User readiness for ICI

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ECMWF

EPS-SG: EUMETSAT Polar System - Second Generation

- **The EUMETSAT Polar System (EPS) in Low Earth Orbit (LEO) Second Generation system (EPS-SG): European contribution to the Joint Polar System**

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

- **Payload complementary distributed between the two parallel satellites Metop-SG A and B.**

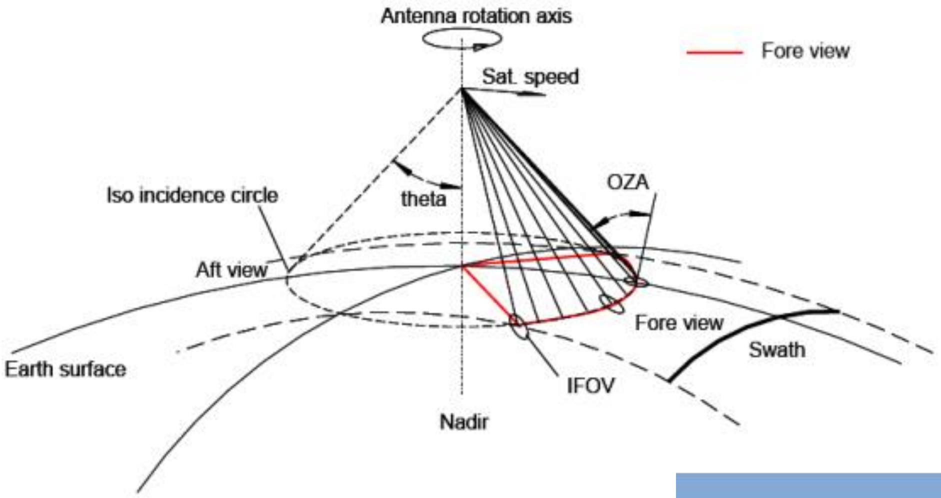
- **Nominal lifetime of 7.5 years/spacecraft for an operational lifetime of the programme over 21 years.**

- **Launch currently foreseen for: Satellite A - Feb 2024; Satellite B - Oct 2024**

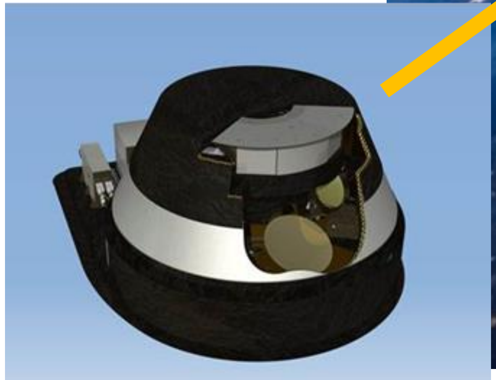
Metop payload	Metop-SG payload	Metop-SG satellite
Infrared Atmospheric Sounding Interferometer (IASI)	Infrared Atmospheric Sounding Interferometer – New Generation (IASI-NG)	A
Advanced Very High Resolution Radiometer (AVHRR)	Visible-Infrared Imager (METimage)	A
–Advanced Microwave Sounding Unit A (AMSU-A1/A2),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

Ice Cloud Imager

•**ICI:** **Conically scanning counterclockwise at 45 rpm. Incidence angles within 53°±2° . Observations acquired ± 65° in azimuth in the fore view (about 1700 km swath)**



Courtesy of ESA


Credit: Airbus Defence and Space

Motivation

ICI

- **Provision of ice cloud products for climate monitoring**
- **Support the validation of the representation of ice clouds in weather and climate models**
- **Fill observational gap: provide information on non-precipitating ice that are not covered either in the optical/thermal IR or in the mm-wave range**

The Ice Cloud Imager (ICI)

ICI is the first radiometer of this type designed with the objective of remote sensing of cloud ice.

- **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).**

- **Channels in the atmospheric windows at 243 and 664 GHz, implemented with dual polarisation.**

•Few data:
- **mass: 170 kg**
- **height: 1.3 m**
- **reflector diameter: 30 cm**

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

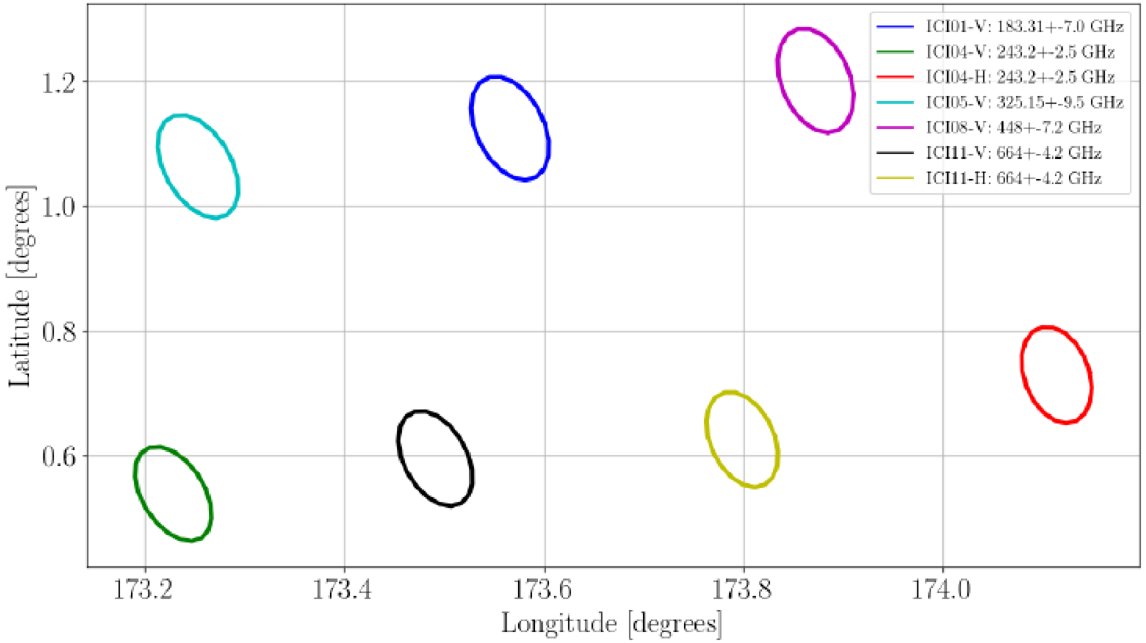
ICI expected performance

ICI Swath - about 800 samples per scan

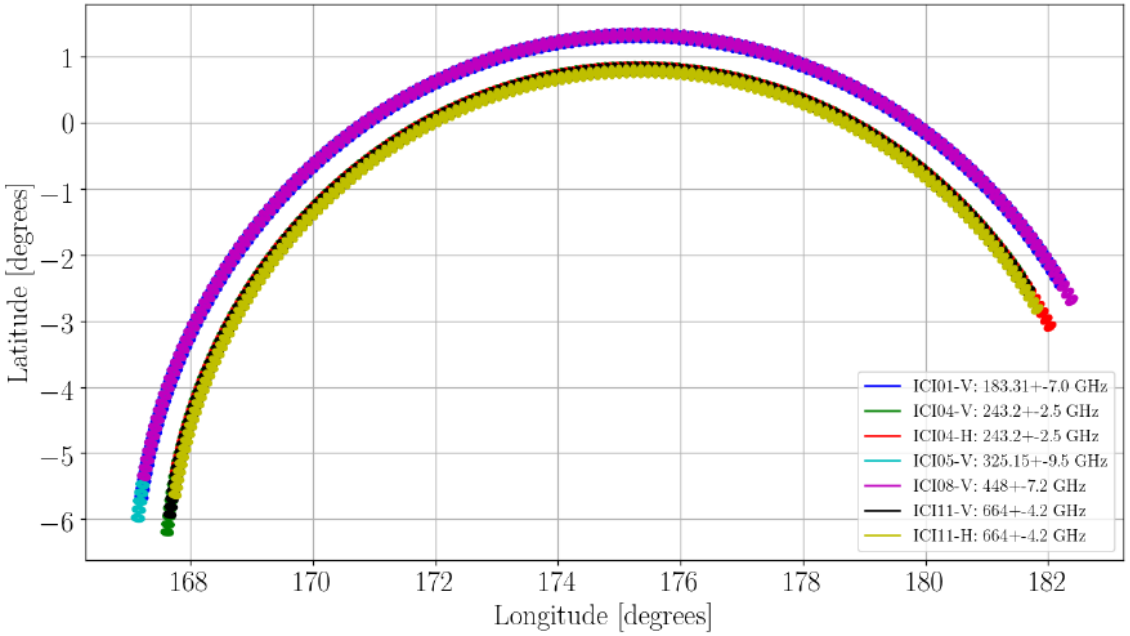
•**ICI: Conically scanning counterclockwise at 45 rpm. Incidence angles within 53°±2° . Observations acquired ± 65° in azimuth in the fore view (about 1700 km swath)**

ICI footprint: 16 km (ICI-1 to ICI-11);

Across-track footprint overlap 3-4x; spatial sampling ~2.7 km
Along-track footprint overlap ~ 40%; spatial sampling ~9 km



instantaneous, relative positions of -3-dB footprints on the geoid for ICI channels.



relative positions of -3-dB footprints on geoid for ICI channels of a complete scan.

EUMETSAT

Mission products

- **Level 1B Radiances: ICI L1B-RAD (NetCDF and BUFR);**
- **Level 2 products: MWI-ICI L2-LIW (NetCDF)**
  Cloud ice water path, mean ice particle size by mass and mean mass height (ICI)

Timeliness:

70 min. for global L1, 80 min. for global L2 EPS-SG

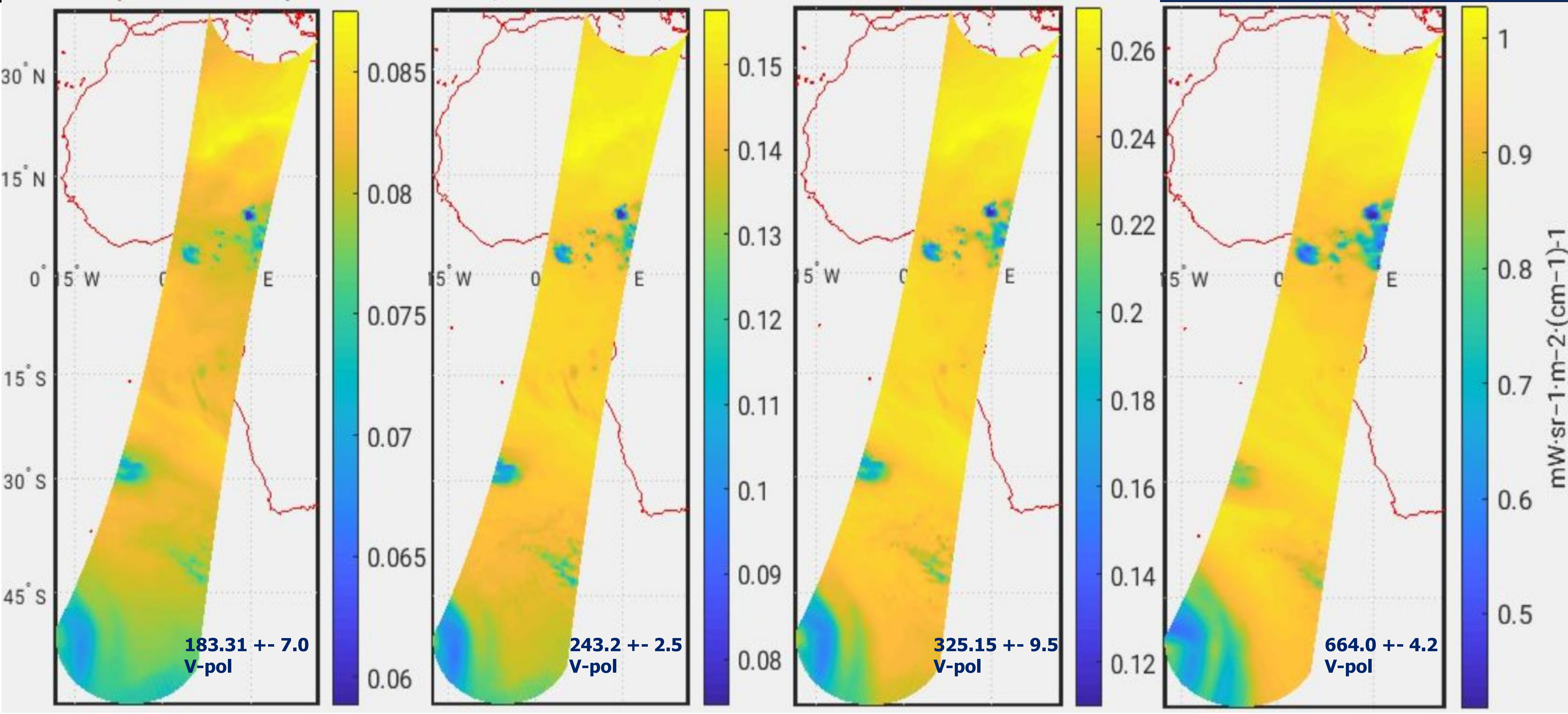
30 min. for regional L1, 40 min. for regional L2 EPS-SG

Coverage:

Global (through LEO missions)

In addition to the centrally generated products at EUMETSAT Headquarters, several L2 and L3 products are developed by the EUMETSAT Satellite Application Facilities (SAFs):

L1B Test Data : ICI Radiances
https://www.eumetsat.int/release-simulated-eps-sg-mwi-ici-test-data-2021



EUMETSAT

Benefit to global NWP

- All-sky assimilation of humidity and frozen hydrometeors
- From these primary geophysical sensitivities, 4D data assimilation infers the wind field; improves dynamical initial conditions, improves forecasts generally
- Model development and validation (ice microphysics; deep convection)

Observation operator preparation: focus on sub-mm radiative transfer

- Gas spectroscopy
  - WV lines, O3 lines, continuum
  - EUMETSAT workshop: Atmospheric Gas Absorption Knowledge in the Submillimeter: Modeling, Field Measurements, and Uncertainty Quantification, Mattioli et al., 2019, https://doi.org/10.1175/BAMS-D-19-0074.1
  - Reference model development: Turner and Saunders, 2019, Sub-millimetre Spectroscopy for AMSUTRAN. Part One: The Theoretical Basis, https://nwp-saf.eumetsat.int/publications/tech_reports/amsutran_1Thz_NWPSAF_report.pdf
  - Ongoing EUMETSAT-funded Met Office study: characterising bias and error in sub-mm spectroscopy using ISMAR (airborne microwave/sub-mm spectrometer)
- Cloud and precipitation: scattering radiative transfer (see later slide)
  - 3D models for frozen particles (ice cloud, anvil, graupel, hail, snow, melting particles) and databases of single-particle optical properties
  - Treatment of particle orientation and polarised scattering
  - Bulk optical properties: appropriate particle model choices and particle size distributions (PSDs)
- Move to radiance, not TB, radiative transfer (RTTOV-SCATT)
  - Actually, Rayleigh-Jeans is just as wrong at 89 GHz as higher – but only small errors

Observation operator preparation: focus on sub-mm radiative transfer

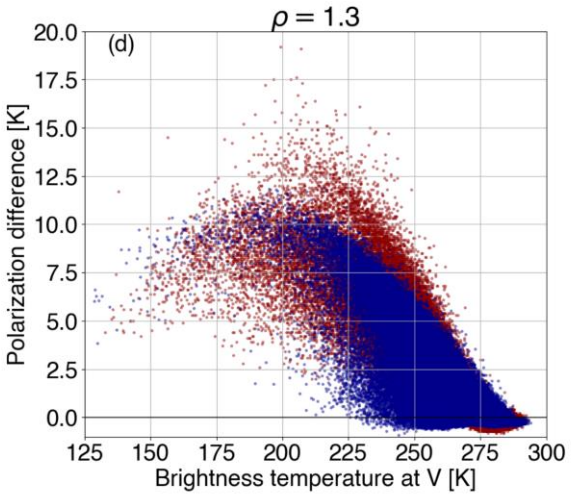
- Many channels have some sensitivity to the surface at high latitudes and high altitudes
  - Sea surface emissivity
    - TESSEM - Sea-surface emissivity parametrization from microwaves to millimetre waves, Prigent et al., 2017, https://doi.org/10.1002/qj.2953)
    - PARMIO - A Reference Quality Model For Ocean Surface Emissivity And Backscatter From The Microwave To The Infrared https://www.issibern.ch/teams/oceansurfemiss/index.php/contents/
  - Sea-ice, snow and land surface emissivity
    - Atlas? Very difficult
    - Dynamic emissivity retrieval at lower freqeuncies (e.g. 10 – 100 GHz) with physical extrapolation to higher frequencies?

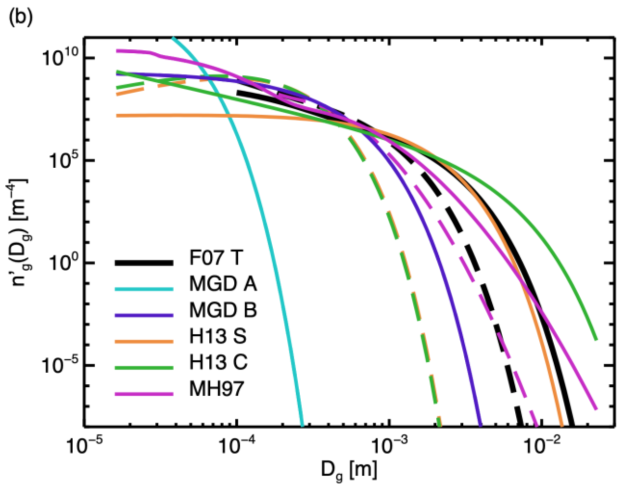
RTTOV-SCATT optical properties for v13.0

(Geer et al., 2021, Bulk hydrometeor optical properties for microwave and sub-mm radiative transfer in RTTOV-SCATT v13.0, submitted to GMD, https://doi.org/10.5194/gmd-2021-73)

First treatment of polarisation from oriented hydrometeors in a fast model

(work led by Chalmers University, Barlakas et al., 2021, https://doi.org/10.5194/amt-14-3427-2021)

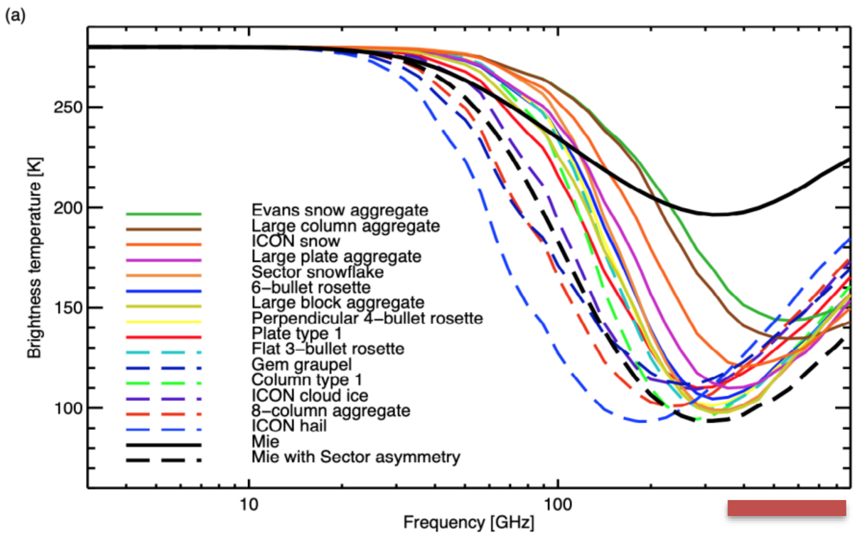




New particle size distributions (PSDs)

New ARTS database particle shapes included

(Eriksson et al., 2018, A general database of hydrometeor single scattering properties at microwave and sub-millimetre wavelengths, Earth Syst. Sci. Data, 10, 1301–1326, 2018 https://doi.org/10.5194/essd-10-1301-2018)



New capability at 350 GHz – 886 GHz to support ICI

How to assimilate ICI in NWP - superobbing

- All-sky assimilation at ECMWF currently uses an 80 km by 80 km superobbing
  - To match effective resolution of the forecast model (about 4x grid resolution; given the model is at ~8km resolution; this will need to be reduced in future)
  - To assimilate cloud features that are more predictable (spatial filtering)
  - To colocate channels, e.g. GMI low- and high-frequency channel sets (ECMWF assimilates L1C, not L1R GMI data)
  - Standardise the FOV across channels with strongly varying footprint sizes
- Possible ICI superobbing
  - Unify all channels onto a fixed grid, e.g. 39 km by 39 km
    - Around 20 raw observations per grid box.
- Combine with MWI into one 19 – 664 GHz “super-sensor”?
  - use low-frequency MWI channels in dynamic emissivity retrieval, QC, and observation error determination
  - represent inter-channel error correlations (e.g. shared, ~colocated 183 GHz channels)

Summary (bold: user preparations still to do?)

- ICI – to be launched 2024
  - Operational radiance measurements at 183 GHz – 664 GHz on Metop-SG
  - Co-flown with Microwave Imager (MWI) and scatterometer on B-satellite
- Test data in NetCDF available now
  - **BUFR format still in preparation** (aim: this year)
- Radiative transfer modelling (e.g. RTTOV-SCATT, **CRTM?**):
  - Sub-mm spectroscopy, error characterisation (**ongoing EUMETSAT / Met Office study**)
  - Ice hydrometeors (**shape, orientation, polarisation, PSD**)
  - Surface emissivity (ocean, **sea-ice, snow, land**)
- Data processing:
  - Possible ECMWF approach: **Assimilate L1B radiances with superobbing (e.g. 40 by 40 km) and combine into one super-sensor with MWI**
  - Alternative possibility: **Optimal convolution onto a single FOV**; to be part of L2 processing