The EUMETSAT Polar System - Second Generation (EPS-SG) microwave and sub-mm wave imaging and sounding missions

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Outline

Introduction

EPS-SG passive microwave and sub-mm wave missions:

- Microwave Sounder (MWS)
- Microwave Imaging (MWI)
- Ice Cloud Imaging (ICI)

Mission Products

Benefits for the users

Summary

EPS-SG: EUMETSAT Polar System - Second Generation

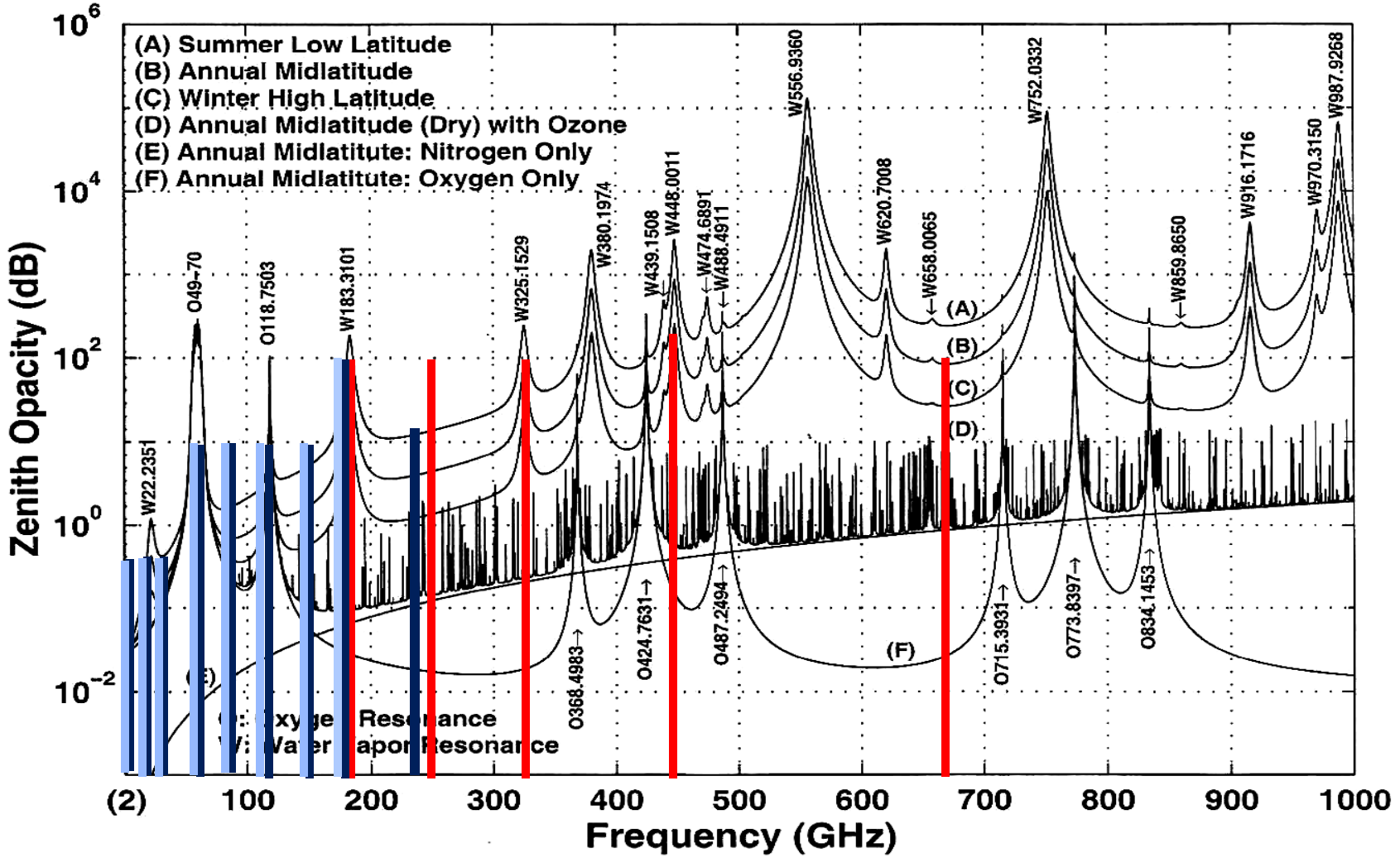
•The EUMETSAT Polar System (EPS) in Low Earth Orbit (LEO) will be followed by a second generation system (EPS-SG). European contribution to the Joint Polar System set up with NOAA.

• 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

Main channels of EPS-SG passive missions in spectrum



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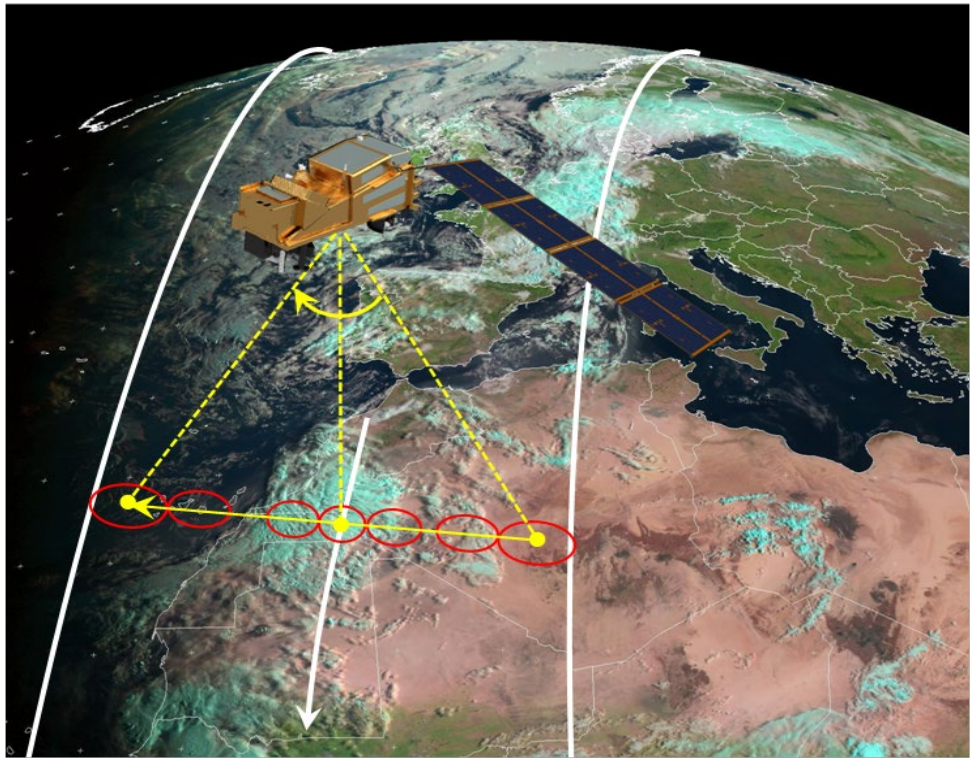
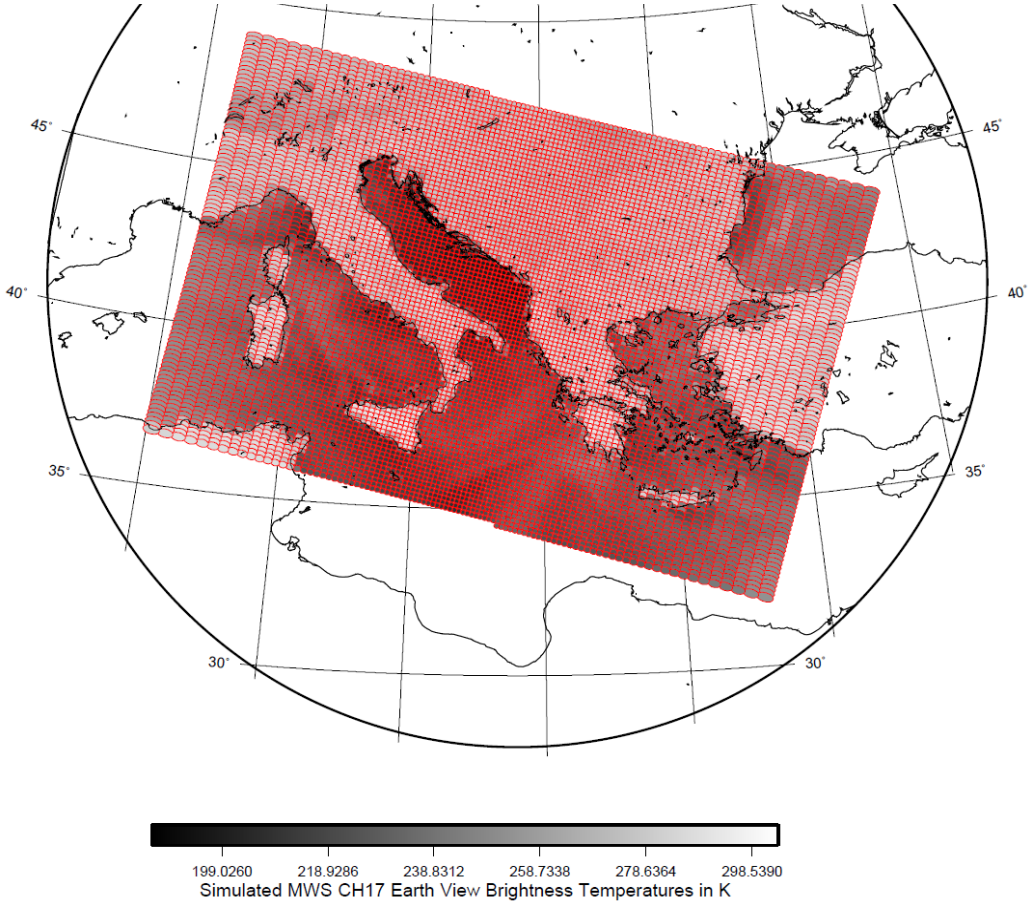
MW sounding mission (MWS)

- **MWS is a cross-track scanning passive sounder.**
- **24 channels ranging from 23.8 to 229 GHz.**
- **Observations acquired within an angle greater of ± 49° relative to Nadir, equivalent to a swath of about 2100 km.**



MWS Channel 17 scan pattern and brightness temperature simulations.



MWS channels

The 14 oxygen-band channels (MWS-3 to MWS-16) provide microwave temperature sounding for regions from near surface up to about 42 kilometres, i.e. from surface pressure level to 2 hPa.

Channels MWS-19 to MWS-23 are sensitive to the 183 GHz water vapour line, therefore providing humidity sounding capability.

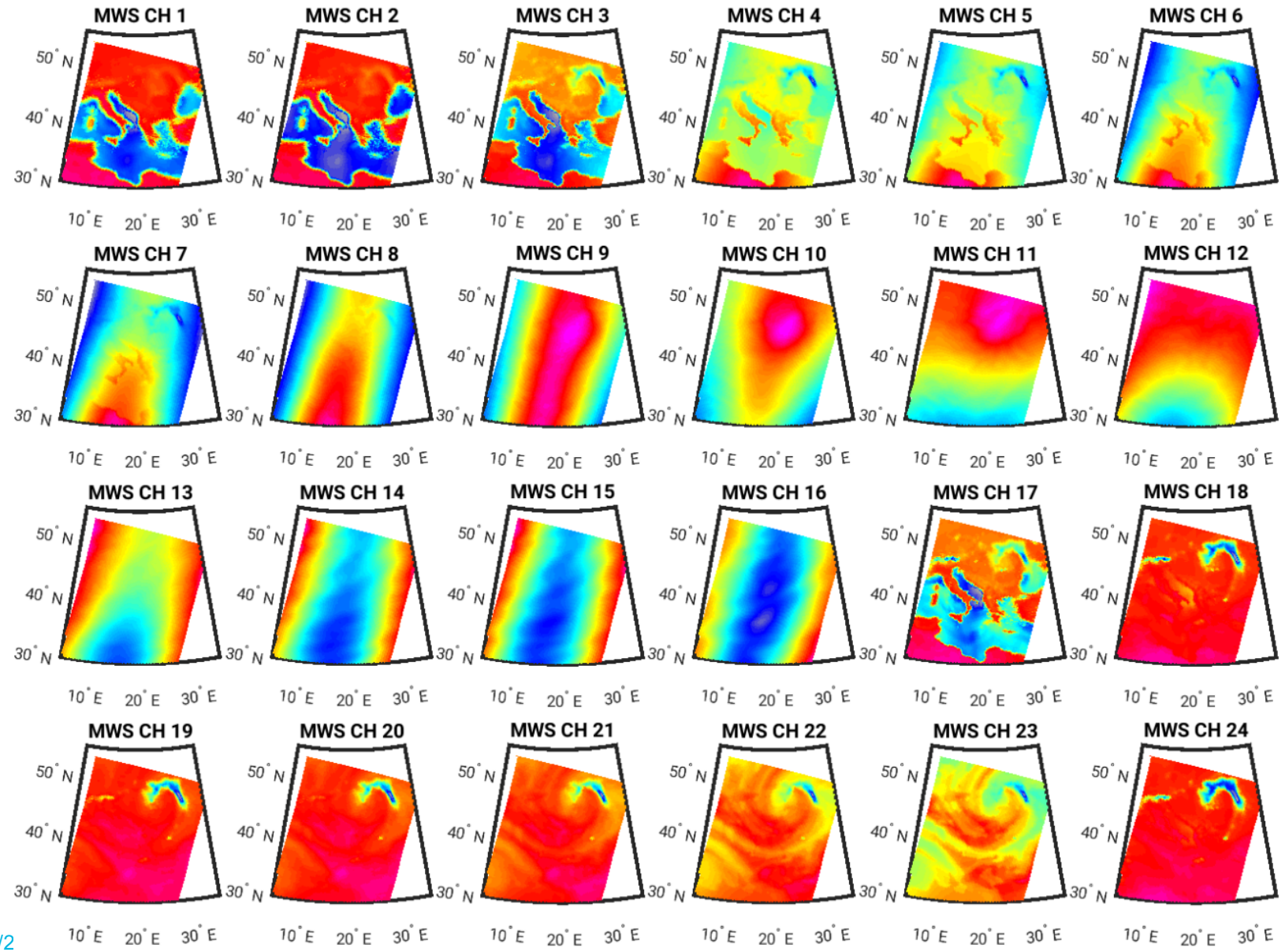
The window channel at 166 GHz (MWS-18) yields information on the total column water vapour.

The new channel at 229 GHz (MWS-24) provides enhanced sensitivity for the detection of cloud ice that would affect channels MWS-19 to 23.

The window channels also provide information about precipitation, sea ice and snow coverage.

Channel	Center frequency (GHz)	Bandwidth (MHz)	NEΔT (K)	Polarisation (Nadir)	Nadir 3dB footprint size (IFOV) (km)
MWS-1	23.8	270	<0.25	QH	40
MWS-2	31.4	180	<0.35	QH	40
MWS-3	50.3	180	<0.5	QH (QV)	20
MWS-4	52.8	400	<0.35	QH (QV)	20
MWS-5	53.246±0.08	2 x140	<0.4	QH (QV)	20
MWS-6	53.596±0.115	2 x 170	<0.4	QH (QV)	20
MWS-7	53.948±0.081	2 x 142	<0.4	QH (QV)	20
MWS-8	54.4	400	<0.35	QH (QV)	20
MWS-9	54.94	400	<0.35	QH (QV)	20
MWS-10	55.5	330	<0.4	QH (QV)	20
MWS-11	57.290344	330	<0.4	QH (QV)	20
MWS-12	57.290344±0.217	2 x 78	<0.55	QH (QV)	20
MWS-13	57.290344±0.3222±0.048	4 x 36	<0.6	QH (QV)	20
MWS-14	57.290344±0.3222±0.022	4 x 16	<0.9	QH (QV)	20
MWS-15	57.290344±0.3222±0.010	4 x 8	<1.2	QH (QV)	20
MWS-16	57.290344±0.3222±0.0045	4 x 3	<2.0	QH (QV)	20
MWS-17	89	4000	<0.25	QV	17
MWS-18	165.5±0.725	2 x 1350	<0.5	QH	17
MWS-19	183.311±7.0	2 x 2000	<0.4	QV	17
MWS-20	183.311±4.5	2 x 2000	<0.4	QV	17
MWS-21	183.311±3.0	2 x 1000	<0.6	QV	17
MWS-22	183.311±1.8	2 x 1000	<0.6	QV	17
MWS-23	183.311±1.0	2 x 500	<0.75	QV	17
MWS-24	229.0	2000	<0.7	QV	17

MWS simulations over Italy and the Mediterranean sea



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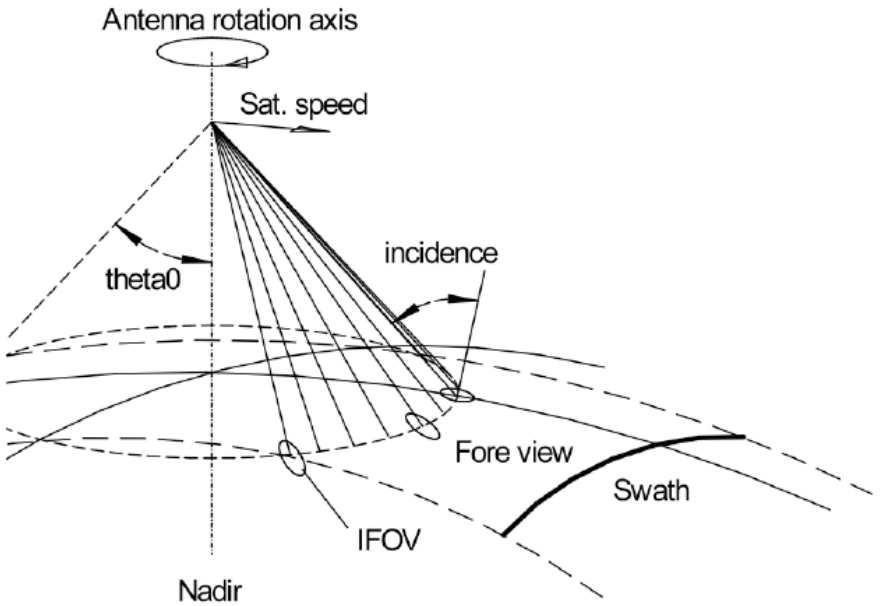
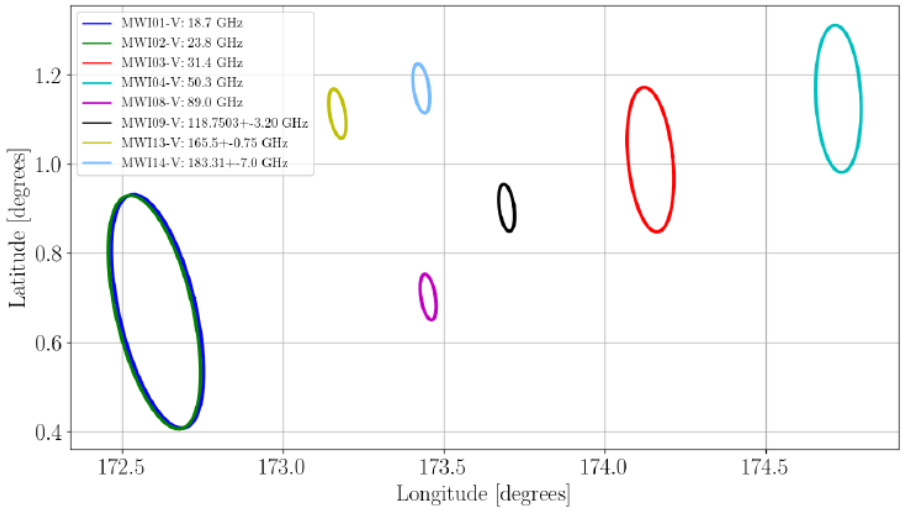
MW and Sub-mm Wave Imaging missions (MWI & ICI)

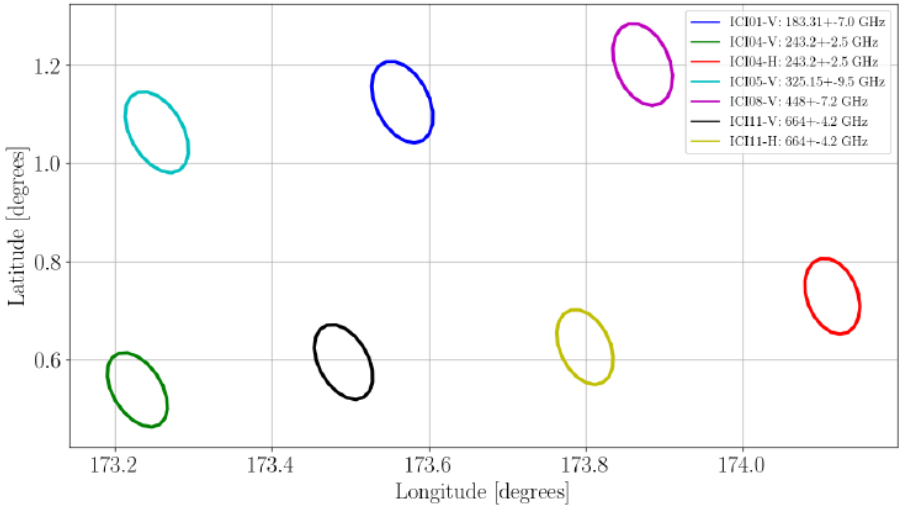
- **ICI and MWI are conically scanning passive imagers**
- **MWI ranging from 18 to 183 GHz**
- **ICI ranging from 183 GHz to 664 GHz**
- **Incidence angles within 53°±2°**
- **Observations acquired ± 65° in azimuth in the fore view (about 1700 km swath)**



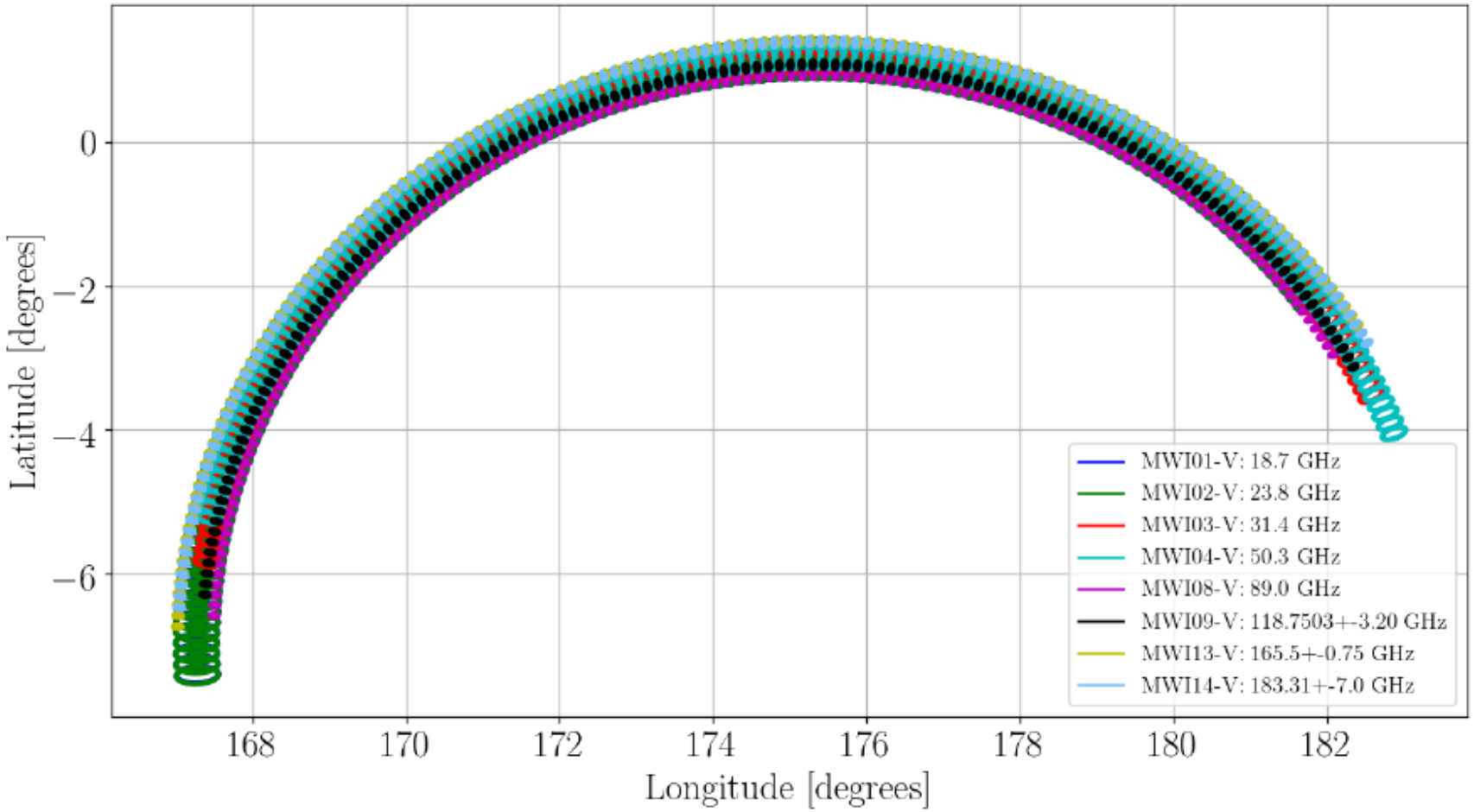
MWI



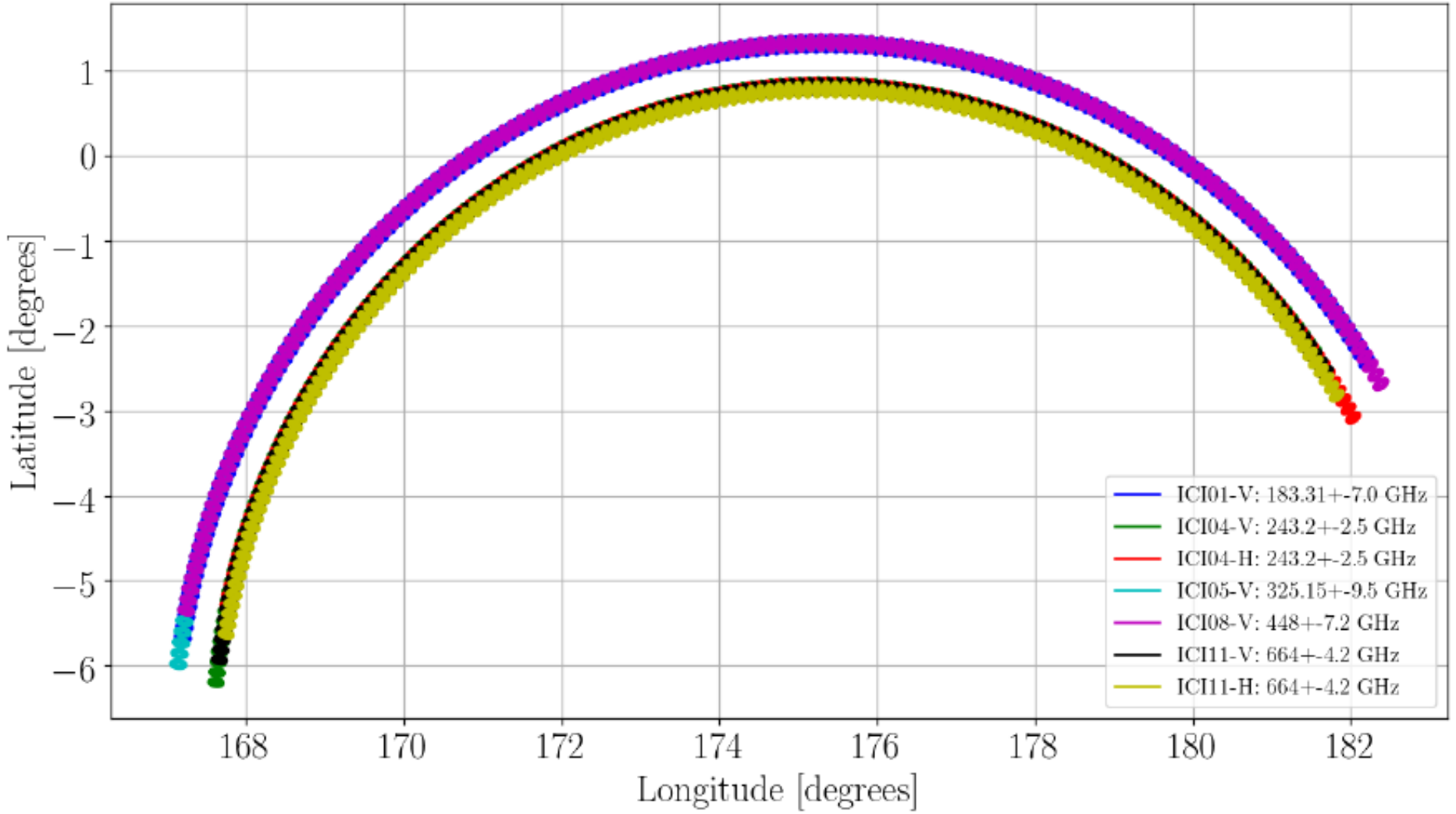
ICI



MWI Swath


Latitude [degrees]
0
−2
−4
−6
168
170
172
174
176
178
180
182
Longitude [degrees]
MWI01-V: 18.7 GHz
MWI02-V: 23.8 GHz
MWI03-V: 31.4 GHz
MWI04-V: 50.3 GHz
MWI08-V: 89.0 GHz
MWI09-V: 118.7503+-3.20 GHz
MWI13-V: 165.5+-0.75 GHz
MWI14-V: 183.31+-7.0 GHz

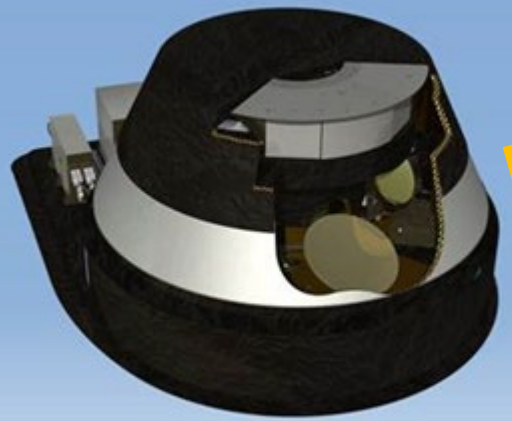
ICI Swath

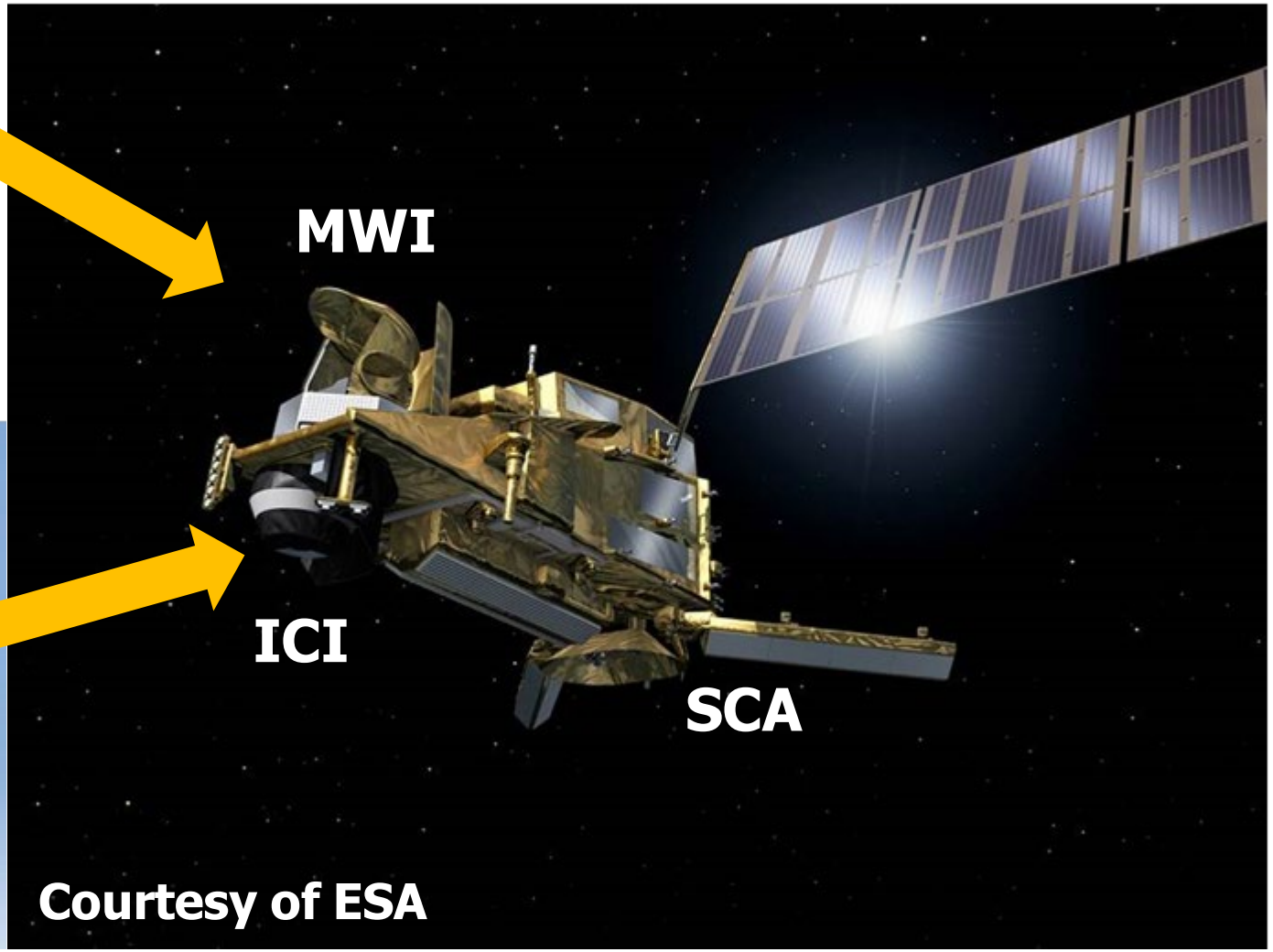

Latitude [degrees]
1
0
−1
−2
−3
−4
−5
−6
168
170
172
174
176
178
180
182
Longitude [degrees]
ICI01-V: 183.31+-7.0 GHz
ICI04-V: 243.2+-2.5 GHz
ICI04-H: 243.2+-2.5 GHz
ICI05-V: 325.15+-9.5 GHz
ICI08-V: 448+-7.2 GHz
ICI11-V: 664+-4.2 GHz
ICI11-H: 664+-4.2 GHz

The MWI and ICI instruments on EPS-SG Satellite B

MWI:
- **mass: 250 kg**
- **height: 1.8 m**
- **reflector ø: 80 cm**

ICI:
- **mass: 170 kg**
- **height: 1.3 m**
- **reflector ø: 30 cm**





The Microwave Imager (MWI)

- Continuity of key microwave imager channels for weather forecasting (e.g. SSM/I, AMSR-E, GMI) and surface monitoring.

- All MWI channels up to 89 GHz measured with both vertical (V) and horizontal (H) polarisations.

- Innovative set of channels in the oxygen absorption band near 50–60 GHz and 118 GHz. Enabling the retrieval of information on weak precipitation and snowfall.

- Channels MWI-13 to MWI-18 provide information on water vapour profiles and snowfall. Less sensitive to surface, more usable globally and enabling cloud slicing.

Channel	Frequency (GHz)	Bandwidth (MHz)	NE∆T (K)	Polarisation	Footprint Size 3dB (km)
MWI-1	18.7	200	0.8	V, H	50
MWI-2	23.8	400	0.7	V, H	50
MWI-3	31.4	200	0.9	V, H	30
MWI-4	50.3	400	1.1	V, H	30
MWI-5	52.610	400	1.1	V, H	30
MWI-6	53.24	400	1.1	V, H	30
MWI-7	53.750	400	1.1	V, H	30
MWI-8	89.0	4000	1.1	V, H	10
MWI-9	118.7503±3.20	2x500	1.3	V	10
MWI-10	118.7503±2.10	2x400	1.3	V	10
MWI-11	118.7503±1.40	2x400	1.3	V	10
MWI-12	118.7503±1.20	2x400	1.3	V	10
MWI-13	165.5±0.75	2x1350	1.2	V	10
MWI-14	183.31±7.0	2x2000	1.3	V	10
MWI-15	183.31±6.1	2x1500	1.2	V	10
MWI-16	183.31±4.9	2x1500	1.2	V	10
MWI-17	183.31±3.4	2x1500	1.2	V	10
MWI-18	183.31±2.0	2x1500	1.3	V	10

MWI expected performance

The Ice Cloud Imager (ICI)

ICI is the first radiometer of this type designed with the objective of remote sensing of cloud ice, providing good cloud penetration capability and sensitivity to a significant portion of particle size range that not covered either in the optical/thermal IR or in the mm-wave range

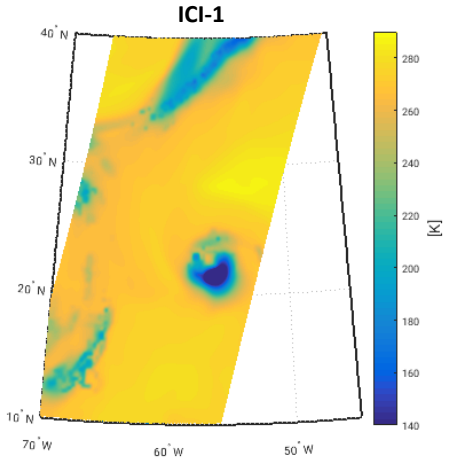
- **Novel mission**
- **In support of a synergetic use of ICI and MWI, both instruments carry common spectral channels at 183 GHz.**
- **Set of channels providing information related to total vertical column of cloud ice and ice particles size**
- **Use of channels around weak absorption lines (around 325.15 GHz and 448 GHz) allows performing cloud slicing**

Channel	Frequency (GHz)	Bandwidth (MHz)	NE∆T (K)	Polarisation	Footprint Size 3dB (km)
ICI-1	183.31±7.0	2x2000	0.8	V	16
ICI-2	183.31±3.4	2x1500	0.8	V	16
ICI-3	183.31±2.0	2x1500	0.8	V	16
ICI-4	243.2±2.5	2x3000	0.7	V, H	16
ICI-5	325.15±9.5	2x3000	1.2	V	16
ICI-6	325.15±3.5	2x2400	1.3	V	16
ICI-7	325.15±1.5	2x1600	1.5	V	16
ICI-8	448±7.2	2x3000	1.4	V	16
ICI-9	448±3.0	2x2000	1.6	V	16
ICI-10	448±1.4	2x1200	2.0	V	16
ICI-11	664±4.2	2x5000	1.6	V, H	16

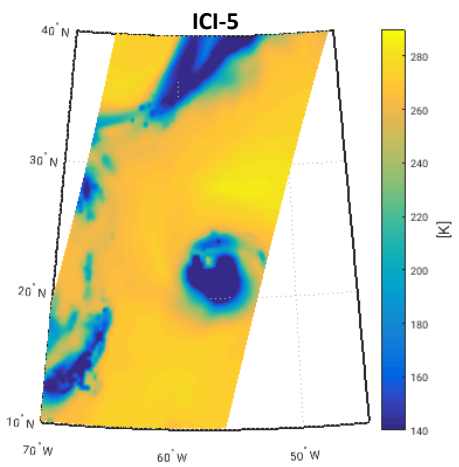
ICI expected performance

MWI & ICI simulations of hurricane “IKE” , sept 2008

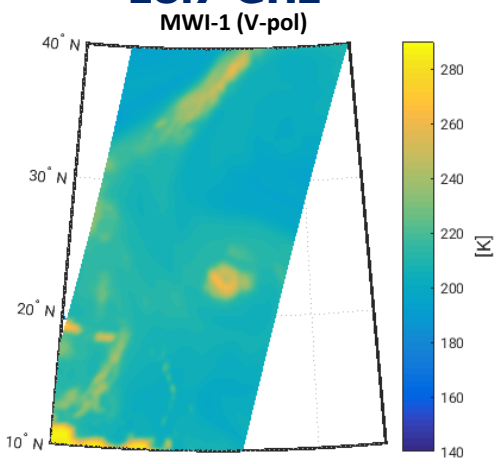
183.3 ±7 GHz



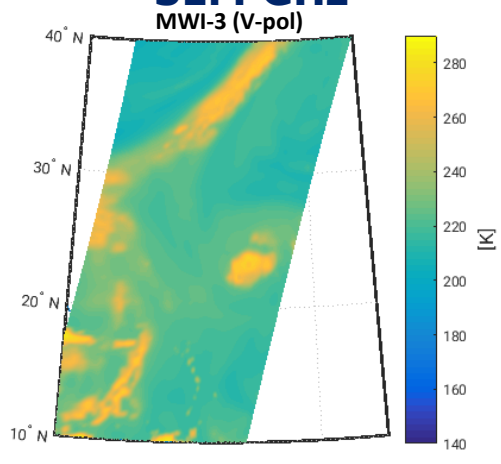
325.15±9 GHz

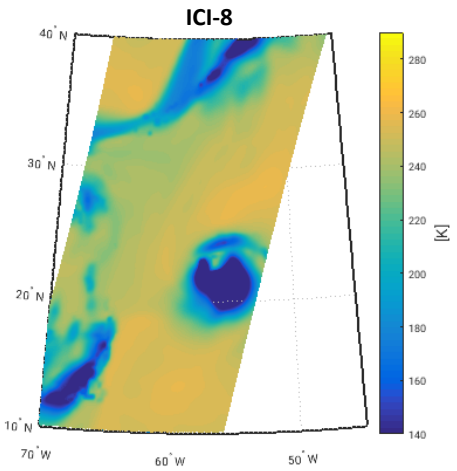


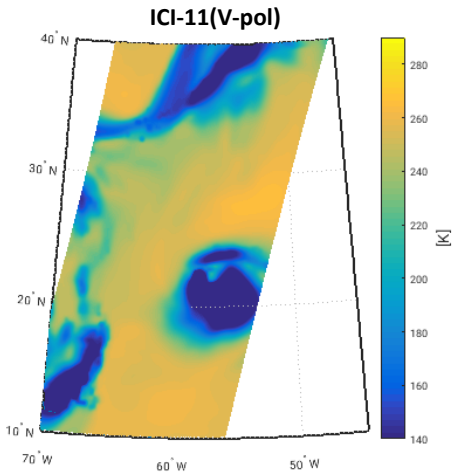
18.7 GHz

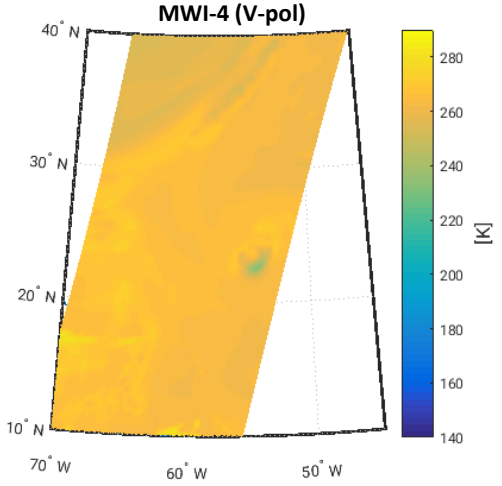


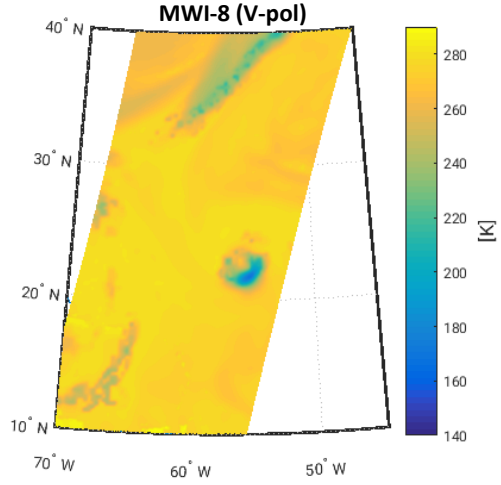
31.4 GHz











448±7 GHz

664±4 GHz

50.3 GHz

89 GHz

Mission products

MWS

- **Level 1B Radiances**
- **Level 2 :**
  - ✓ **Temperature profile**
  - ✓ **Water-vapour profile**
  - ✓ **Cloud liquid-water total column (droplet size < 100µm)**

Further products to which MWS contributes are spectral radiances with information on:

- ✓ **Cloud liquid-water profile (droplet size < 100 µm)**
- ✓ **Cloud ice total column**

Mission products

ICI

- Level 1B Radiances
- Level 2 products: Cloud ice water path, mean ice particle size by mass and mean mass height , snowfall

MWI

- Level 1B Radiances
- Level 2 products:
  - ✓ Cloud and precipitation including bulk microphysical variables
  - ✓ Total column water vapour over ocean
  - ✓ Water vapour and temperature gross profiles capability
  - ✓ All weather surface imagery including: sea ice coverage (and type), snow coverage and water equivalent, sea surface wind speed (complementary to the scatterometer - SCA)

Several L2 products are developed by the EUMETSAT Satellite Application Facilities (SAFs) like the Hydrology SAF, Nowcasting SAF, Climate Monitoring SAF, Ocean and Sea Ice SAF

Benefits for the users (ICI)

ICI

- **Provision of ice cloud products for climate monitoring. IWP is an essential climate variable that is highly uncertain. Current observations are not able to derive accurate global estimates.**

- **Support the validation of the presentation of ice clouds in weather and climate models:**
  - **cloud microphysical schemes**
  - **cloud radiation interaction**

- **Fill observational gap: provide information on non-precipitating ice that are neither accessible in the micro-wave region nor in the infrared domain.**

- **Further objectives include the measurement of water-vapour gross profiles and snowfall distributions in support of numerical weather prediction and nowcasting.**

- **Synergy with MWI (on the same platform!)**

Benefits for the users (MWI)

MWI

- **Provision of cloud and precipitation products including bulk microphysical variables, and all weather surface imagery.**
- **Support Numerical Weather Prediction at regional and global scales: all-weather direct assimilation into NWP systems, information related to the integrated total column water vapor as well as near-surface wind speed derived from MWI data is considered crucial.**
- **MWI has to be viewed as part of an international partnership for global precipitation observations (Global Precipitation Measurement – GPM – like constellation).**
- **Continuity of measurements of key microwave imager channels as observed by SSM/I, TRMM TMI, SSMIS, AMSR-E, GMI, in support of long-term climate records.**
- **MWI observations of sea-ice extent and other sea ice variables in Arctic and Antarctic Oceans, as polar nights and persistent cloud cover prevent complete coverage by optical imagers.**
- **The availability of high quality retrievals of cloud, precipitation and all weather land surface variables would also contribute to fulfil other key requirements common to Nowcasting and very short-range forecasting (VSRF) at regional scales.**

Benefits for the users (MWS)

MWS

- **Main users of the MWS mission will be the WMO real time users (e.g. NWP centres of National Meteorological Services, ECMWF) through the provision of spectral radiance measurements with all-sky information on temperature and water vapour profiles and cloud liquid.**

- **The frequent availability of detailed temperature and moisture soundings also contribute to fulfil other key requirements common to Nowcasting and Very Short Range Forecasting.**

- **The MWS mission is also relevant to non real-time users and services (e.g. the Climate Monitoring SAF) which will use MWS data to continue temperature and humidity sounding records, mainly for climate monitoring applications.**

Summary

- **The ICI radiometer provides an unprecedented set of microwave passive measurements from 183.3 GHz up to 664 GHz.**

- **The MWI (on the same platform with ICI) will continue and enhance important measurements of cloud and precipitation. Synergy among missions.**

- **The MWS mission ensures continuity of existing MW sounding instruments.**

These missions will:

- **Provide continuation and enhancement of EUMETSAT service from polar orbit in 2021 – 2042.**
- **Expand by 20+ years the EUMETSAT contribution to climate data records.**
- **Contribute to GPM constellation.**