Emission model requirements for next generation satellite instruments

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Outline

Missions of interest (MW and sub-mm wave)

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

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

- Relevant applications

- Copernicus Microwave Imaging Radiometer (CIMR)

EPS-SG: EUMETSAT Polar System - Second Generation

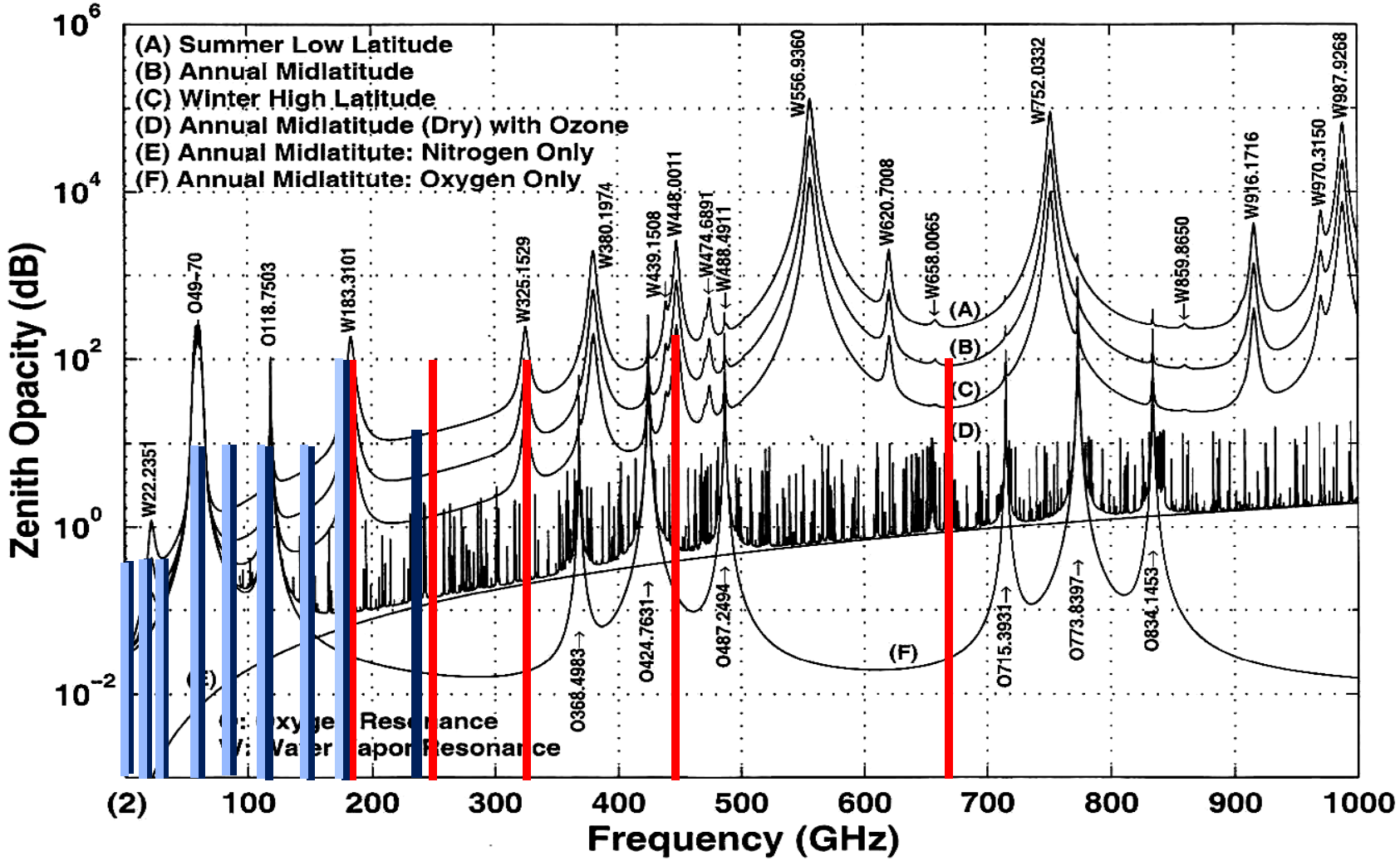
•The EUMETSAT Polar System (EPS) in Low Earth Orbit (LEO) will be followed by a second generation system (EPS-SG). European contribution to the Joint Polar System set up with NOAA.

• 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.

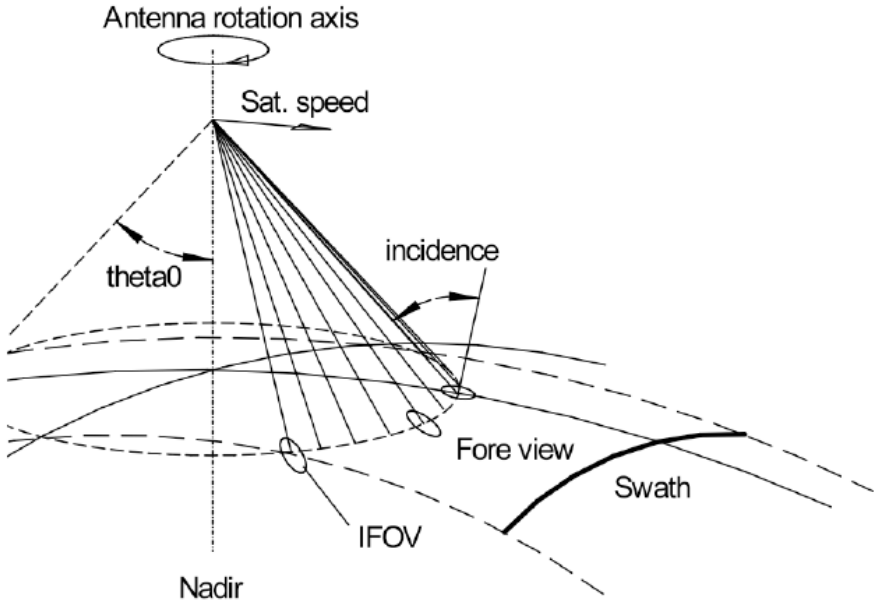
Metop payload	Metop-SG payload	Metop-SG satellite
Infrared Atmospheric Sounding Interferometer (IASI)	Infrared Atmospheric Sounding Interferometer – New Generation (IASI-NG)	A
Advanced Very High Resolution Radiometer (AVHRR)	Visible-Infrared Imager (METimage)	A
–Advanced Microwave Sounding Unit A (AMSU-A1/A2), 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

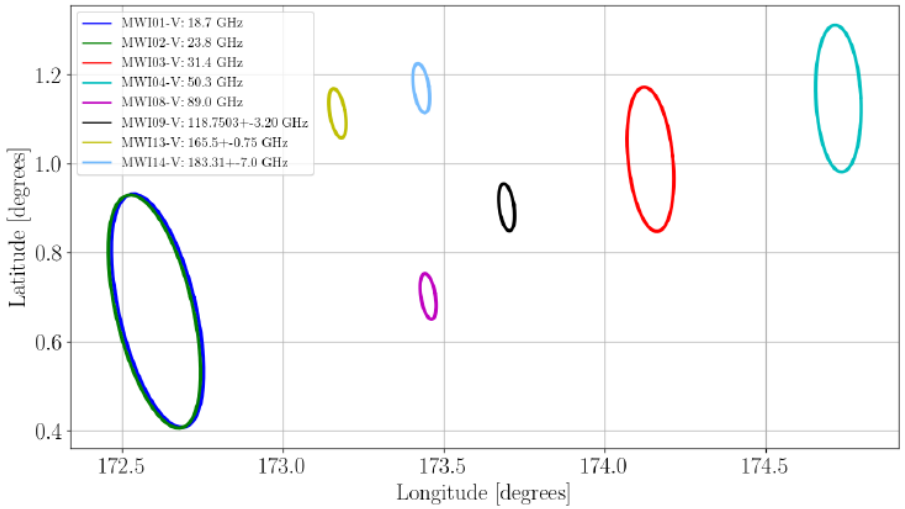


MW and Sub-mm Wave Imaging missions (MWI & ICI)

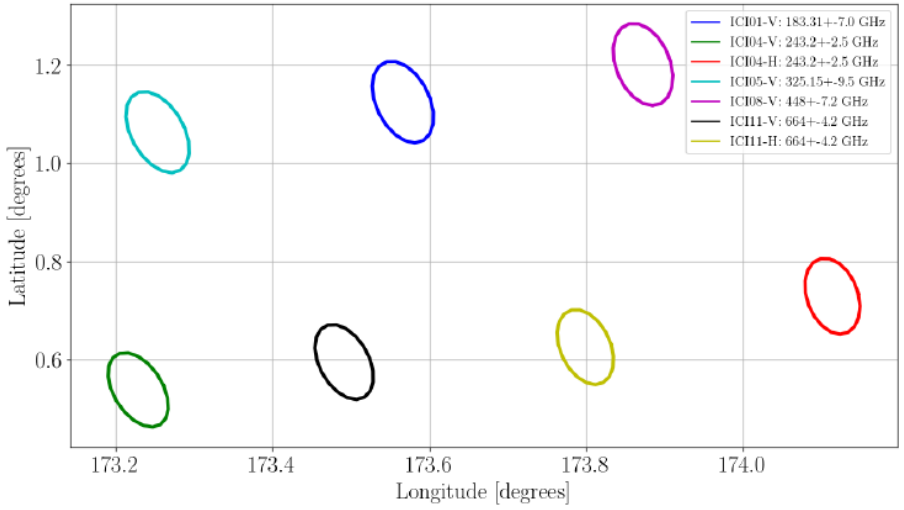
- **ICI and MWI are conically scanning passive imagers**
- **MWI ranging from 18 to 183 GHz**
- **ICI ranging from 183 GHz to 664 GHz**
- **Incidence angles within 53°±2°**
- **Observations acquired ± 65° in azimuth in the fore view (about 1700 km swath)**



MWI



ICI



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)	NEΔT (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

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.

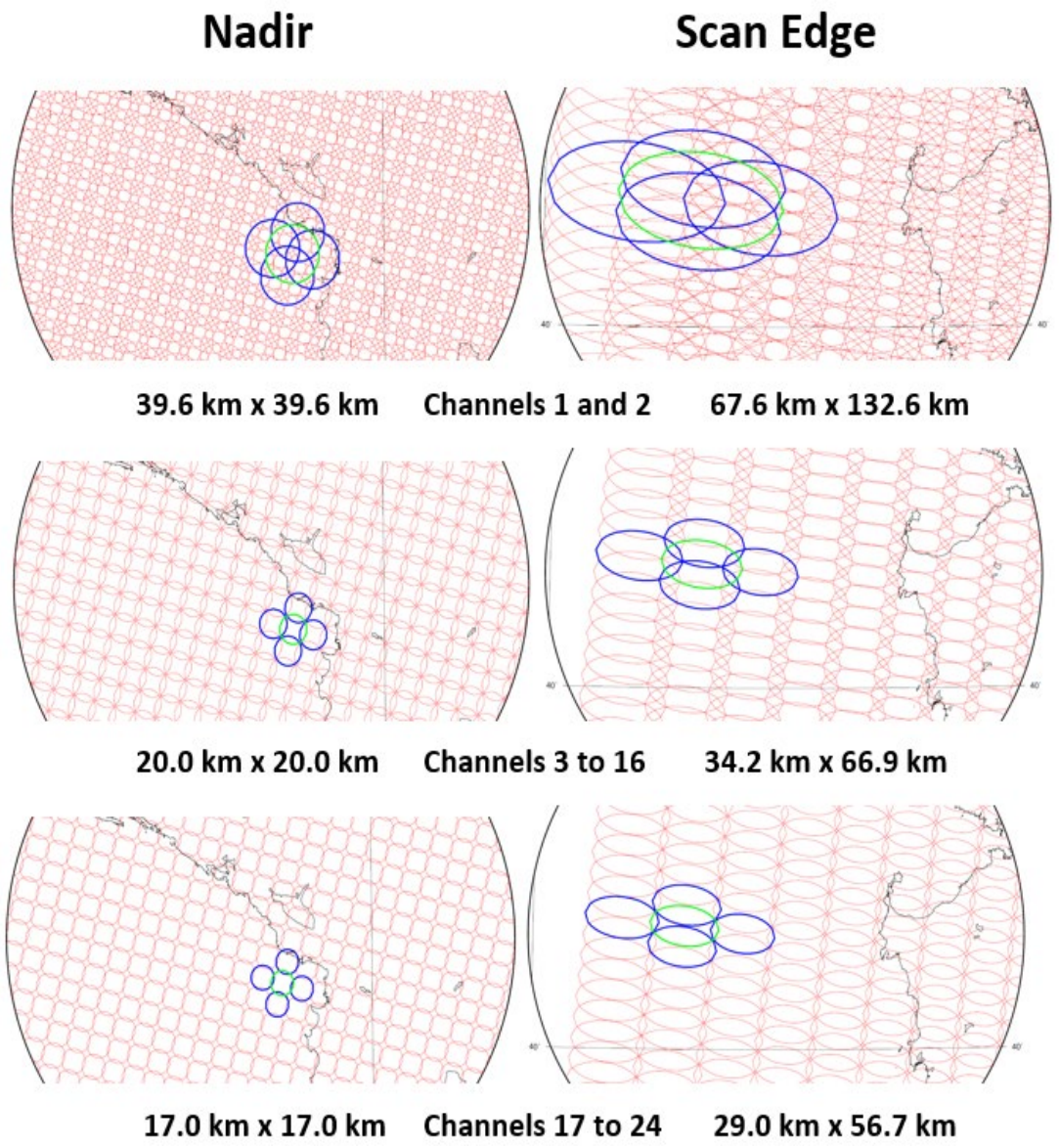
The new channel at 229 GHz (MWS-24) provides enhanced sensitivity for the detection of cloud ice that would affect channels MWS-19 to 23.

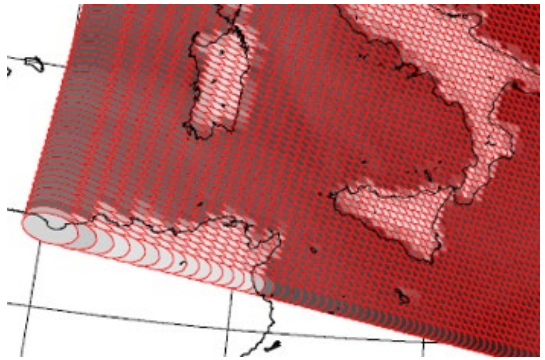
The window channels also provide information about precipitation, sea ice and snow coverage.

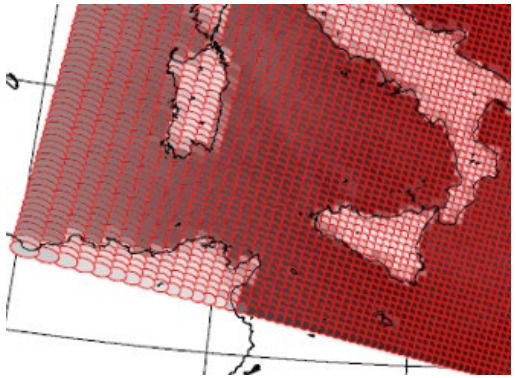
Channel	Center frequency (GHz)	Bandwidth (MHz)	NEΔT (K)	Polarisation (Nadir)	Nadir 3dB footprint size (IFOV) (km)
MWS-1	23.8	270	<0.25	QH	40
MWS-2	31.4	180	<0.35	QH	40
MWS-3	50.3	180	<0.5	QH (QV)	20
MWS-4	52.8	400	<0.35	QH (QV)	20
MWS-5	53.246±0.08	2 x140	<0.4	QH (QV)	20
MWS-6	53.596±0.115	2 x 170	<0.4	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

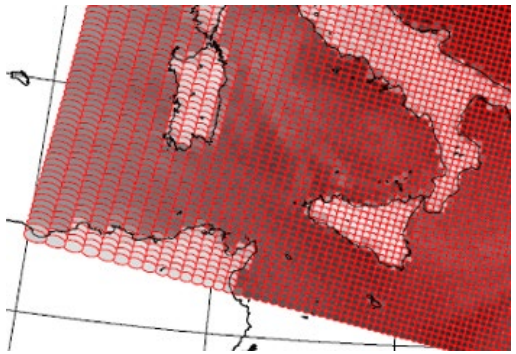
EPS-SG MWS: Geometric Data (Level 1)

- 95 pixels per scan line
- 2.25 seconds scan duration
- 49.85° maximum scanning angle
- ~2250 km swath width





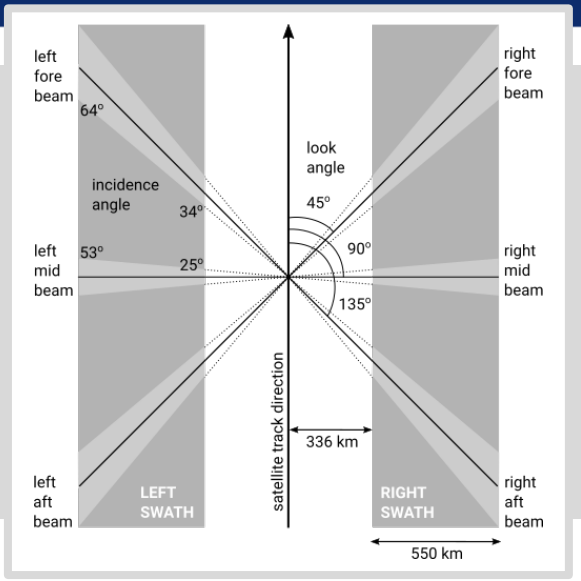




EPS and EPS-SG scatterometer missions

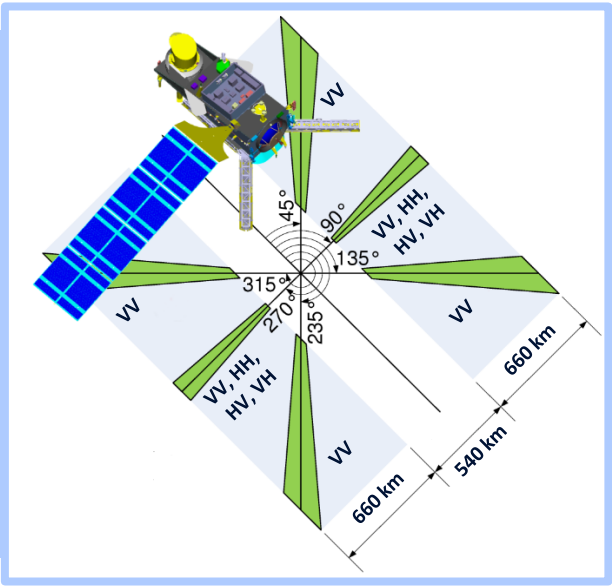
First Generation – ASCAT

- Frequency 5.255 GHz (C-band)
- Swath width 550 km
- Incidence angles
  - 25° to 53° (mid beams)
  - 34° to 65° (side beams)
- Polarization: VV



Second Generation – SCA

- Frequency 5.355 GHz (C-band)
- Swath width ~650 km
- Incidence angles
  - 20° to 53.7° (mid beams)
  - 28.4° to 65° (side beams)
- Polarizations: VV, HH + HV + VH on mid-beams for improved high winds retrieval



EPS-SG missions

- EPS-SG missions offer new measurement possibilities:

- 243 GHz from ICI, x-pol measurements with SCA (HV, mid beam)

- Most of the MW instruments are on satellite B: Synergy!

Sinergy from EPS-SG could offer opportunities

- EPS-SG MWI measurements can be collocated with SCA measurements

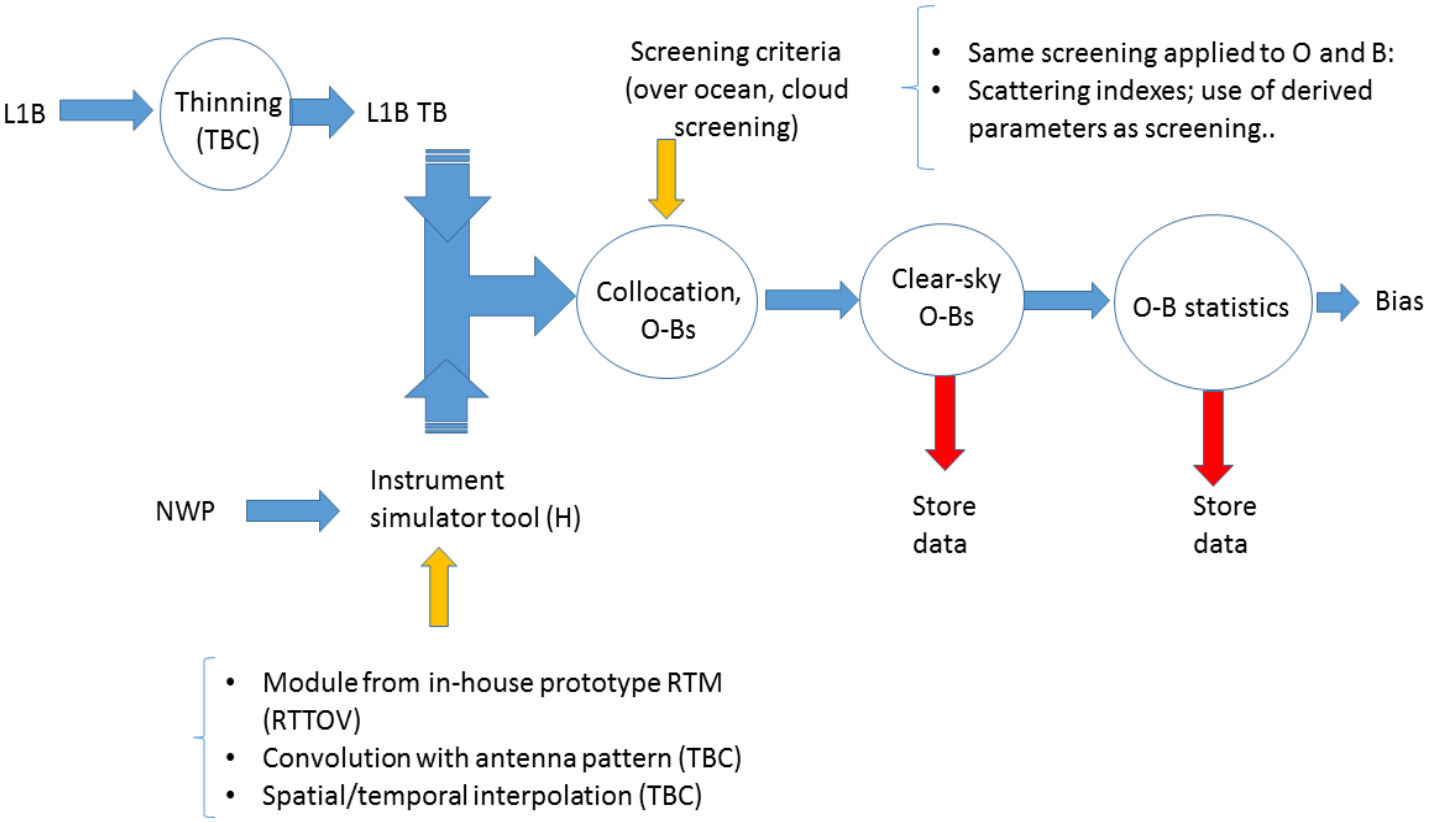
- Assimilation of data (either at L1 or L2) from SCA and MWI over the same area might require physical consistency between the backscatter model at C band and the emissivity model.

Relevant applications

Main applications of interest from EUMETSAT perspective of a reference ocean emissivity model:

- Cal/Val and radiance observation monitoring in-flight
- Level 2 retrievals (e.g. use in 1D-Var LWP retrieval)
- Simulation studies of new satellite sensors: test data

Cal/Val example: Comparison with NWP



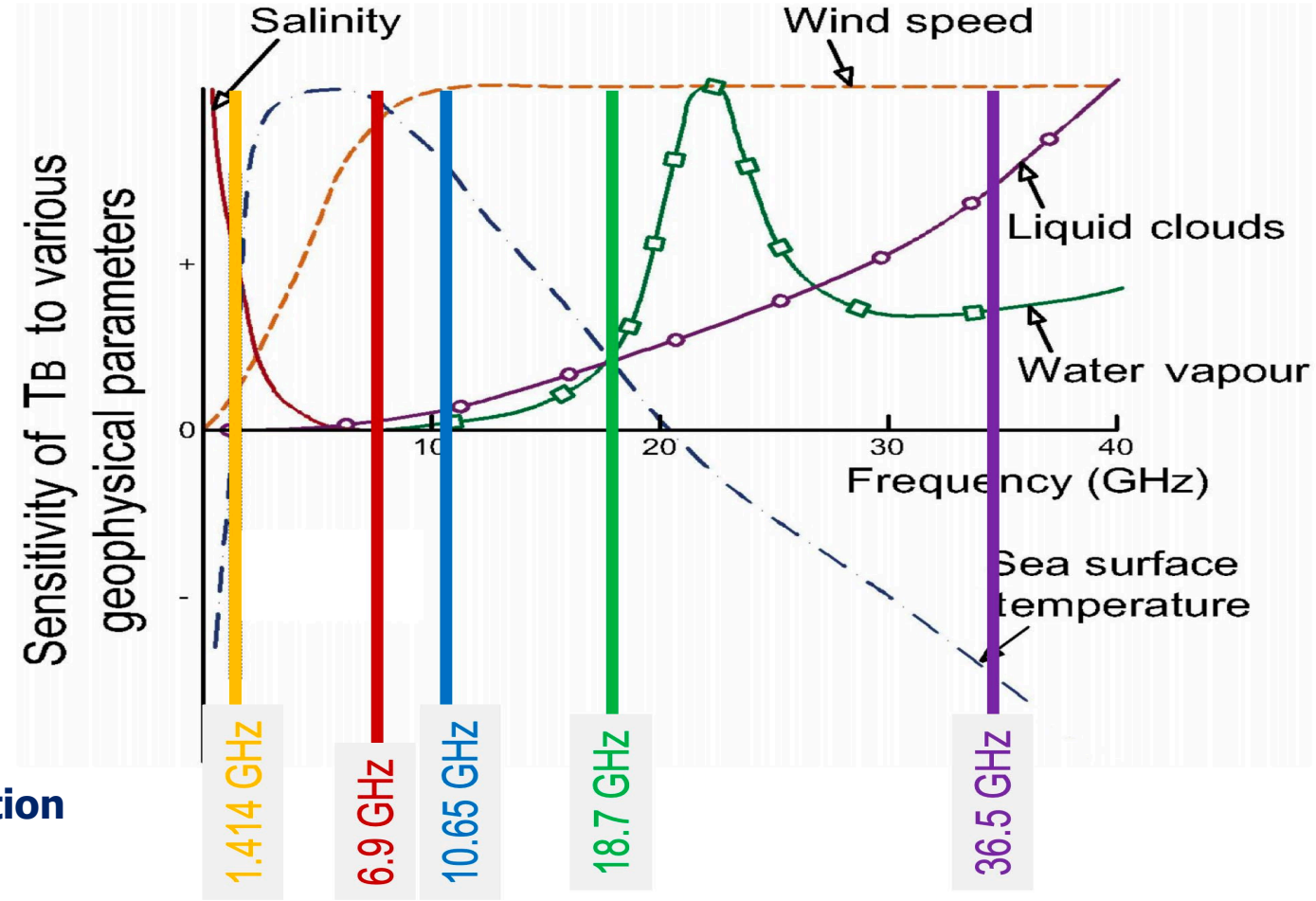
- Apply thinning to TBs (TBC)
- Collect corresponding NWP profiles for space and time;
- Compute simulated TBs using the RTTOV, (convolving with antenna pattern if necessary);
- Apply cloud/precipitation screening to O and B; Eventually using of geostationary cloud mask
- Collect O-B;
- Perform final screening on cloudy pixels (cold tail histogram);
- Binning the O-B as a function of latitude, scan, TB, land/ocean, and any other predictor for bias correction;
- Compute overall bias (O-B) and std (O-B), inter-channel, inter-pixel, latitude, time, orbital angle, ascending vs descending.

Screening is applied to compare measurements where RTM should be more robust: clear scenes, over ocean. Thus the relevance of the ocean emissivity model in order to perform the proper error attribution

CIMR

CIMR bands and sensitivity of brightness temperature for open seawater over a range of observing frequencies in the microwave band for a set of key geophysical parameters (From *Gabarro et al*, 2017).

Full polarimetric capability (Stokes vector)



CIMR channels are chosen to maximize the information available in the 1.4-37 GHz frequency range

Requirements

- Fully polarimetric model (CIMR)
- It shall be anyway compatible for an implementation within RTTOV (operational RTM)
- Validation: the reference surface emissivity model shall be validated, this would require a dedicated effort in this direction