
Calipso

2011
JPSS
(S-NPP)
ATMS
CrIS
VIIRS
OMPS

2014
China
FY3-C
MWHS-2
MWTS-2
MWRI
IRAS
GNOS

2017
Russia
Meteor-M N2
MTVZA-GY
IKFS

EPS Second Generation

Pair of satellites in 9:30 polar orbit:

- **Metop-SG-A** : 1st launched Aug 2025
- **Metop-SG B** : 1st launch 2026



Updated counterparts to Metop 1st generation

AMSU-A/MHS → MWS

AVHRR → MetImage

IASI → IASI-NG

ASCAT → SCA

GOME-2 → Sentinel-5 UVNS

GRAS → RO (on both satellites)

Microwave sounder

Vis/IR imager

Hyperspectral Infrared

Scatterometer

UV/VIS spectrometer

Radio occultation

New capability

3MI: based on POLDER and PARASOL

MWI: based on SSM/I

ICI: completely new! Sub-mm imager for cloud ice

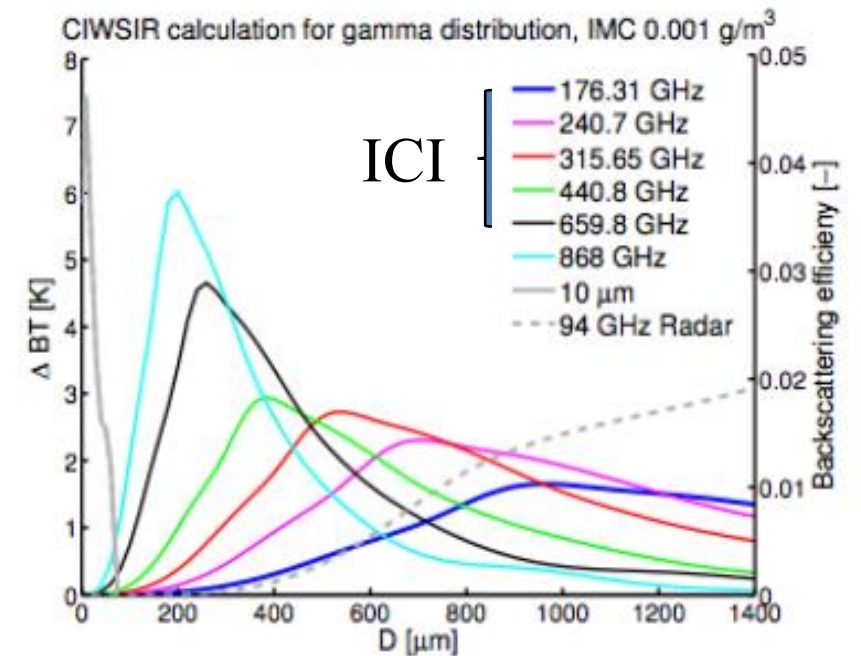
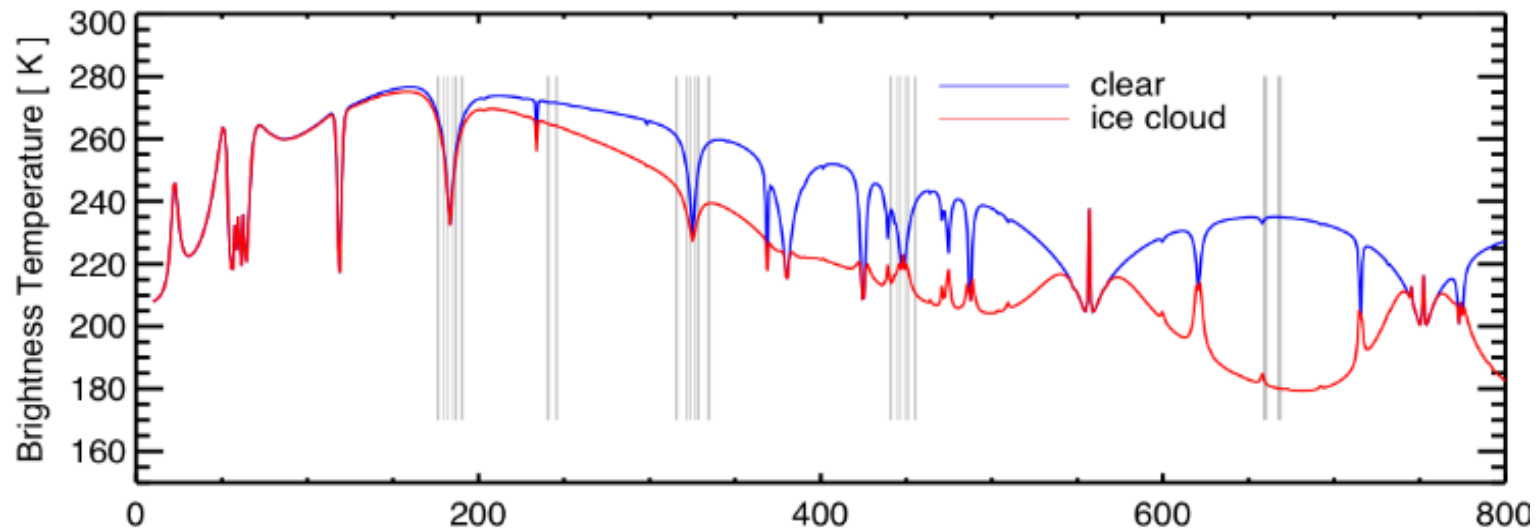
VIS/NIR/SWIR imager

Microwave imager

Ice-cloud imager

EPS-SG: Ice Cloud Imager - ICI

- Conically scanning passive MW imager with completely new capabilities
- Channels at 183 – 664 GHz
- Information on ice clouds, incl some on particle size, shape, orientation



Copernicus Missions: Sentinel 1-6 and Copernicus Expansion Missions

Operational missions, complementing meteorological missions and addressing the needs of the Copernicus programme



Copernicus Missions: Sentinel 1-6

Operational missions, complementing meteorological missions and addressing the needs of the Copernicus programme

Sentinel-1:

- 4-80m resolution **C-band SAR**
- Polar-orbiting, all-weather, **day-and-night radar imaging for land and ocean services**
- Wave spectrum assimilation under development at ECMWF
- Sentinel-1d launched Nov 2025



Sentinel-2:

- 10-60m resolution **NIR/VIS/UV imager**, 13 bands 443-2190nm
- Polar-orbiting; continuity of Landsat, SPOT for **land applications**
- Sentinel-2c launched Sept 2024; 2d planned 2028



Sentinel-3:

- Multi-instrument: altimeter (SRAL), IR imager (SLSTR), visible imager (OLCI), MW radiometer (MWR) and others
- Polar-orbiting; **ocean and land services**
- Sentinel-3c planned 2026, 3d 2028

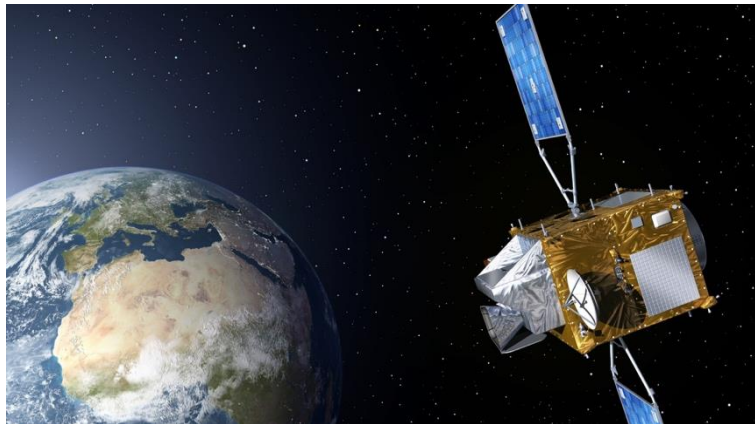


Copernicus Missions: Sentinel 1-6

Operational missions, complementing meteorological missions and addressing the needs of the Copernicus programme

Sentinel-4:

- 8km resolution **NIR/VIS/UV grating spectrometer**
- **Atmospheric chemistry**
- Geostationary orbit on MTG-S1
- Launched 2025



Sentinel-5/Sentinel-5p:

- 7km resolution **NIR/VIS/UV grating spectrometer**
- **Atmospheric chemistry**
- Polar-orbiting on Metop-SG-A
- Sentinel-5 launched 2025



Sentinel-6:

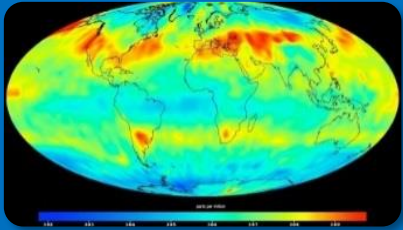
- **Radar altimeter** 5.4 and 13.58 GHz
- Sea-surface height, for **operational oceanography** and climate studies
- Polar orbiting
- Sentinel-6b launched 2025, 6c 2030



Copernicus Expansion Missions

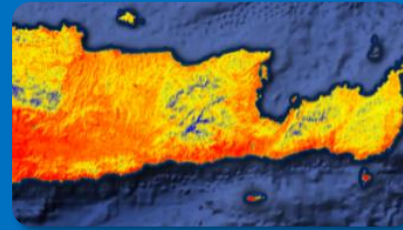


CO2M - Anthropogenic CO₂ Monitoring



Causes of
Climate Change

LSTM – Land Surface Temperature Mission



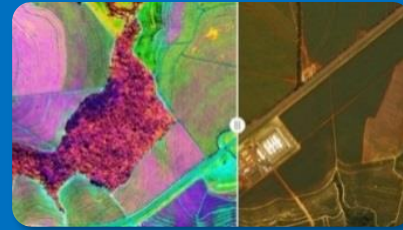
Agriculture & Urban
Management

CRISTAL – Polar Ice & Snow Topography



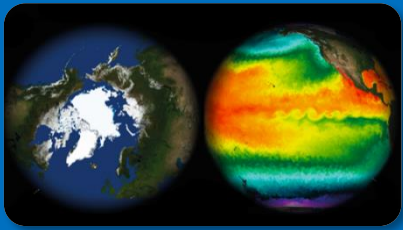
Effects of
Climate Change

CHIME – Hyperspectral Imaging Mission



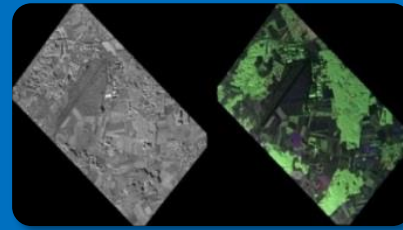
Food Security, Soil,
Minerals, Biodiversity

CIMR – Passive Microwave Radiometer



Sea Surface Temp.
& Ice Concentration

ROSE-L – L-band SAR Mission



Vegetation & Ground
Motion & Moisture

First launches planned 2026 - 2030



The global satellite observing system and its future evolution

1. The WMO Integrated Global Observing System (WIGOS)
2. New operational missions:
 - EPS-SG, MTG, Sentinels, Copernicus expansion missions
3. Guiding the evolution of the observing system with data assimilation
4. Future trends:
 - Small satellites, commercial programmes, etc

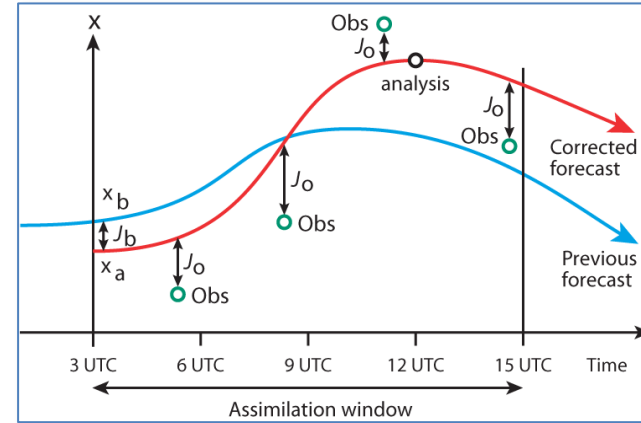
Factors that affect the evolution of the observing system

- Strengths/weaknesses of the current global observing system



Can NWP help guide the evolution?

- Evolution of applications



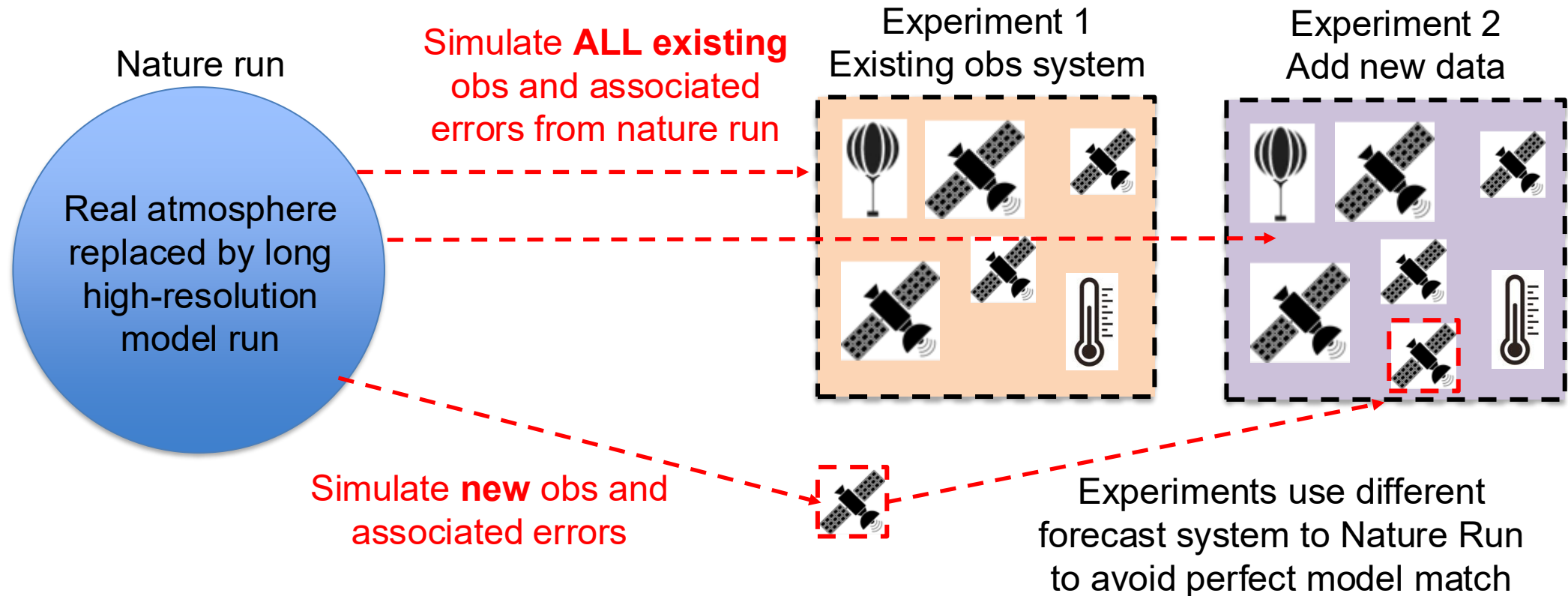
- National and financial interests



- Technological evolution and interests



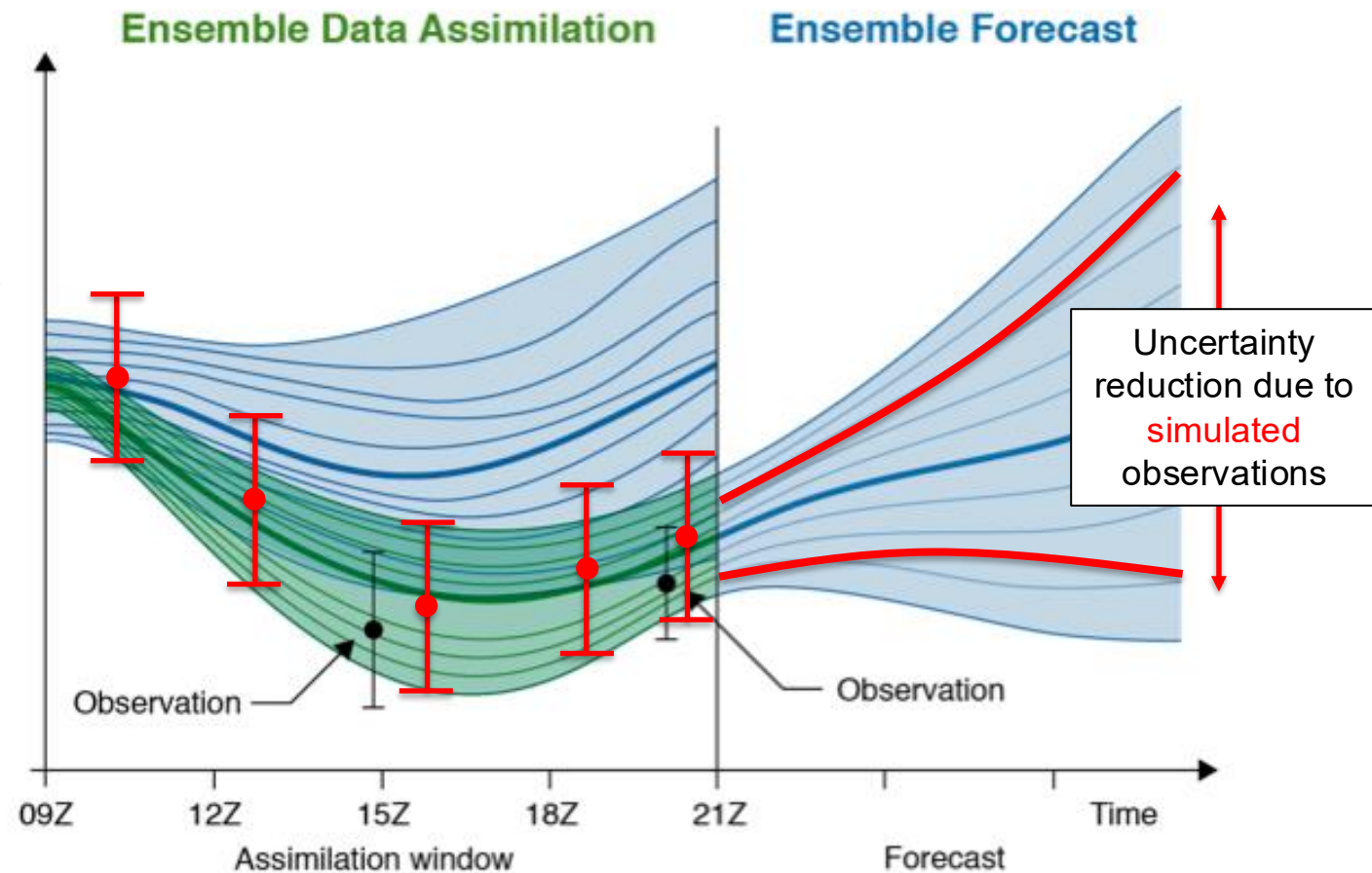
Estimating the impact of potential future observations: Observing System Simulation Experiments (OSSEs)



- Experiments directly verified against the nature run “truth”
- Analysis/forecast error computed over experiment period

Estimating the impact of potential future observations: Ensemble of data assimilations (EDA)

- Ensemble of data assimilations (EDA):
 - Finite number of independent cycling assimilation systems
 - Observations, forecast model and SSTs perturbed to generate different inputs for each member
 - Can use **real** and **added simulated** observations
- Reduction in EDA spread from adding observations → reduced forecast/analysis uncertainties
- Assumes errors of the simulated observations are realistic
- Focus on spread changes at 12-hour forecast range

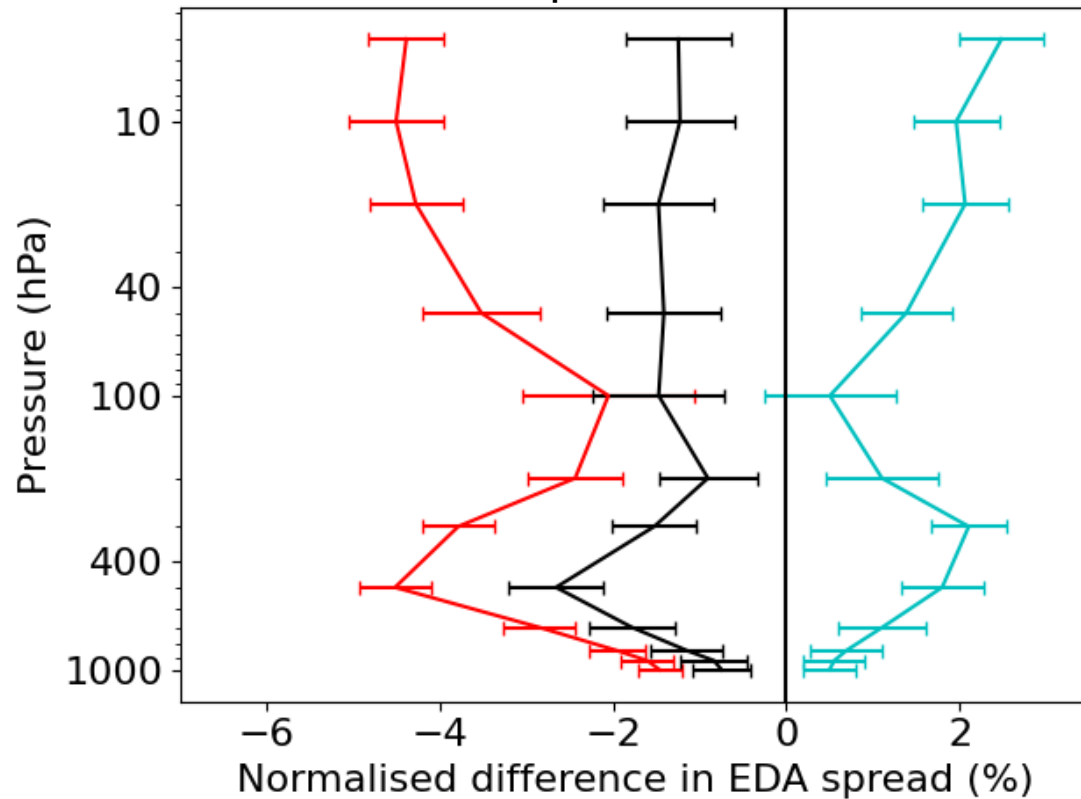


EDA spread = standard deviation of ensemble members around the ensemble mean

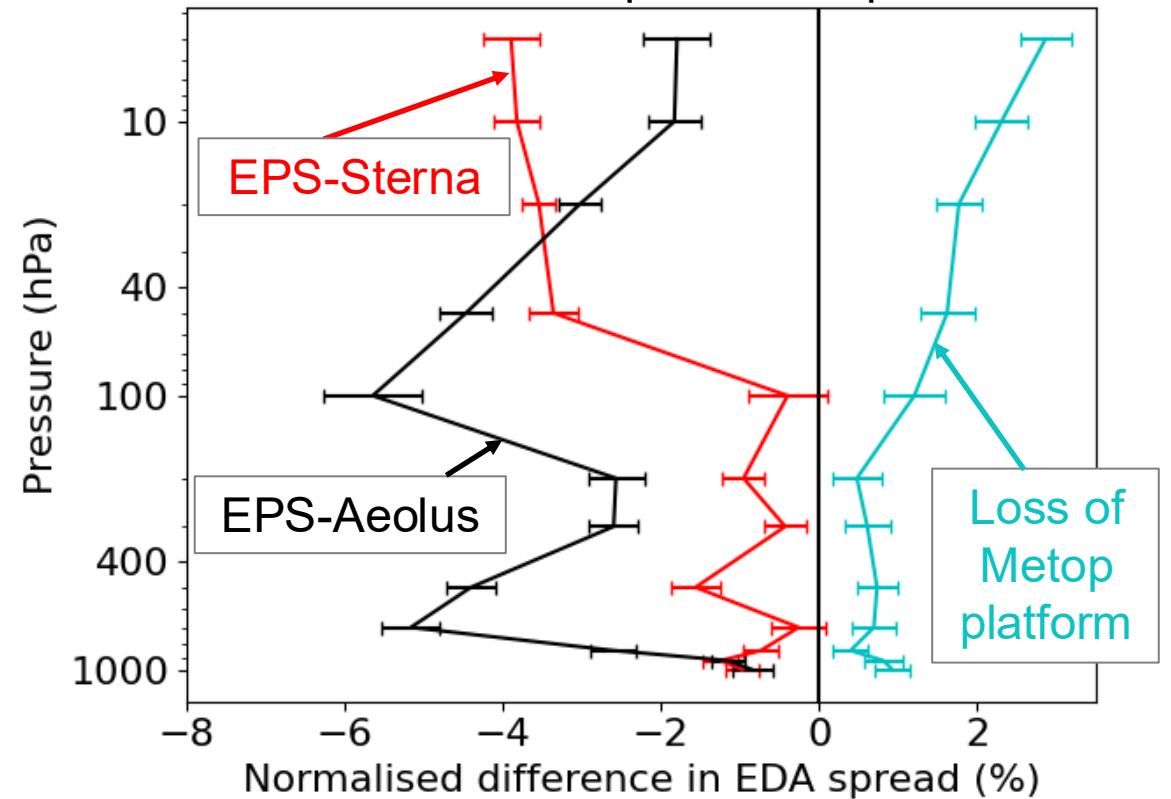
Example: EDA impact evaluations for EPS-Sterna and EPS-Aeolus

EPS-Sterna: 6 small satellites with MW sounders; EPS-Aeolus: Follow on to Aeolus Doppler Wind Lidar

Geopotential, NH



U wind component, Tropics



- EPS-Aeolus
- EPS-Sterna
- Metop-C denial

8-28 July 2019



The global satellite observing system and its future evolution

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Satellite sizes

1U 10x10x10 cm³ Cubesat 1.3 kg
e.g. TROPICS

3U 3 x 10x10x10 cm³ Cubesat 4 kg
e.g. RainCube

6U 6 x 10x10x10 cm³ Cubesat 12 kg
e.g. ESA's AWS, Quicksounder

Small satellite ~1x1x1m³ 120 kg
e.g. Metop, ENVISAT, JPSS

Large satellite 17.6x6.5x5.2m³ 800 kg
e.g. Metop, ENVISAT, JPSS

The ISS 420,000 kg
= 500 Metop satellites!



Pictures indicate size not weight of these satellites!

Examples of Earth Observation from small satellites/cubesats

TROPICS (NASA):

- Constellation of low-inclination cubesats (+ sun-synchronous pathfinder)
- Passive MW sounders
- Launched 2021 & 2023



Arctic Weather Satellite (ESA):

- Small satellite in polar orbit
- Size of washing machine
- Passive MW sounder
- Launched 2024



Arctic Weather Satellite (AWS)

ESA mission with EUMETSAT support

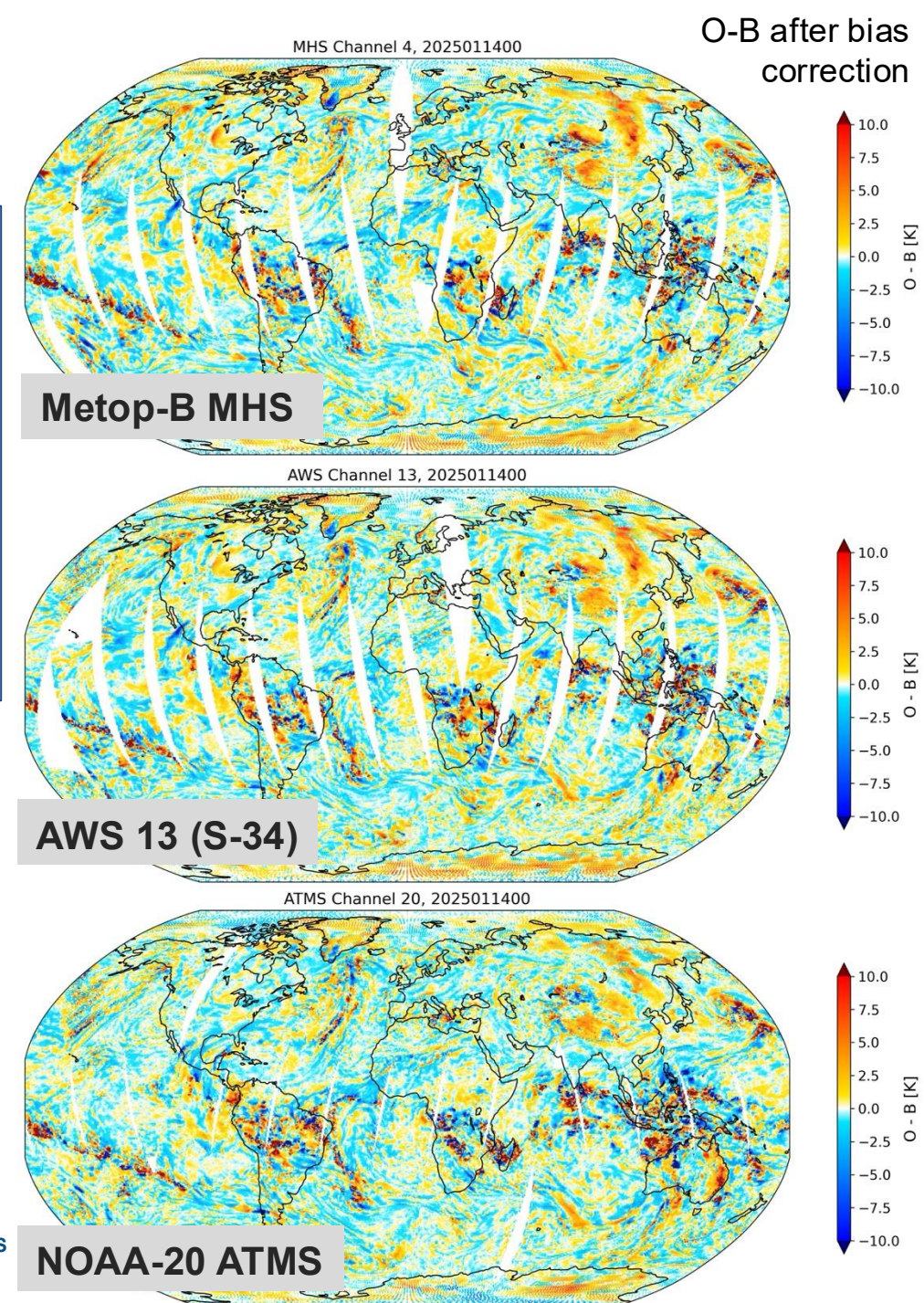
- Following 'new space' approach:
 - Small satellite
 - 3 years from signing contract to completion of satellite
 - Launched with a ride-share
- First MW sounder to use 'sub-mm' wavelengths (>300 GHz)
 - much more sensitivity to ice clouds than we've had before



(David
Duncan)

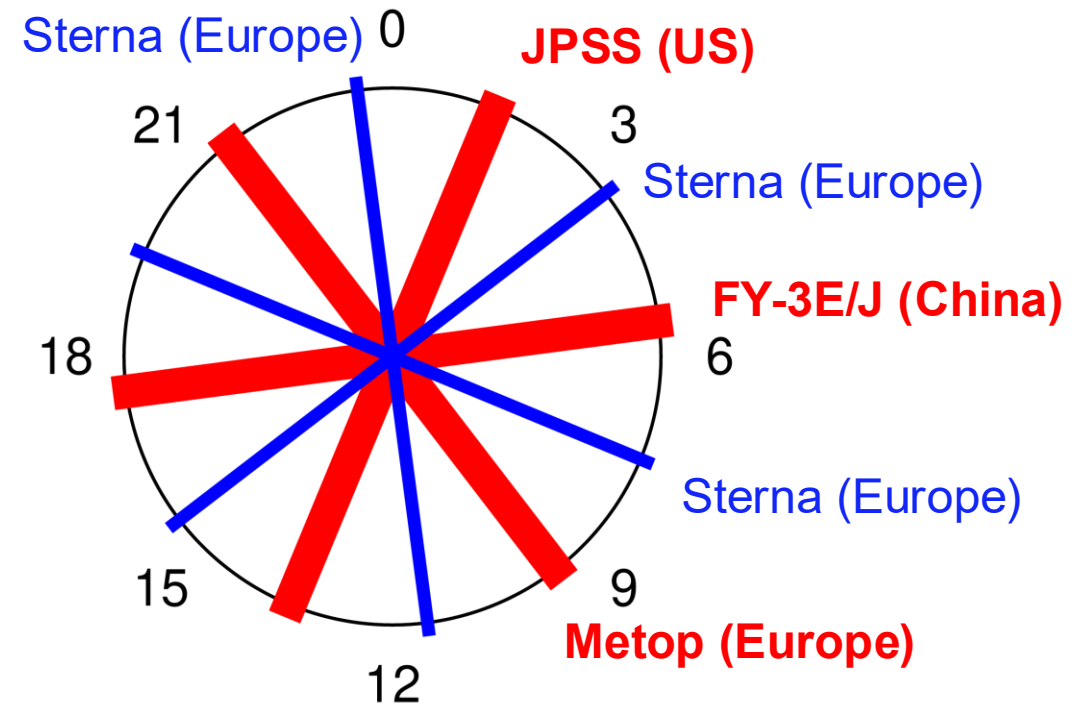


EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS



EPS-Sterna

- 6 small satellites with MW sounder in 3 orbital planes
 - Based on Arctic Weather Satellite
 - Design life for each satellite: 5 years
 - 20 satellites in total
- Total mission lifetime: 13 years
- Planned launch: 2029
- To complement the current 3-orbit CGMS back-bone

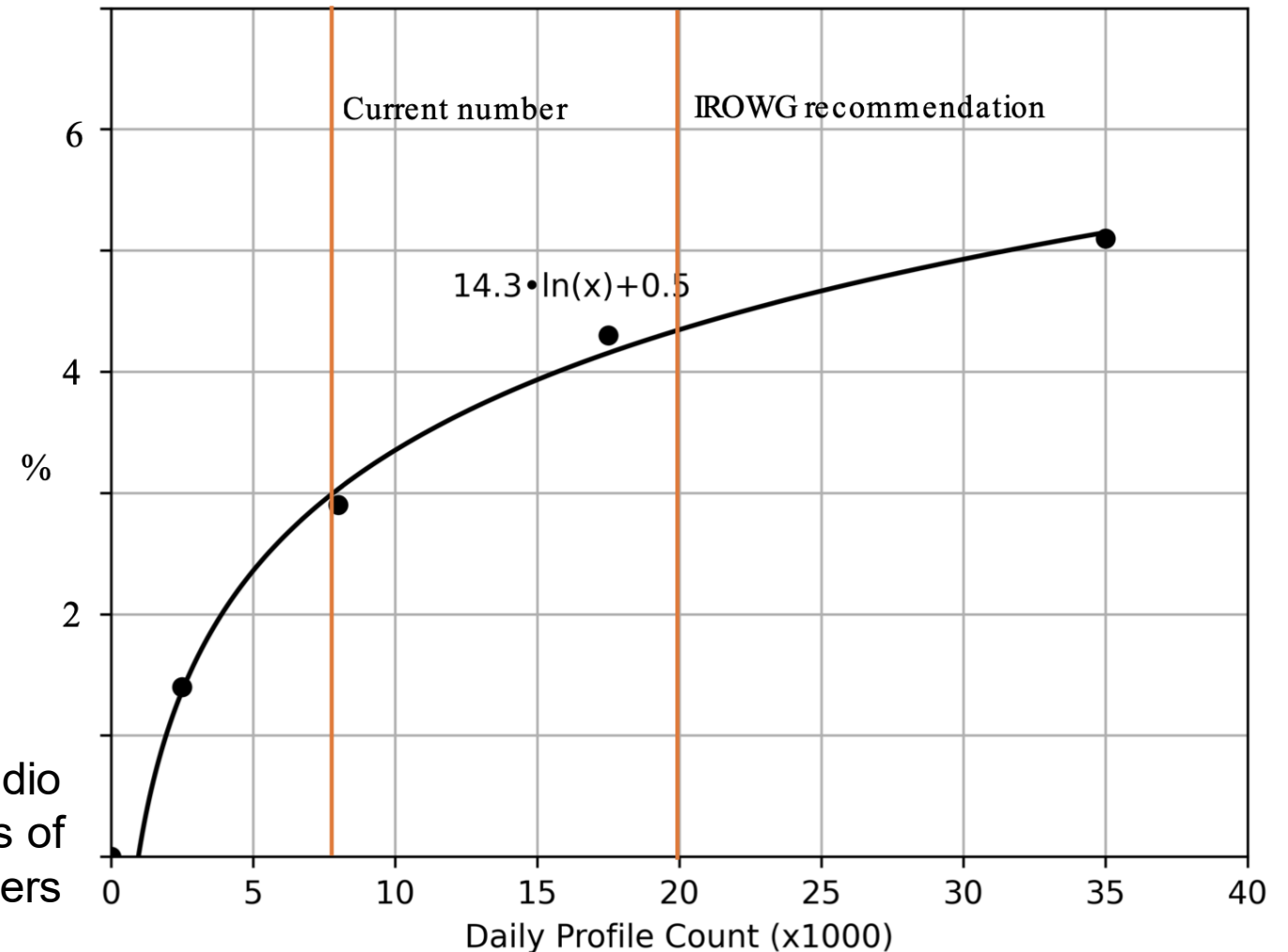


The advent of commercial data: radio occultation example

- In recent years, commercial data providers have emerged, e.g., for radio occultation measurements
- **How does commercial data fit with established WMO data sharing principles?**
 - Practice established for radio occultation:
 - EUMETSAT & NOAA purchase data with a global license to share

Impact achieved by pooling radio occultation observations from lots of publicly-funded and private providers

Impact vs Number of RO profiles per day
Reduction in STDV temperature error vs radiosondes at 100 hPa
ECMWF ROMEX data (Lonitz, 2024)



Other future programmes

- **USA:** in planning: future polar and geostationary satellites for mid-2030s (post-JPSS: disaggregated system rather than large satellite; potentially: GeoXO with hyperspectral IR)
- **China:** LEO FY-5 late 2020s: likely to be mix of core satellite(s) plus free-flyers potentially making a constellation
- **Japan:** Conical MW imager AMSR3 launched 2025; Himawari follow-on, with hyperspectral IR sounder in planning
- **Commercial:** More RO; MW sounder and radar constellations; hyperspectral MW sounder

Under consideration:

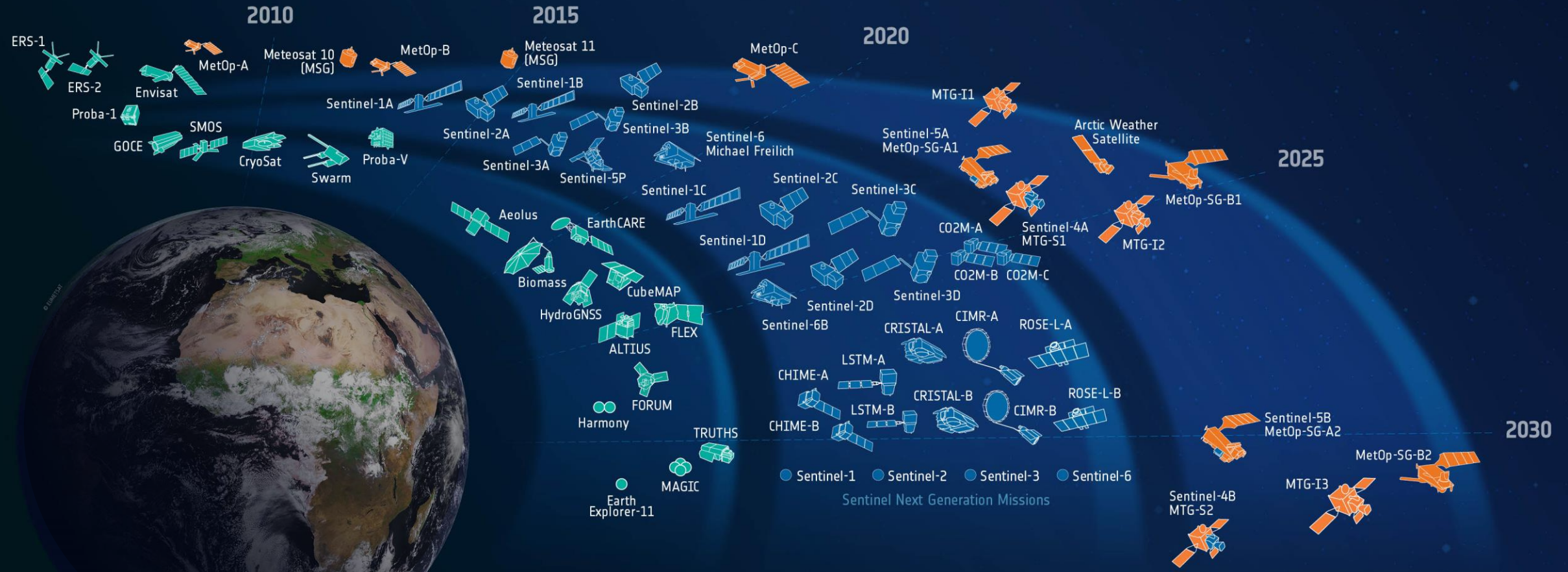
- **EPS-Aeolus** (or Aeolus-2) – Follow on Doppler Wind Lidar to Aeolus
- **ESA's Earth Explorer** programme (research missions)
 - EE 11 WIVERN (conically scanning doppler radar)
 - EE 12 candidates: CryoRad (low-frequency MW), ECO (radiation measurements), Hydroterra+ (C-band SAR in geo-orbit), Keystone (THz limb-sounding radiometer)

Summary: main points of lecture

- **The global satellite observing system is growing and diverse, benefitting from many contributors and observing methods**
 - Different observation types add different strengths – data assimilation combines them all!
- **WMO and CGMS play an important role to coordinate the evolution of WIGOS**
 - WMO's OSCAR is an invaluable tool to look up capabilities: <https://space.oscar.wmo.int>
 - NWP can help guide the evolution of WIGOS (requirements, Observing System Experiments, simulations of expected impact of future observations)
- **Exciting new satellite missions are coming online now:**
 - MTG, EPS-SG
 - Sentinels, Copernicus Expansion Missions
- **Current trends for Earth Observation from satellites:**
 - Small satellites, constellations, disaggregated systems
 - Commercial data providers

European Earth Observation Missions

We live in an incredible era for earth observation!!! Fantastic scope for research, innovation, impact.



Science

Copernicus

Meteorology

