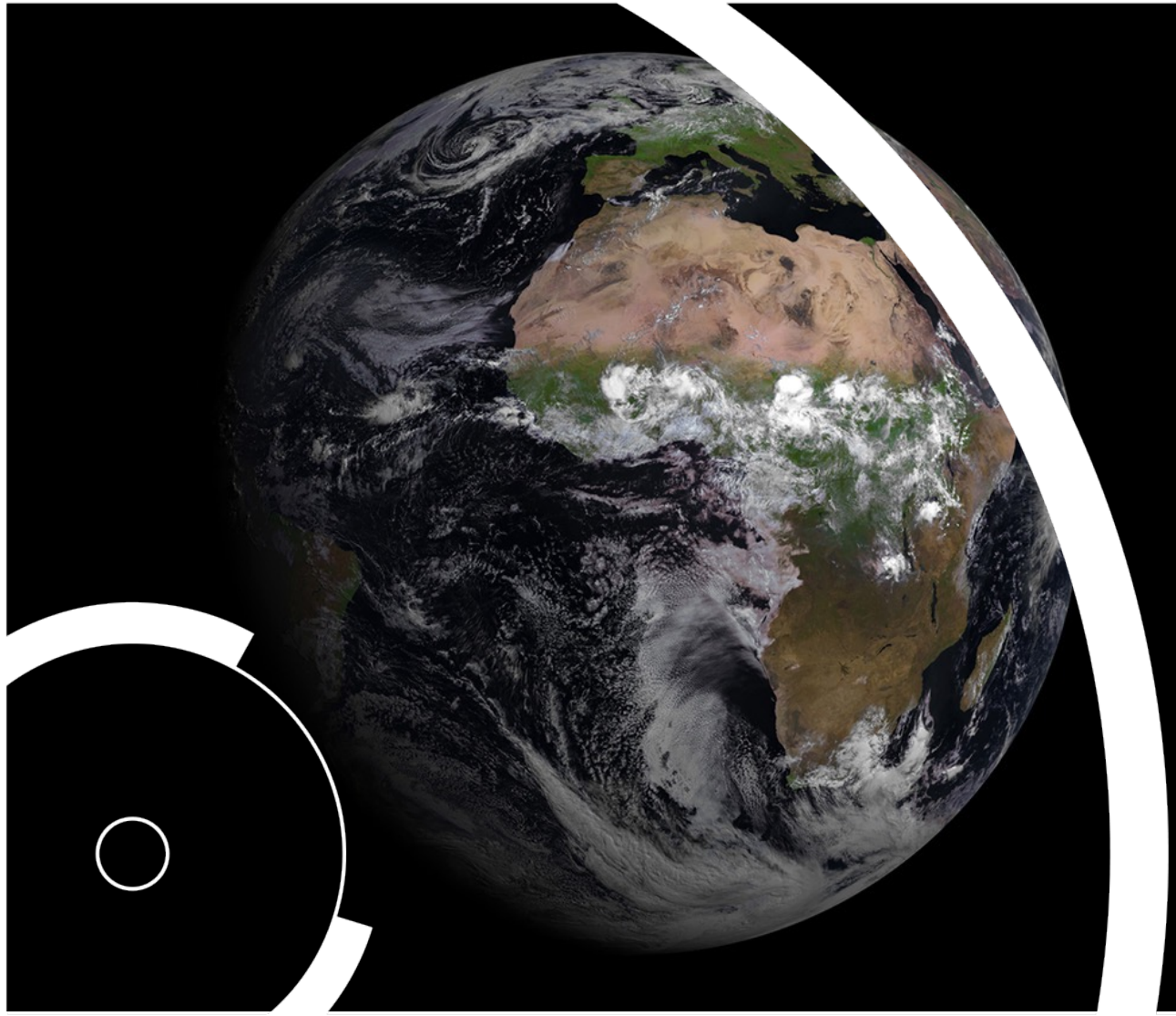


EUMETSAT plans/status for EPS-SG microwave missions, CIMR and EPS Sterna

Christophe Accadia, Jörg Ackermann, Sabatino Di Michele, Imke Krizek, Vinia Mattioli, Francesco De Angelis, Robin Ekelund, Vasileios Barlakas, Linda Corucci

IPWG Virtual Workshop on Precipitation Estimation from LEO Satellites: Retrieval and Applications 1-2 March 2023

Agenda

EPS-SG MW and sub-mm wave missions

MWS, MWI and ICI

CIMR at EUMETSAT

EUMETSAT activities in support of CIMR mission

EPS Sterna

Status and plans for the Sterna Constellation

EPS-SG: EUMETSAT Polar System - Second Generation

The EUMETSAT Polar System (EPS) in Low Earth Orbit (LEO) will be followed by a second generation system (EPS-SG). European contribution to the Joint Polar System set up with NOAA.

Same orbit as Metop (sun-synchronous, 832 km mean altitude, 09:30 local time of the descending node).

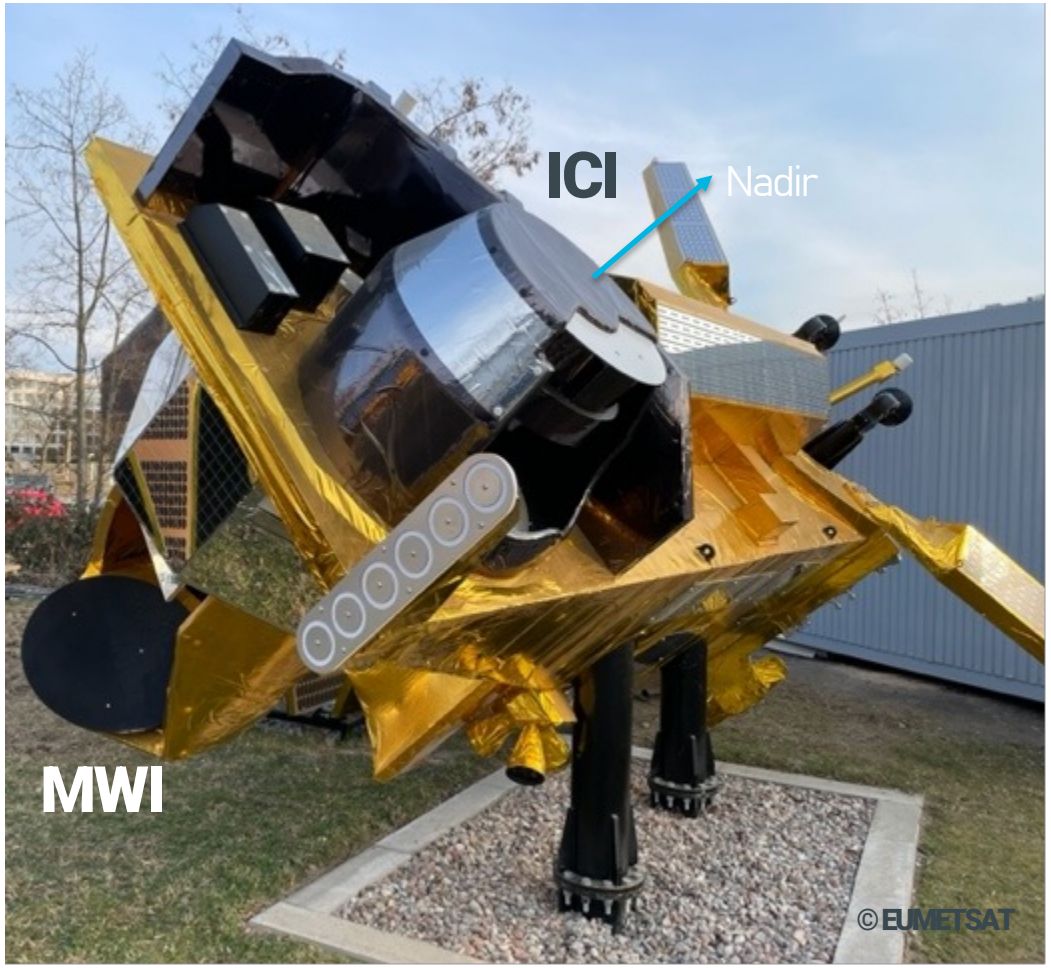
Payload distributed between the two parallel satellites Metop-SG A and B. Nominal lifetime of 7.5 years/spacecraft for an operational lifetime of the programme over 21 years.

Metop payload	Metop-SG payload	Metop-SG satellite
Infrared Atmospheric Sounding Interferometer (IASI)	Infrared Atmospheric Sounding Interferometer – New Generation (IASI-NG)	A
Advanced Very High Resolution Radiometer (AVHRR)	Visible-Infrared Imager (METimage)	A
Advanced Microwave Sounding Unit A (AMSU-A1/A2), Microwave Humidity Sounder (MHS)	Micro-Wave Sounder (MWS)	A
Global Ozone Monitoring Experiment 2 (GOME-2)	UV-VIS-NIR-SWIR Sounder (Sentinel-5)	A
Advanced Scatterometer (ASCAT)	Scatterometer (SCA)	B
Global Navigation Satellite System Receiver for Atmospheric Sounding (GRAS)	Radio Occultation (RO)	A and B
-	Micro-Wave Imager (MWI)	B
-	sub-mm wave Ice Cloud Imager (ICI)	B
-	Multi-viewing, -channel, -polarisation Imager (3MI)	A

EPS-SG MWS, MWI and ICI

Metop-SG A

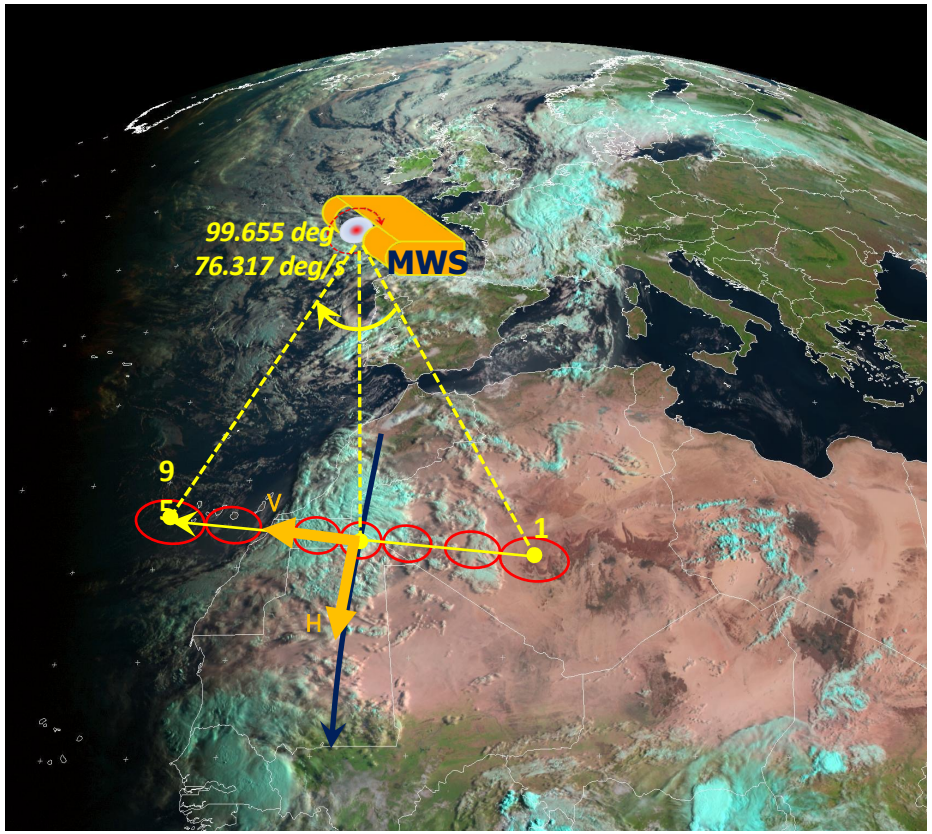
Metop-SG B



Microwave Sounding mission (MWS)

Test data version 2 now available at:

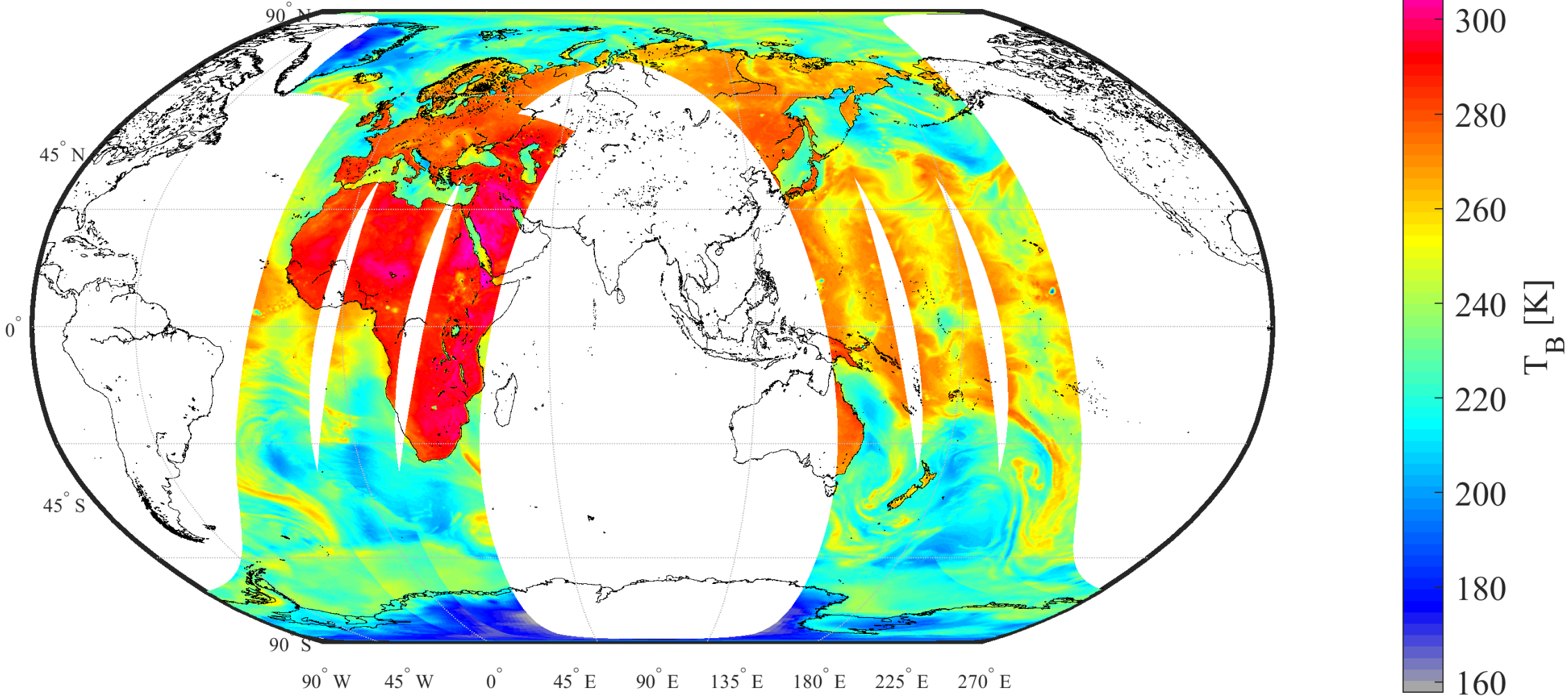
https://www.eumetsat.int/new-version-eps-sg-mws-test-data-released



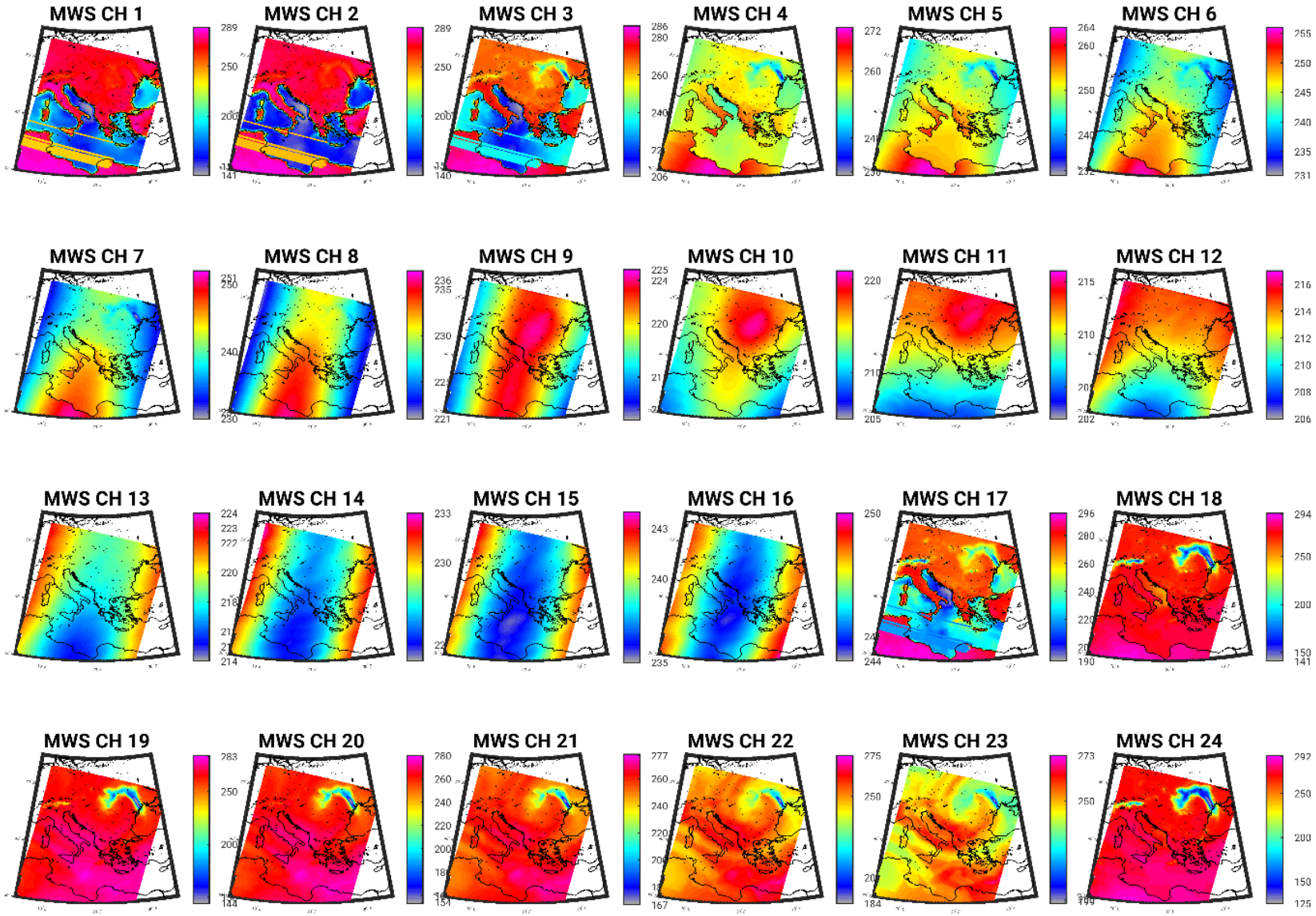
Channel	Centre Frequency (GHz)	Bandwidth per passband (MHz)	Footprint (km)
MWS-1	23.8	270	40
MWS -2	31.4	180	
MWS -3	50.3	180	
MWS -4	52.8	400	
MWS-5	53.246 ± 0.08	2x140	
MWS -6	53.596±0.115	2x170	
MWS-7	53.948 ± 0.081	2x142	
MWS -8	54.40	400	
MWS -9	54.94	400	20
MWS -10	55.50	330	
MWS -11	57.290344	330	
MWS-12	57.290344±0.217	2x78	
MWS-13	57.290344 ±0.3222±0.048	4x36	
MWS-14	57.290344±0.3222±0.022	4x16	
MWS-15	57.290344±0.3222±0.010	4x8	
MWS-16	57.290344±0.3222±0.0045	4x3	
MWS-17	89.0	4000	17
MWS-18	164-167	3000	
MWS-19	183.311±7.0	2x2000	
MWS-20	183.311±4.5	2x2000	
MWS-21	183.311±3.0	2x1000	
MWS-22	183.311±1.8	2x1000	
MWS-23	183.311±1.0	2x500	
MWS-24	229	2000	

MWS L1B Reference Test Data: L1B product

MWS Channel 17 (89 GHz) – Three consecutive orbits

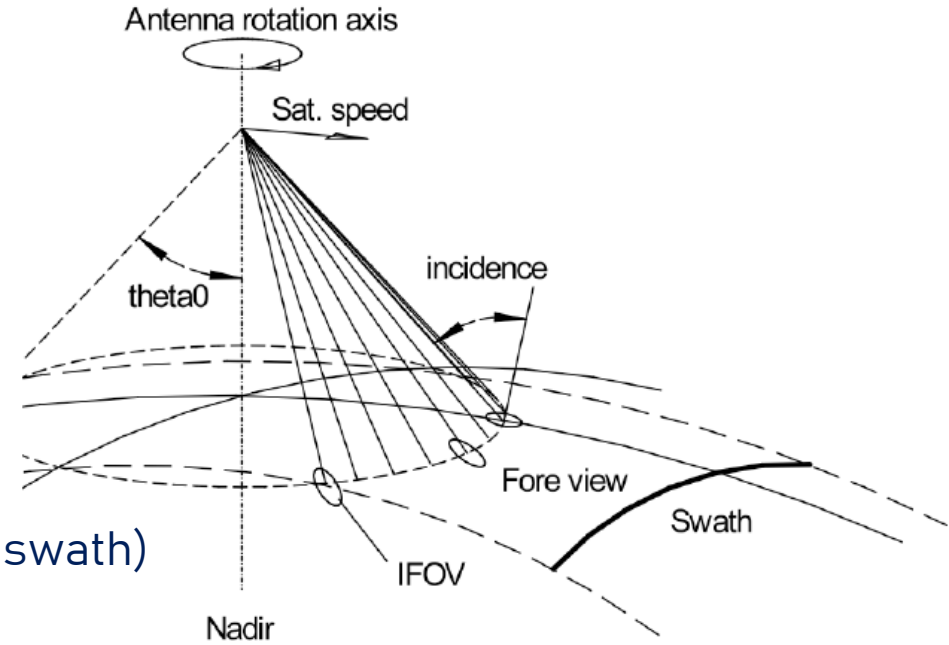


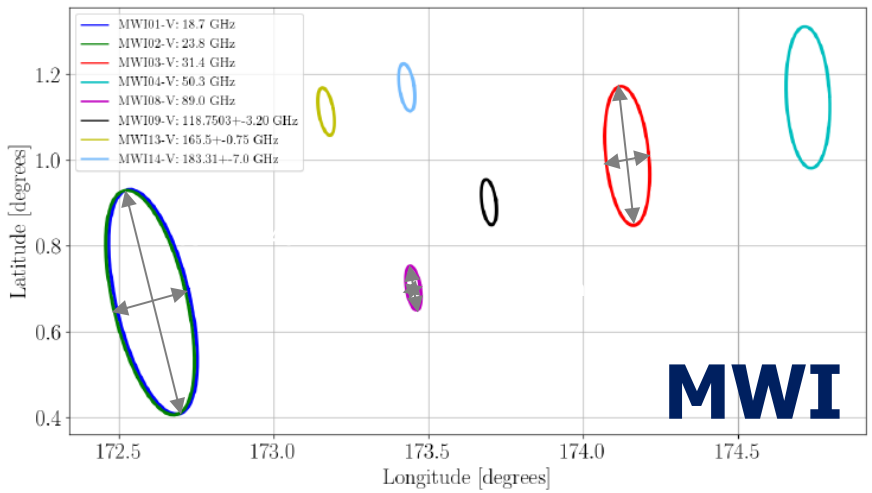
MWS L1B: TOA brightness temperatures

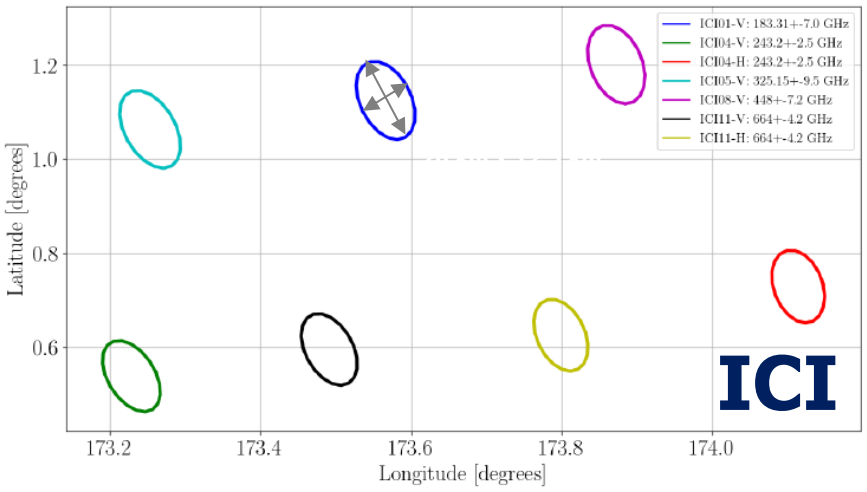


MW and Sub-mm Wave Imaging missions (MWI & ICI)

- ICI and MWI are conically scanning passive imagers
- Incidence angles within 53°±2°
- On the same platform, together with the scatterometer (SCA)
- Observations acquired ± 65° in azimuth in the fore view (about 1700 km swath)







MWI and ICI in a nutshell

MWI

Channel	Frequency (GHz)	Bandwidth (MHz)	Polarisation	Footprint (km)
MWI-1	18.7	200	V, H	50
MWI-2	23.8	400	V, H	
MWI-3	31.4	200	V, H	
MWI-4	50.3	400	V, H	
MWI-5	52.61	400	V, H	30
MWI-6	53.24	400	V, H	
MWI-7	53.75	400	V, H	
MWI-8	89.0	4000	V, H	
MWI-9	118.7503±3.2	2x500	V	
MWI-10	118.7503±2.1	2x400	V	
MWI-11	118.7503±1.4	2x400	V	
MWI-12	118.7503±1.2	2x400	V	
MWI-13	165.5±0.75	2x1350	V	10
MWI-14	183.31±7.0	2x2000	V	
MWI-15	183.31±6.1	2x1500	V	
MWI-16	183.31±4.9	2x1500	V	
MWI-17	183.31±3.4	2x1500	V	
MWI-18	183.31±2.0	2x1500	V	

ICI

Channel	Frequency (GHz)	Bandwidth (MHz)	Polarisation	Footprint (km)
ICI-1	183.31±7.0	2x2000	V	
ICI-2	183.31±3.4	2x1500	V	
ICI-3	183.31±2.0	2x1500	V	
ICI-4	243.2±2.5	2x3000	V, H	
ICI-5	325.15±9.5	2x3000	V	
ICI-6	325.15±3.5	2x2400	V	16
ICI-7	325.15±1.5	2x1600	V	
ICI-8	448±7.2	2x3000	V	
ICI-9	448±3.0	2x2000	V	
ICI-10	448±1.4	2x1200	V	
ICI-11	664±4.2	2x5000	V, H	

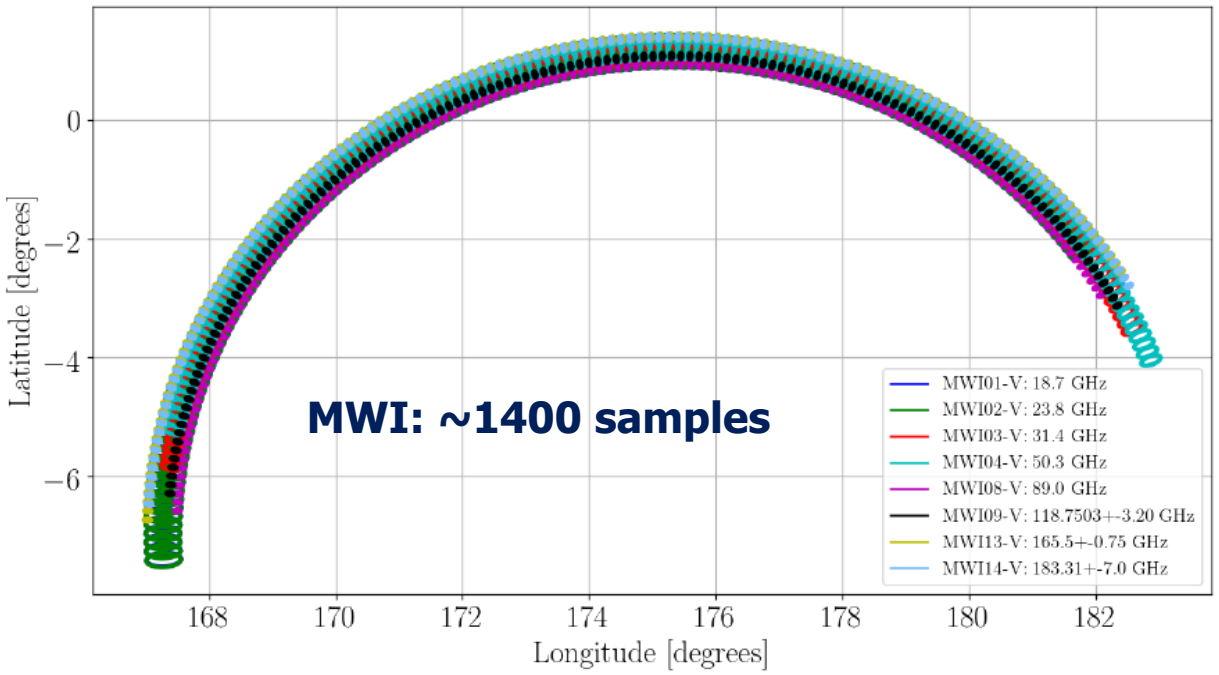
MWI and ICI sampling

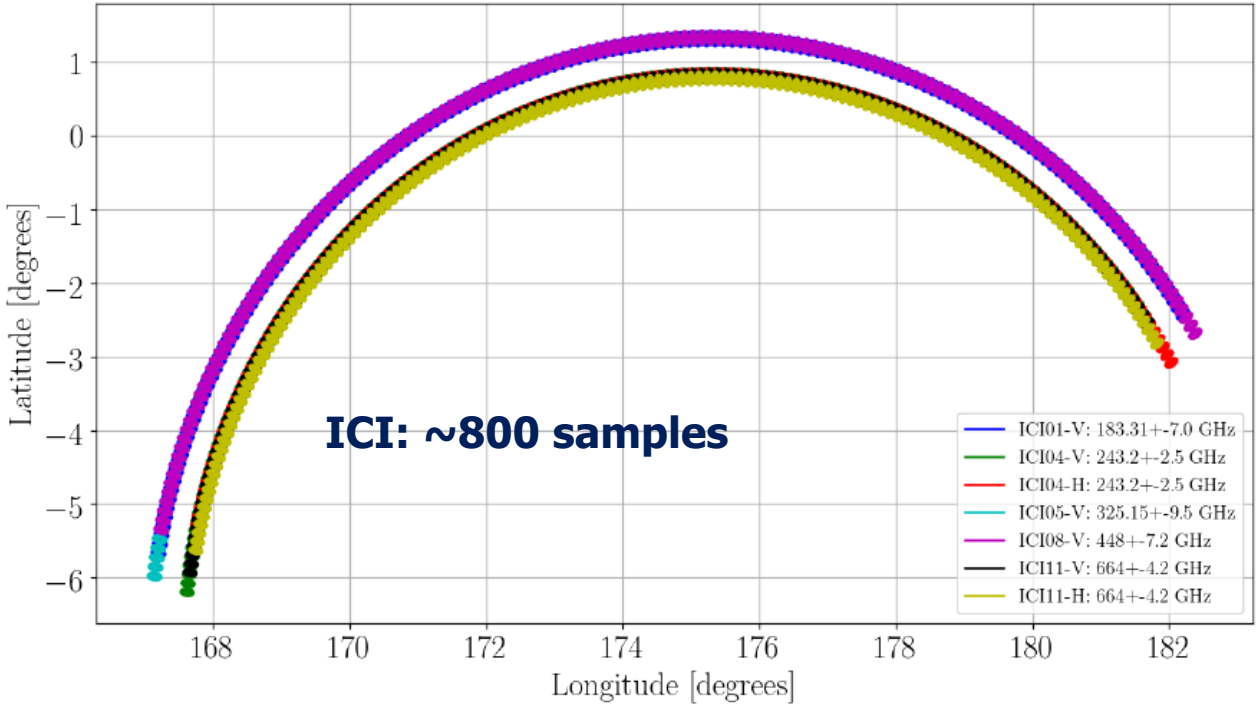
Innovative sampling of both imagers: new opportunities

For more details, test data version 2 now available at:

https://www.eumetsat.int/new-versions-microwave-imager-and-ice-cloud-imager-l1b-test-data-released-nov-2022

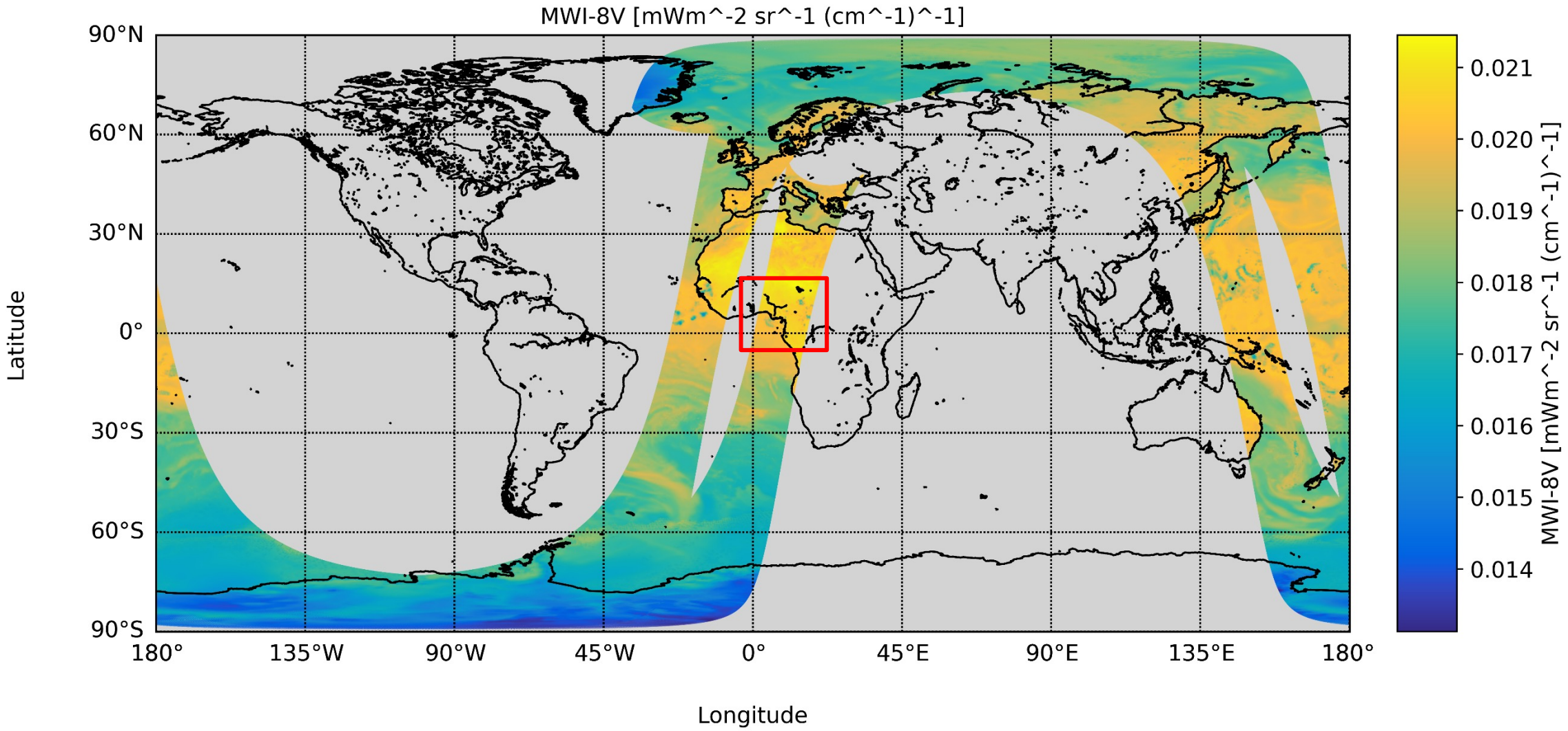
This is the pre-launch test dataset



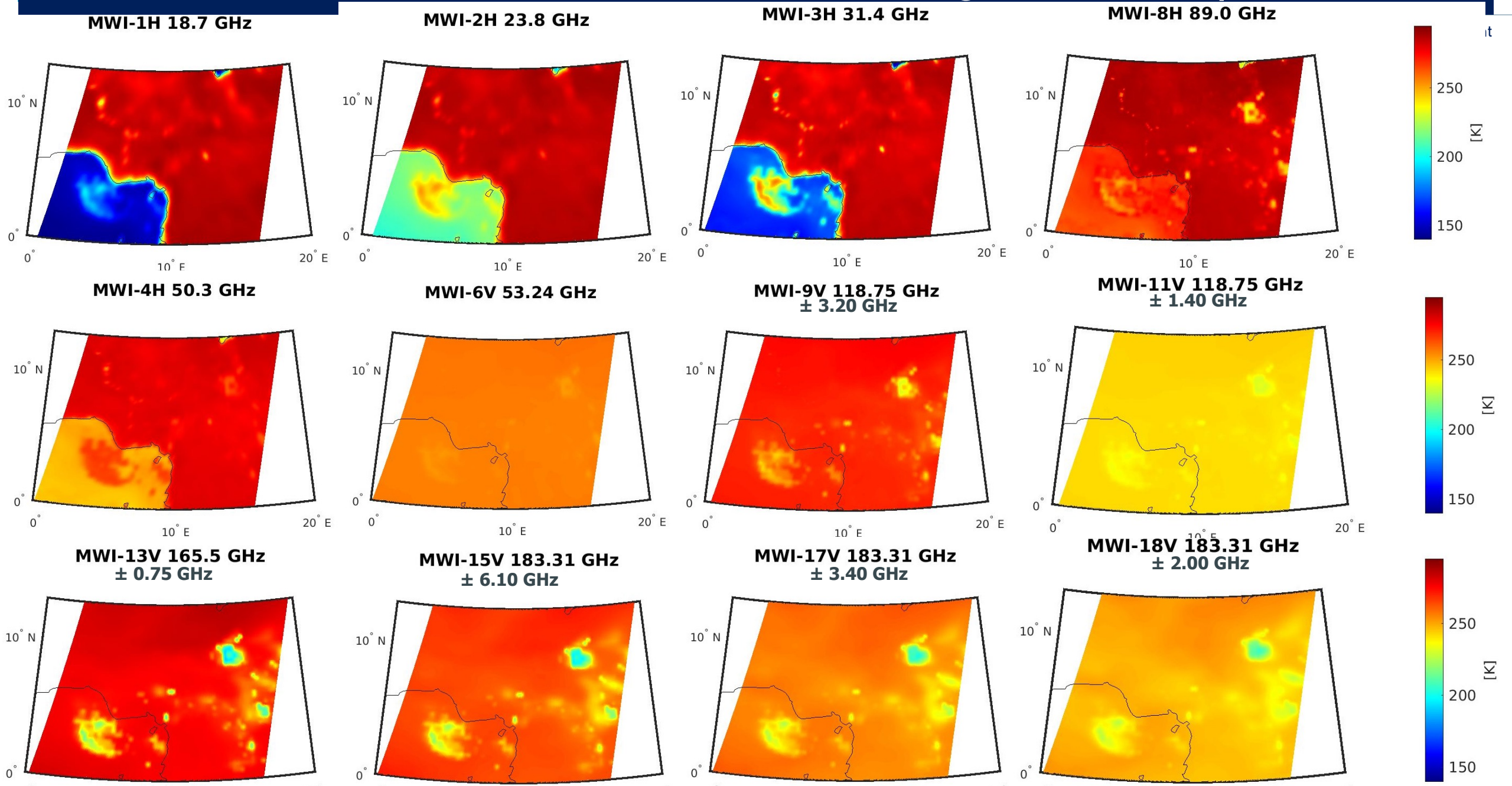


L1B TDP V2: MWI two summer consecutive orbits

MWI-8V

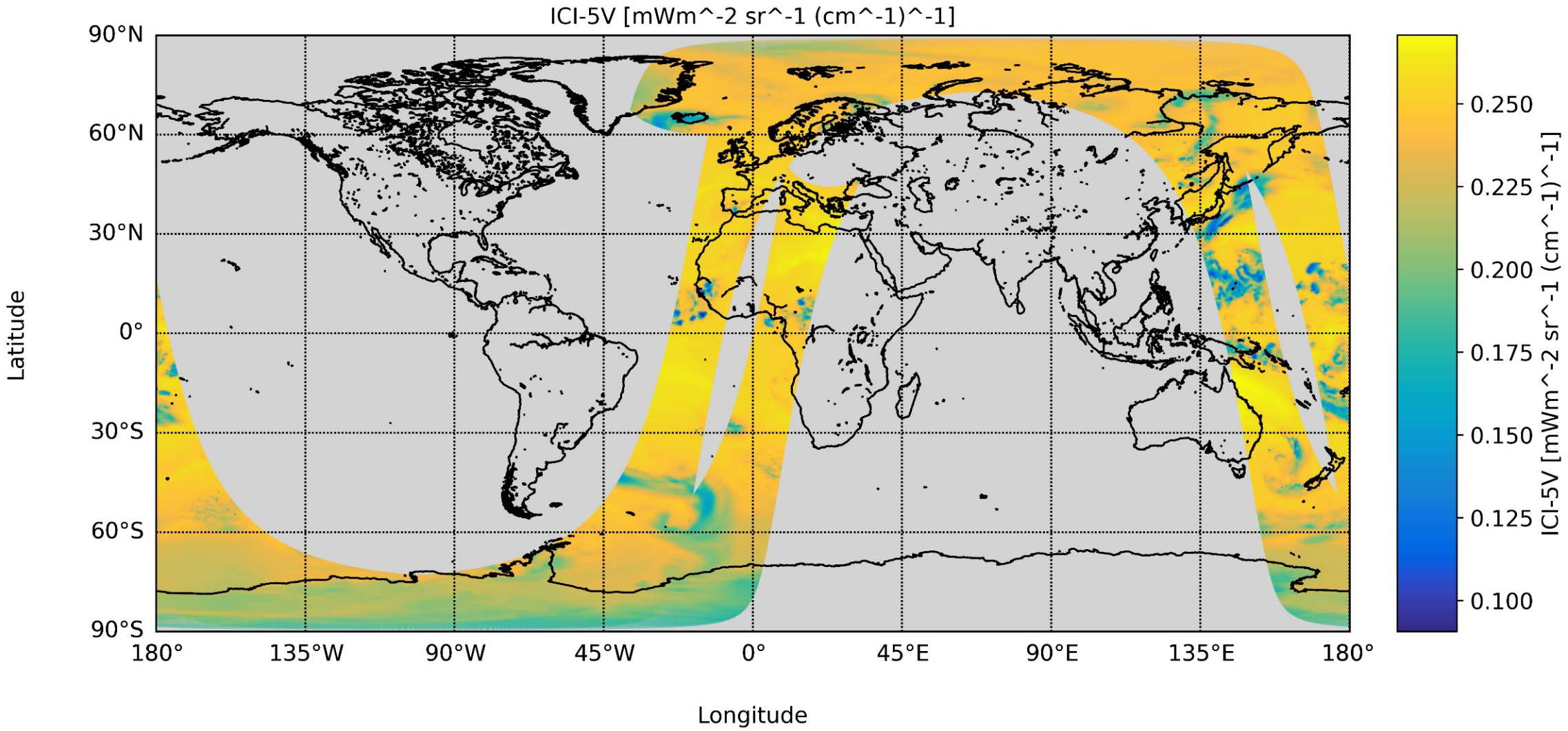


Overview of the MWI channels –TOA brightness temperatures

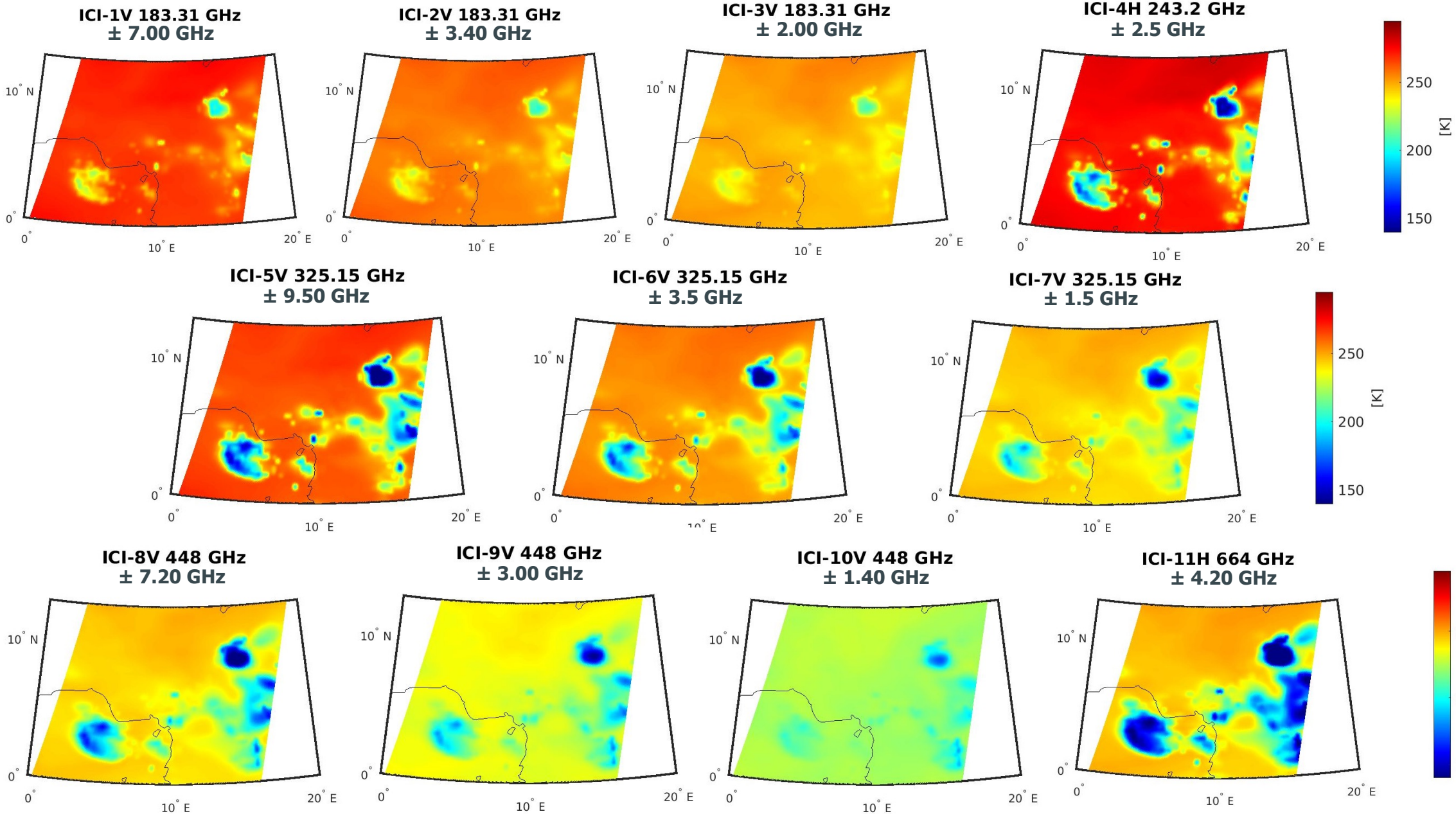


L1B TDP V2: ICI two summer consecutive orbits

ICI-5V (325.15 ± 9.5 GHz)



Overview of the ICI channels – TOA brightness temperatures



EPS-SG: Summary

- MWS will expand the MW sounding capabilities in the mid-morning orbit
- ICI provides an unprecedented set of measurements from 183.3 GHz up to 664 GHz, bridging a “spectral gap” between the microwaves and the far infrared. New possibilities!
- MWI (on the same platform with ICI) will continue and enhance important measurements of cloud and precipitation and support surface measurements.
- Synergy among missions, including EPS-SG SCA (and Copernicus CIMR in the long run).
- These missions will:
  - Provide continuation and enhancement of EUMETSAT service from polar orbit.
  - Expand by 20+ years the EUMETSAT contribution to climate data records.
  - Contribute to GPM constellation.

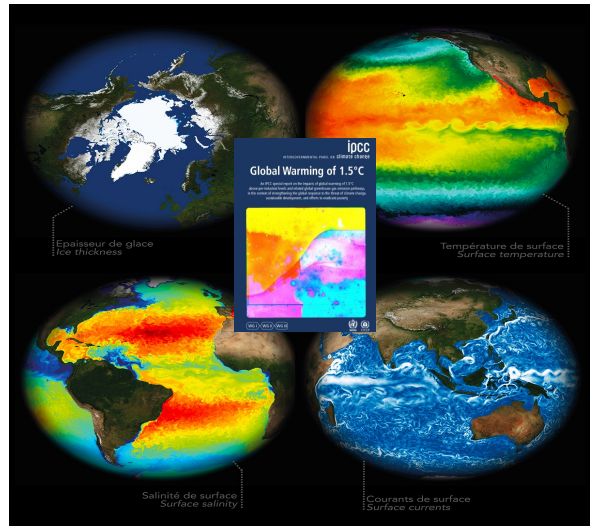
Copernicus Microwave Imager Radiometer (CIMR)

Copernicus Imaging Microwave Radiometer (CIMR)

- CIMR is a European Space Agency (ESA) High Priority Copernicus mission that responds directly to the *Integrated EU Arctic Policy*

- Conically scanning multi-frequency microwave radiometer in a coordinated flight with MetOp-SG(1B)

- About 95% global coverage every day, mean 6 hourly-revisit in Arctic Areas, dawn-dusk sun-synchronous orbit



MAIN REQUIREMENTS

Channels (GHz, Full Stokes):	**1.4**	**6.9**	**10.65**	**18.7**	**36.5**
Footprint (km):	**<60**	**≤15**	**≤15**	**≤5.5**	**<5**
NEΔT (K @150K):	**≤0.3**	**≤0.2**	**≤0.3**	**≤0.4**	**≤0.7**
Swath	**>1900 km**				

Atmosphere (CAMS) · Marine (CMEMS) · Land (CLMS) · Climate (C3S) · Emergency (EMS) · Security

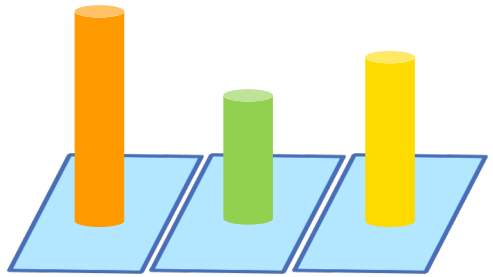
CIMR at EUMETSAT

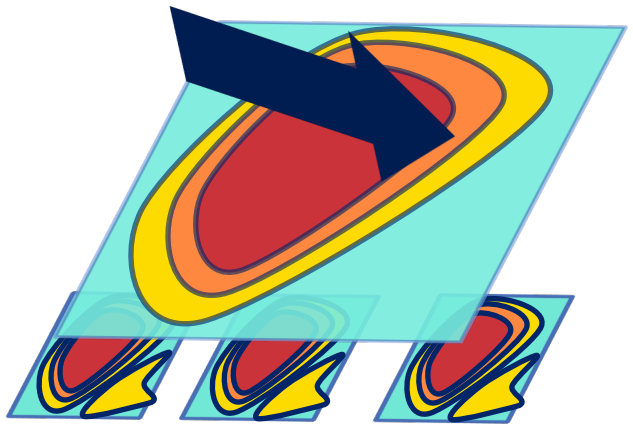
- EUMETSAT will assume responsibility for the production, distribution and archival of **L2 global products over ocean**

- These products are identified in the CIMR Mission Requirements Document (MRD) (see: https://cimr.eu/documents)

- L2 global products over ocean will support the activities of Copernicus Marine Environmental Monitoring Service (**CMEMS**) [http://marine.copernicus.eu] Copernicus Climate Change Service (**C3S**) [https://climate.copernicus.eu/]

CIMR L2 global products over ocean





Description	Spatial resolution [km]	Total Standard Uncertainty	Timeliness	Revisit
Total Column Water Vapour	<15 km (g=5 km)	<10%	NRT3H	Daily
Liquid Water Path	<15 km (g=5 km)	<50%		
Precipitation rate	<15 km (g=5 km)	<80% at 1 mm h−1 or <50% above 10 mmh−1		
Ocean Surface Wind Vector	< 40 km	2 ms-1 and <20° in direction at wind speeds ≥ 6 ms-1		
Sea surface Salinity	<60 km	≤0.3 pss		
Sea Surface Temperature	<15 km	≤0.2 K		

CIMR at EUMETSAT

- Level-2 Operational Processor for global ocean products to be developed and operated at EUMETSAT

- Providing operational infrastructure for:

    - L1 to L2 data processing;
    - Dissemination;
    - Archival;
    - Performing L2 Cal/Val activities for products over global ocean;
    - Supporting L2 reprocessing.

- Scientific study to develop algorithm prototype in the pipeline, planned KO mid 2023

- Main requirements: physical consistency, multi-frequency, multi-scale approach

Synergy/Complementarity

- The CIMR orbit selection allows for the possibility of direct synergy at high latitudes with EPS-SG and other Copernicus missions
- This needs to be explored to enhance the impact of EPS-SG and Copernicus data
- Elsewhere, complementarity is the word: global NWP/Ocean models taking benefit from assimilation of EPS-SG and Copernicus data
- Higher level products (Level 3, Level 4)
- Benefit of combined retrievals, inter-comparison/validation of geophysical parameters

EPS Sterna

EPS-Sterna programme background

- Since December 2018 EUMETSAT identified small microwave sounding satellites complementing the reference EUMETSAT Polar System (EPS-SG) /Microwave Sounder (MWS) mission as a possible additional EUMETSAT contribution to the realisation of the WIGOS Vision 2040, in line with objective 4 of the EUMETSAT strategy "Destination 2030".

- In 2019, EUMETSAT prioritised relevant user requirements, starting from the agreed EPS-SG/MWS user requirements.

- The European Space Agency (ESA) Arctic Weather Satellite (AWS) programme was approved at the ESA ministerial Council in 2019.
- See: **https://www.esa.int/Applications/Observing_the_Earth/Meteorological_missions/Arctic_Weather_Satellite**

- The AWS observational requirements are in line with EUMETSAT requirements' prioritization and were endorsed by the EPS-SG MWS/AWS Science Advisory Group.

AWS PFM and link to EPS-Sterna constellation

- The AWS is a small microwave sounding satellite planned to be launched in Q1/Q2 2024, with the objective to:
  - Provide a one year in-orbit demonstration for a future, operational constellation;
  - Confirm the impact of increased passive microwave soundings on Numerical Weather Prediction (NWP) accuracy and Nowcasting, particularly over the Arctic;
  - Demonstrate a cost-effective approach.

- If successful, the AWS prototype (PFM) will constitute an opportunity for EUMETSAT to implement a constellation of small sounding microwave satellites (i.e. EPS-Sterna) in complementary orbits to EPS-SG and expand the products' envelope of the EPS-SG mission for its users .

- The EPS-Sterna constellation will be developed in cooperation with ESA
- Composed of recurrent small satellites stemming from the AWS PFM
- Programme approval targeted in 2025 after one year in orbit demonstration.

AWS payload channels and performance requirements

Channel	Frequency (GHz)	Bandwidth (MHz)	NEΔT (K)	Footprint (km)	Utilisation
AWS-11	50.3	180	<0.6	≤ 40 km	Temperature sounding
AWS-12	52.8	400	<0.4	≤ 40 km	Temperature sounding
AWS-13	53.246	300	<0.4	≤ 40 km	Temperature sounding
AWS-14	53.596	370	<0.4	≤ 40 km	Temperature sounding
AWS-15	54.4	400	<0.4	≤ 40 km	Temperature sounding
AWS-16	54.94	400	<0.4	≤ 40 km	Temperature sounding
AWS-17	55.5	330	<0.5	≤ 40 km	Temperature sounding
AWS-18	57.290344	330	<0.6	≤ 40 km	Temperature sounding
AWS-21	89	4000	<0.3	≤ 20 km	Window and Cloud detection
AWS-31	165.5	2800	<0.6	≤ 10 km	Window/humidity sounding
AWS-32	176.311	2000	<0.7	≤ 10 km	Humidity sounding
AWS-33	178.811	2000	<0.7	≤ 10 km	Humidity sounding
AWS-34	180.311	1000	<1	≤ 10 km	Humidity sounding
AWS-35	181.511	1000	<1	≤ 10 km	Humidity sounding
AWS-36	182.311	500	<1.3	≤ 10 km	Humidity sounding
AWS-41	325.15±1.2	800	<1.7	≤ 10 km	Humidity sounding/cloud detection
AWS-42	325.15±2.4	1200	<1.4	≤ 10 km	Humidity sounding/cloud detection
AWS-43	325.15±4.1	1800	<1.2	≤ 10 km	Humidity sounding/cloud detection
AWS-44	325.15±6.6	2800	<1	≤ 10 km	Humidity sounding/cloud detection

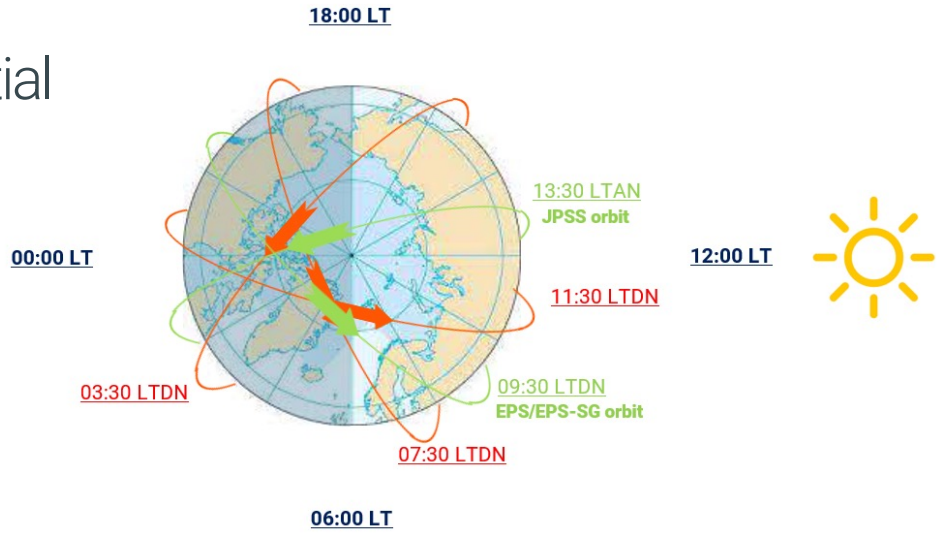
NEDT comparable to legacy missions (e.g. EPS-SG MWS/JPSS ATMS)

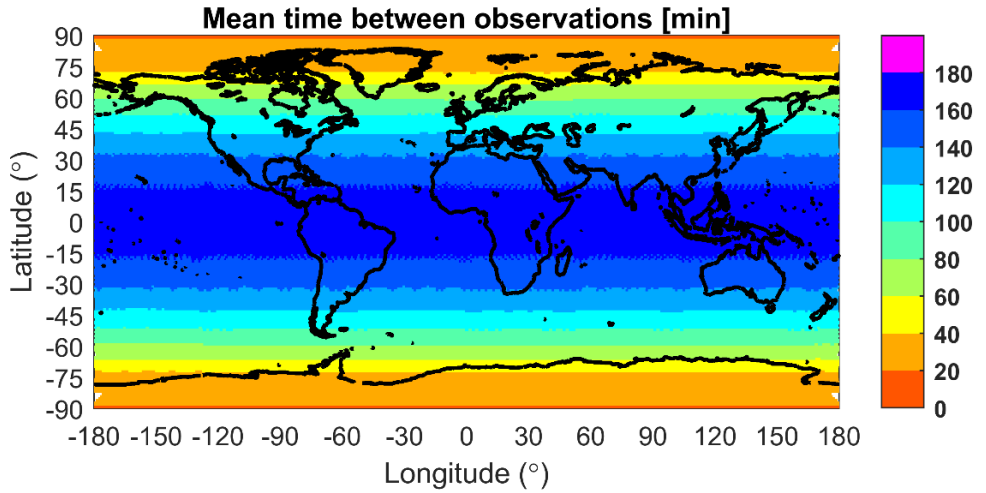
Radiometric accuracy shall be <1K

Lifetime stability < 0.2 K

Constellation characteristics and performances

- Constellation architecture
  - 6 satellites in 3 orbital planes (2 satellite in each plane) for initial constellation
  - Planes chosen to be complementary to EPS/EPS-SG and JPSS orbits (LTDN: 03:30, 07:30, 11:30)
- Constellation performance
  - Time to achieve 90% global coverage (driving requirement):
    - 3.10 - 4.7 hours- Sterna constellation alone
    - 2.37 - 3.5 hours- Sterna +EPS-SG and JPSS
  - Mean time between observations: 20 minutes - 3 hours





EPS Sterna Constellation in a nutshell

- The EPS Sterna Constellation will focus on:
  - Water vapor sounding
  - Temperature sounding
  - Cloud & precipitation detection

- The primary objectives of the EPS Sterna Constellation would be to:
  - Contribute to improved global and regional NWP accuracy
  - Complement the microwave observations from the Metop/Metop-SG and NOAA JPSS (Joint Polar Satellite System) polar-orbiting meteorological satellites

- The mission will also to contribute to nowcasting applications over the Arctic region through the increase the frequency and availability of microwave observations.

- Climate monitoring is not a primary objective of the mission, however EPS Sterna is expected to contribute through the provision of long-term data records and implementation of the necessary capabilities.

Thank you!

Questions are welcome.