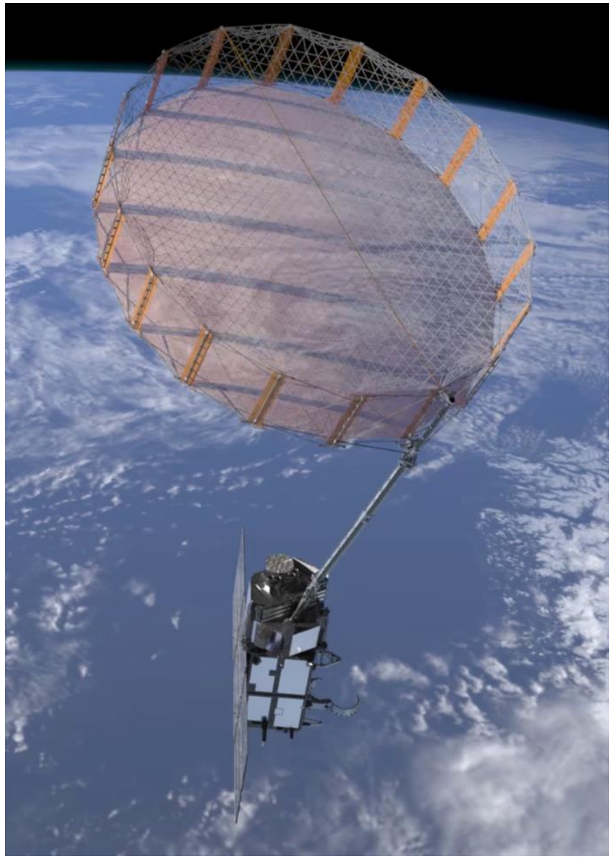
Sea Surface Salinity Retrieval Capabilities of the CIMR mission

Nicolas Reul & Joseph Tenerelli

& CIMR team members (ESA, Eumetsat, Estrellus, ..)

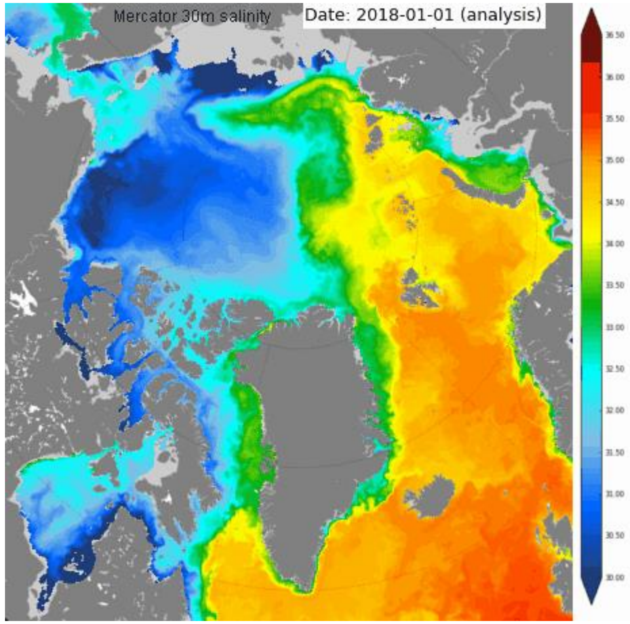


Ifremer

OceanDataLab

2026 Ocean Salinity Science & Technology Meeting

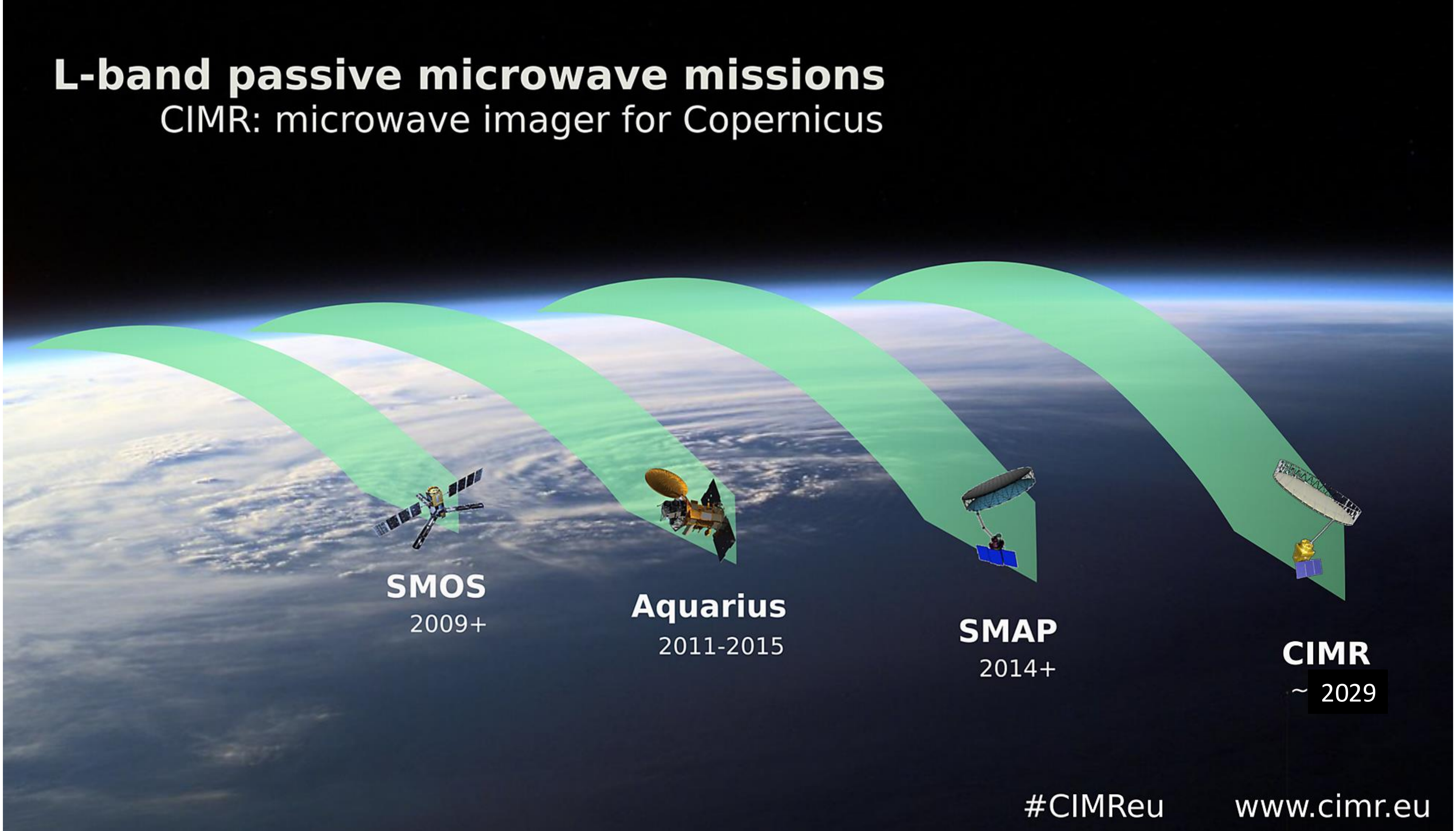
19-21 May 2026, Seattle, Washington, USA



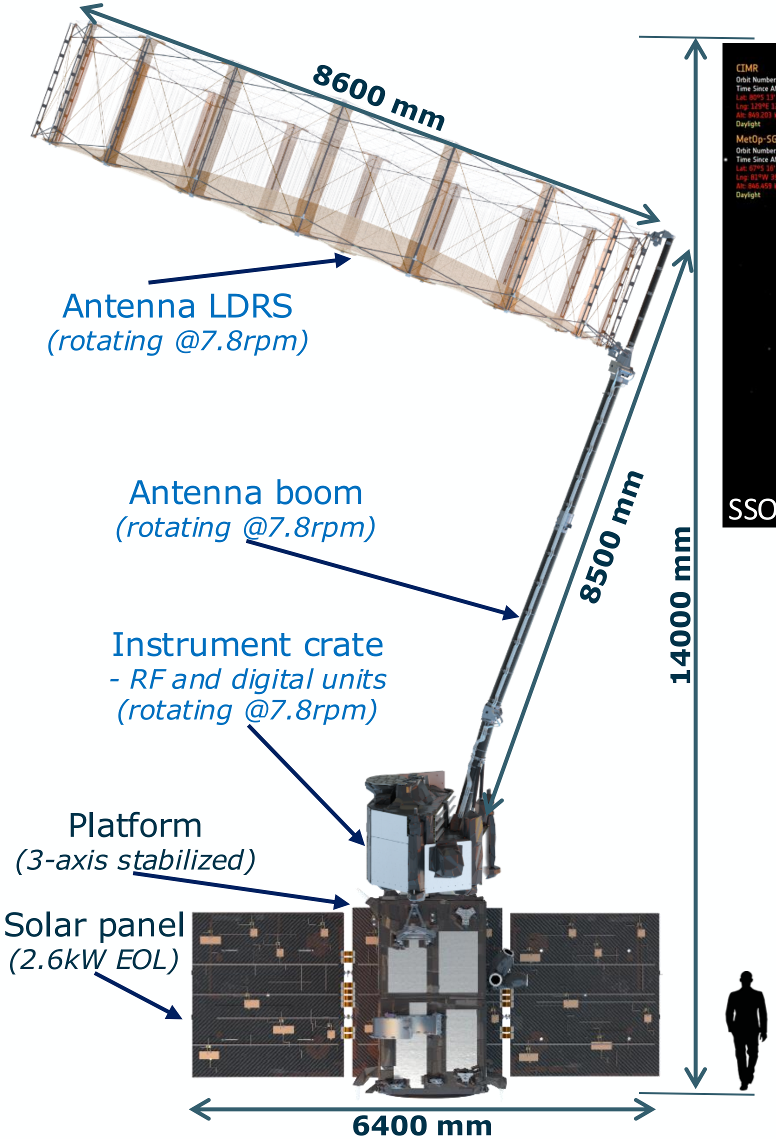
Copernicus
Europe's eyes on Earth

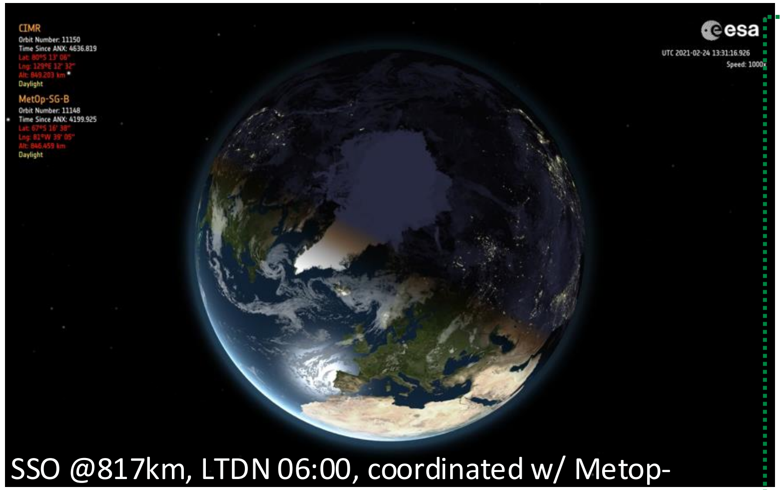
esa

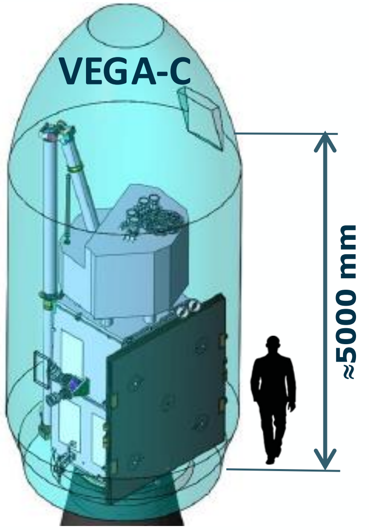
EUMETSAT


L-band passive microwave missions
CIMR: microwave imager for Copernicus
SMOS
2009+
Aquarius
2011-2015
SMAP
2014+
CIMR
~ 2029
#CIMReu
www.cimr.eu

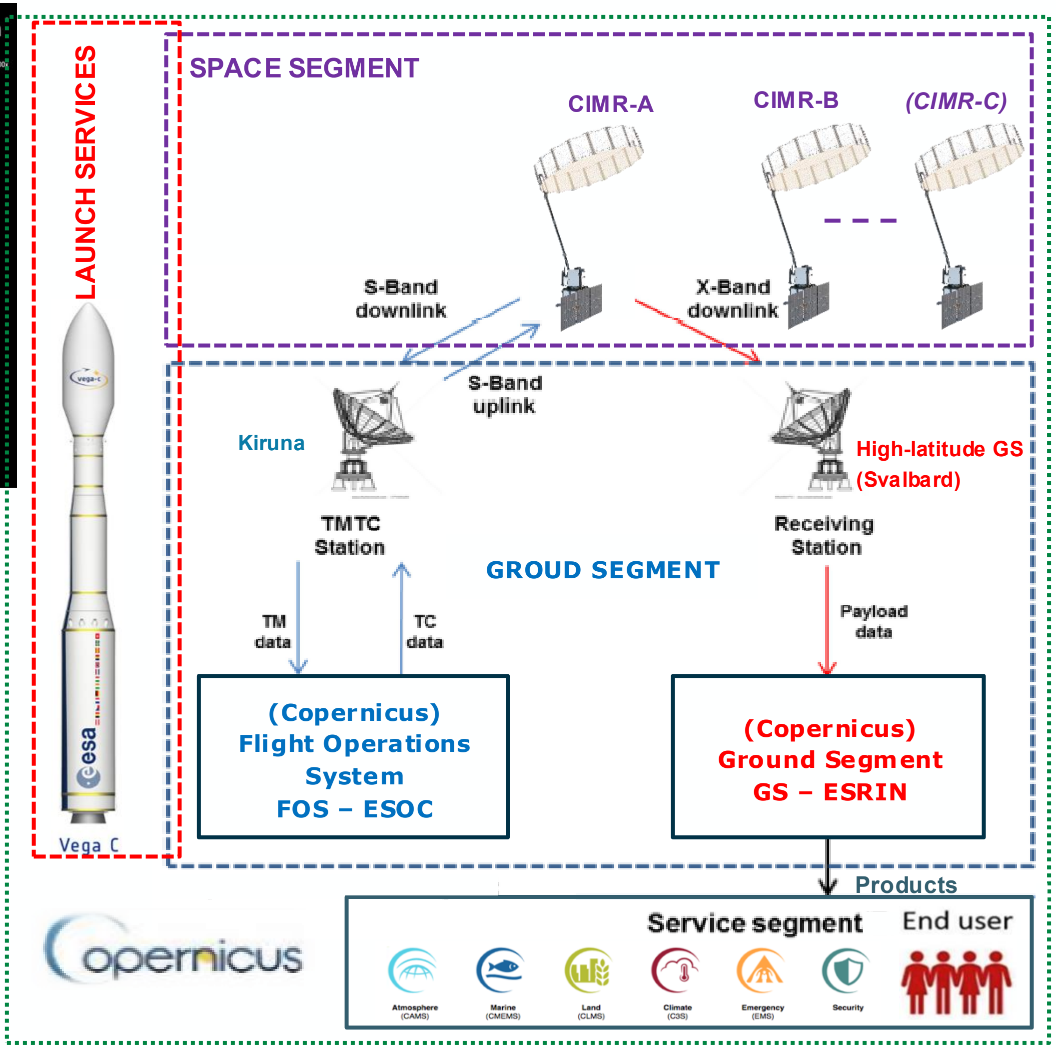
System at a glance







SC mass ~2.1 ton



CIMR Channel selection

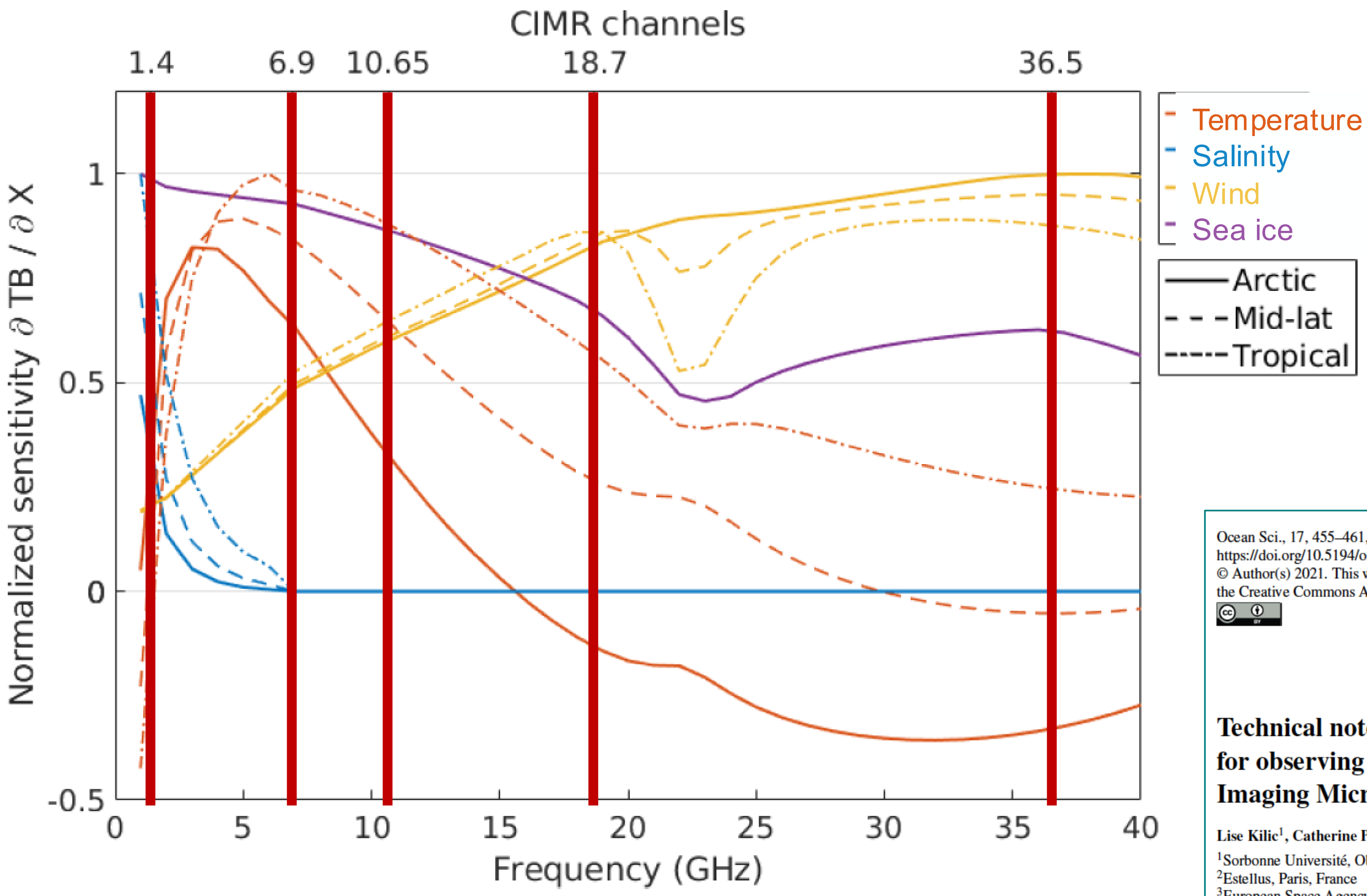
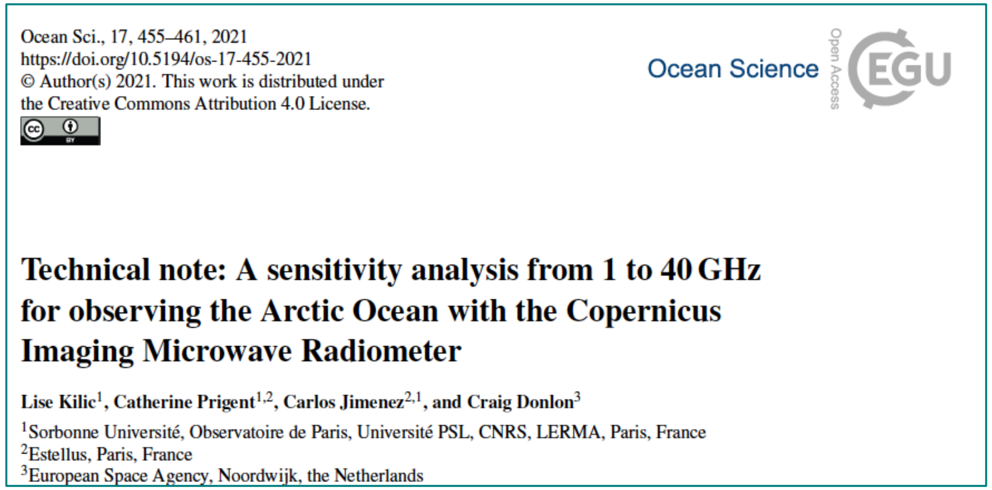


Figure 3 in Kilic et al. (2021). Normalized sensitivities of the satellite measurements to the surface parameters as a function of frequency for the different environments at 55 incidence angle, under clear sky conditions. Solid lines: Arctic. Dashed lines: mid-latitudes. Dotted lines: tropical.


Ocean Sci., 17, 455–461, 2021
https://doi.org/10.5194/os-17-455-2021

Ocean Science

Technical note: A sensitivity analysis from 1 to 40 GHz for observing the Arctic Ocean with the Copernicus Imaging Microwave Radiometer

Lise Kilic[1], Catherine Prigent[1,2], Carlos Jimenez[2,1], and Craig Donlon[3]

[1]Sorbonne Université, Observatoire de Paris, Université PSL, CNRS, LERMA, Paris, France
[2]Estellus, Paris, France
[3]European Space Agency, Noordwijk, the Netherlands

CIMR Mission requirements for SSS

Measure **Sea Surface Salinity (SSS)** over the global ocean from space with a target gridded spatial resolution of 40 km and uncertainty ≤0.3 pss over monthly time-scales

SSS

SST, Surface Wind Vector,SIC, SIT, SI drift,..

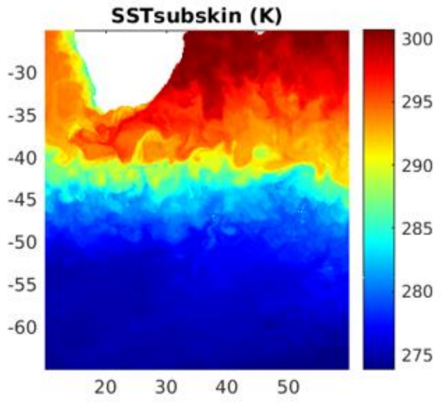
Channels (GHz, Full Stokes):	**1.4**	**6.9**	**10.65**	**18.7**	**36.5**
Resolution (km):	**<60**	**≤15**	**≤15**	**≤5.5**	**≤5** (g:4km)
NEΔT (K @150K):	**≤0.3**	**≤0.2**	**≤0.3**	**≤0.4**	**≤0.7**
Tot. Standard Uncertainty(K):	≤0.5	≤0.5	≤0.5	≤0.6	≤0.8
Swath width:	**>1900 km**				

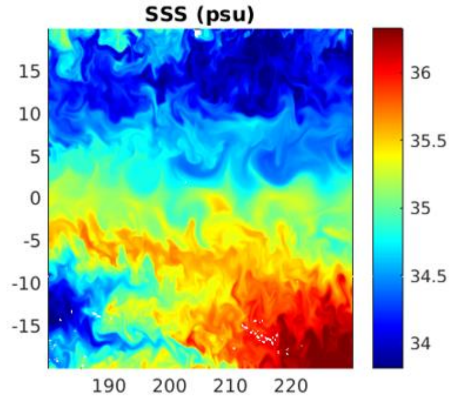
CIMR L2 Products – Global Ocean and Atmosphere

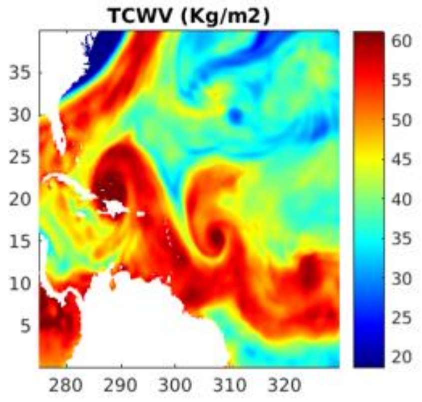
- EUMETSAT responsible for Global Ocean and Atmosphere L2 products.
    - Timeliness in near real time 3 hours, in addition to non time critical 30 days – starting from sensing time by the instrument.
    - Input is the ESA L1B product.
- Product format: NetCDF4

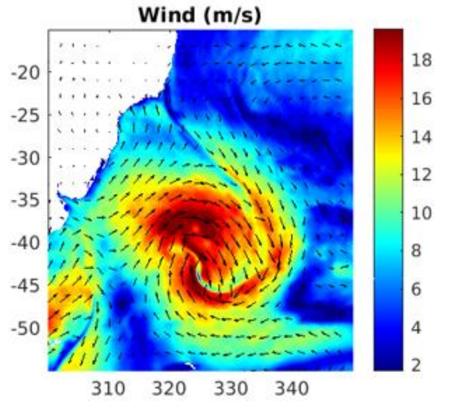
MRD requirements

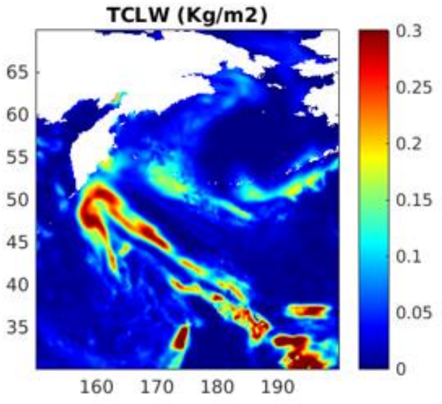
	L2 Variable ID	Description	Spatial resolution	Total standard uncertainty
Ocean	SST-O	Sea Surface Temperature	≤15 km	≤0.2 K
	SSS-O	Sea Surface Salinity	≤60 km (g=40 km)	≤0.3 pss
	OWV-O	Ocean Surface Wind Vector	≤ 40 km	2 ms-1 and ≤20° in direction at wind speeds ≥6 ms-1
Atmosphere	PCP-A	Precipitation rate	≤15 km (g=5 km)	≤80% at 1 mm h−1 or ≤50% above 10 mmh−1.
	LWP-A	Liquid Water Path	≤15 km (g=5 km)	≤50%
	TCWV-A	Total Column Water Vapour	≤15 km (g=5 km)	≤10%



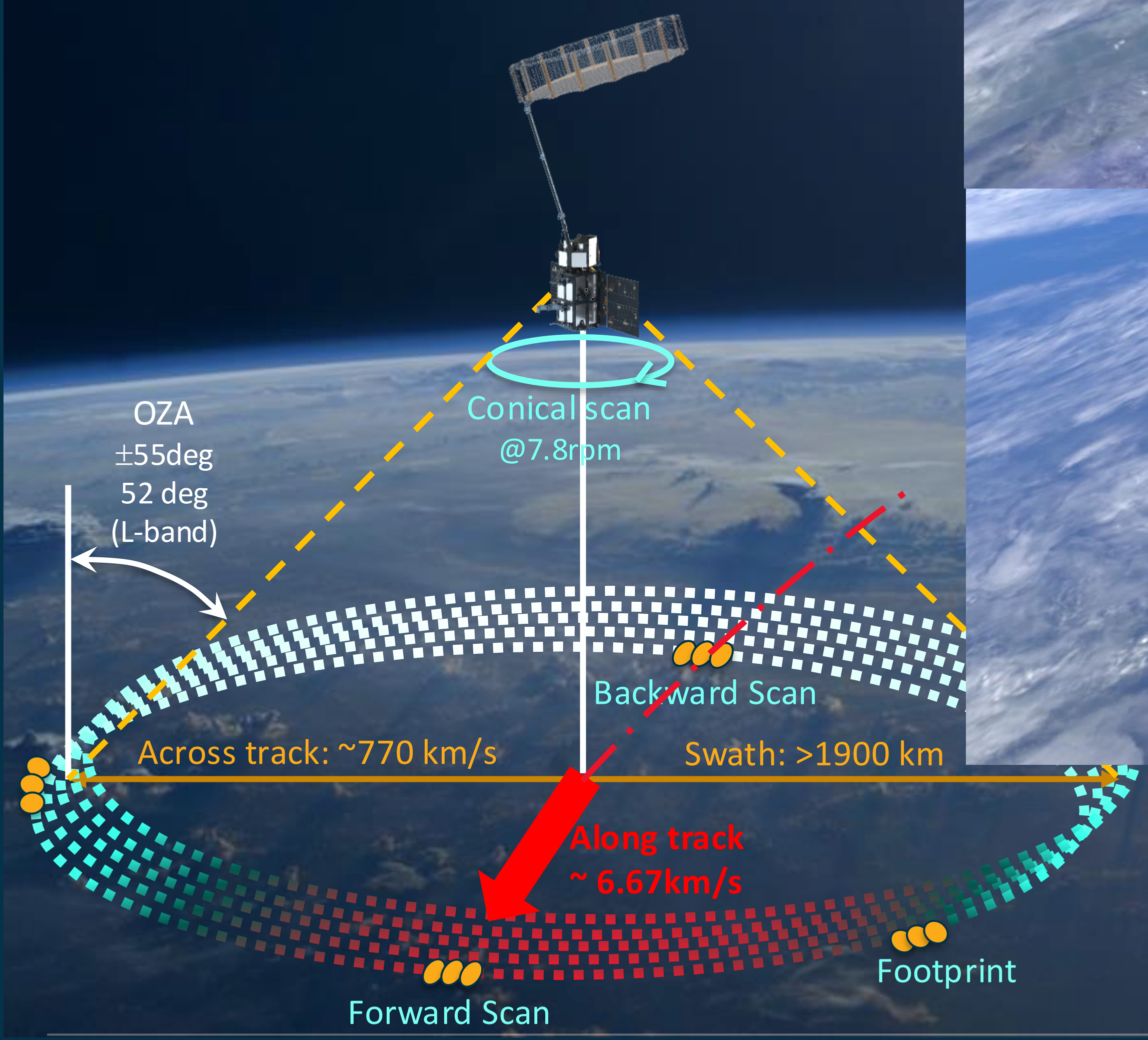


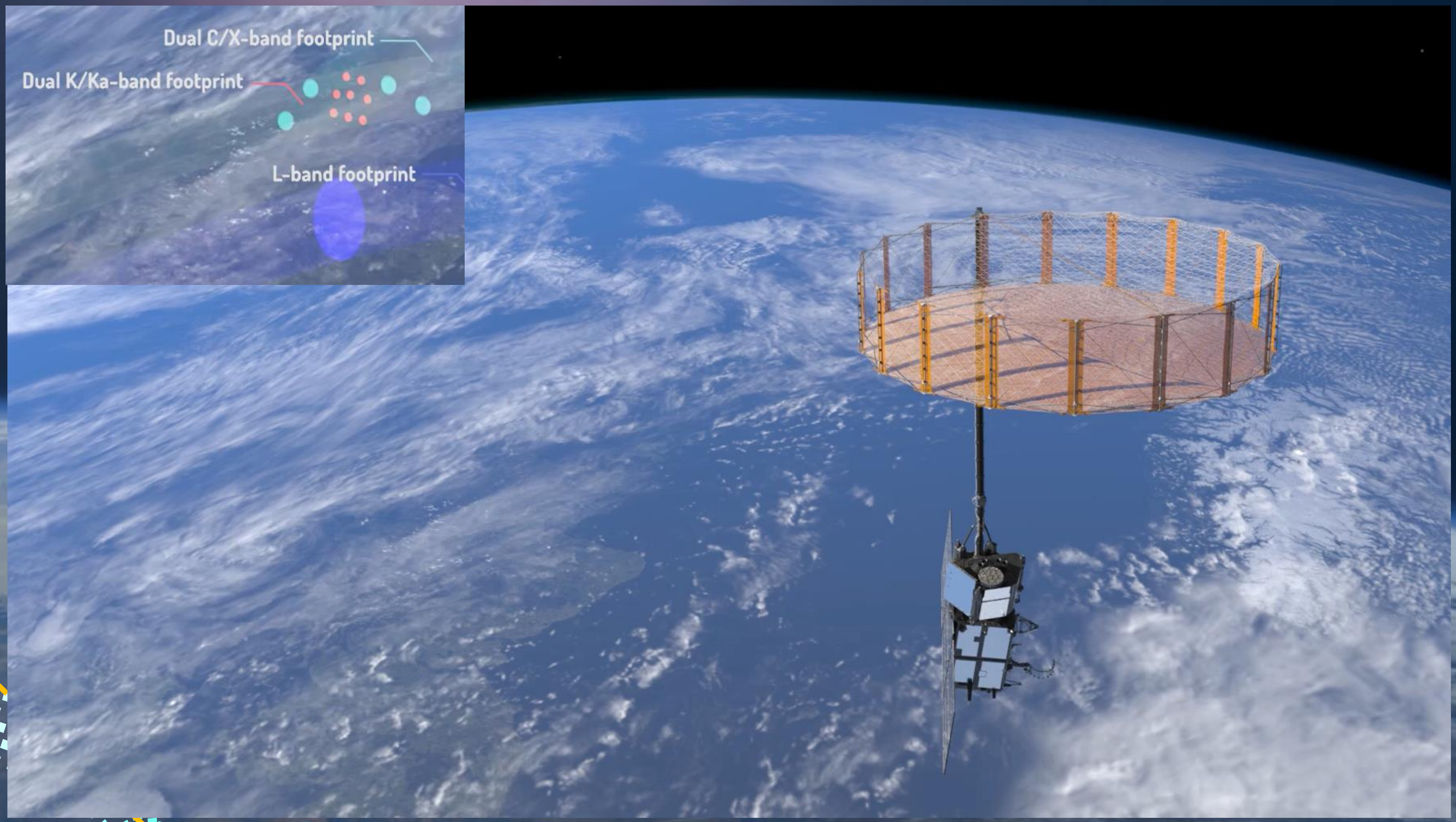




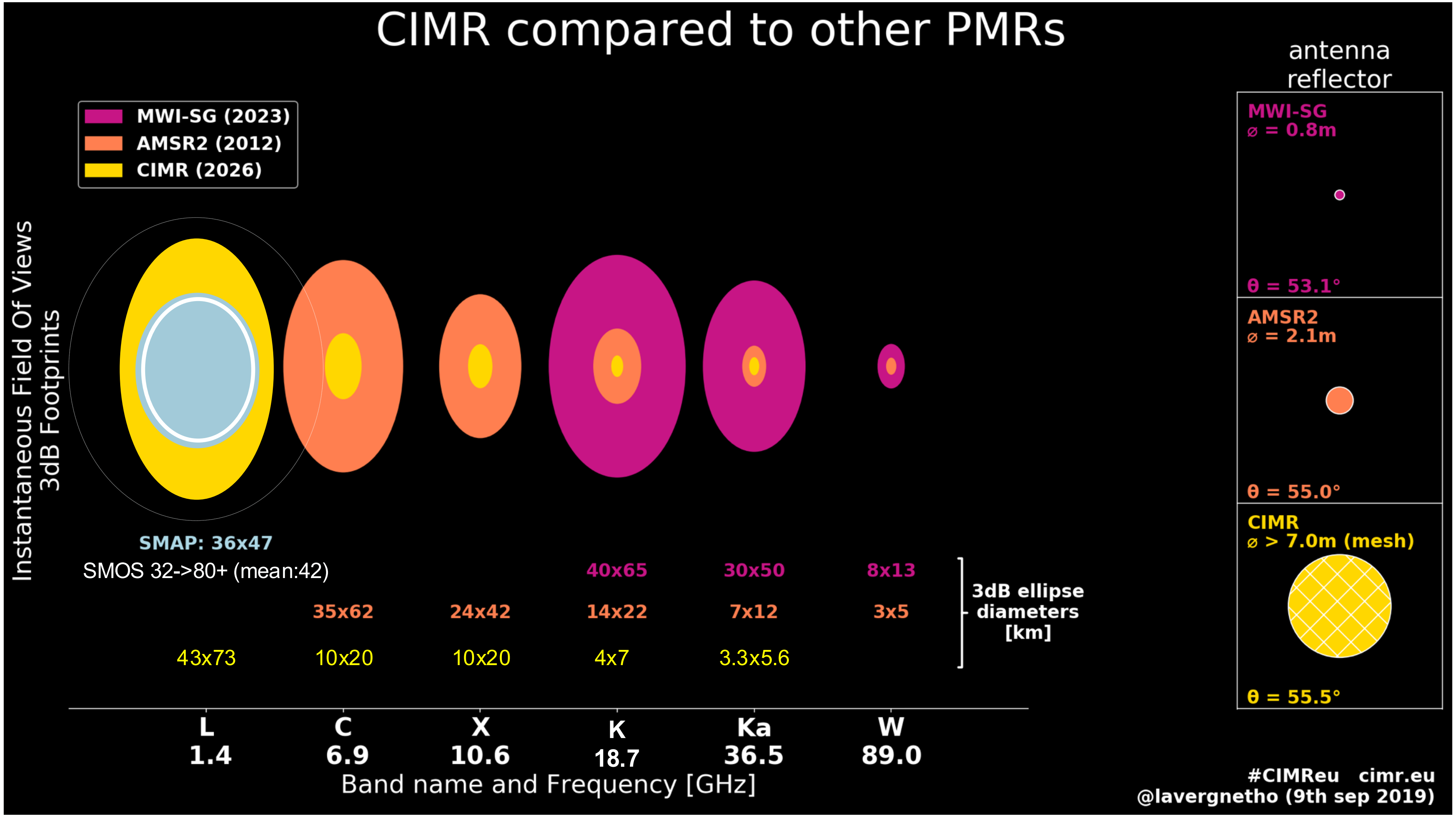


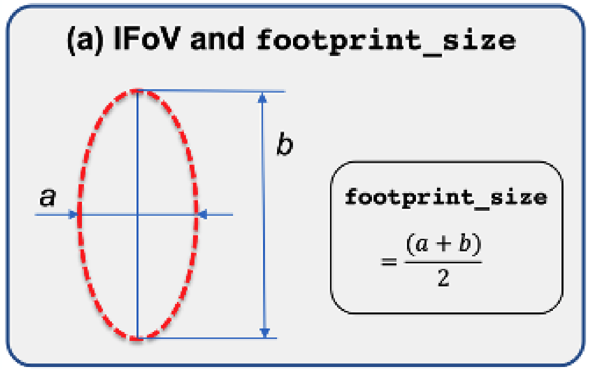
Imaging concept





CIMR -3dB projected IFoV and footprint_size





footprint_size:

L: <60 km
C: ≤15 km
X: ≤15 km
K: ≤ 5.5 km
Ka: ≤5 (g:4) km

we lose a bit of spatial resolution at L-band with respect SMOS & SMAP

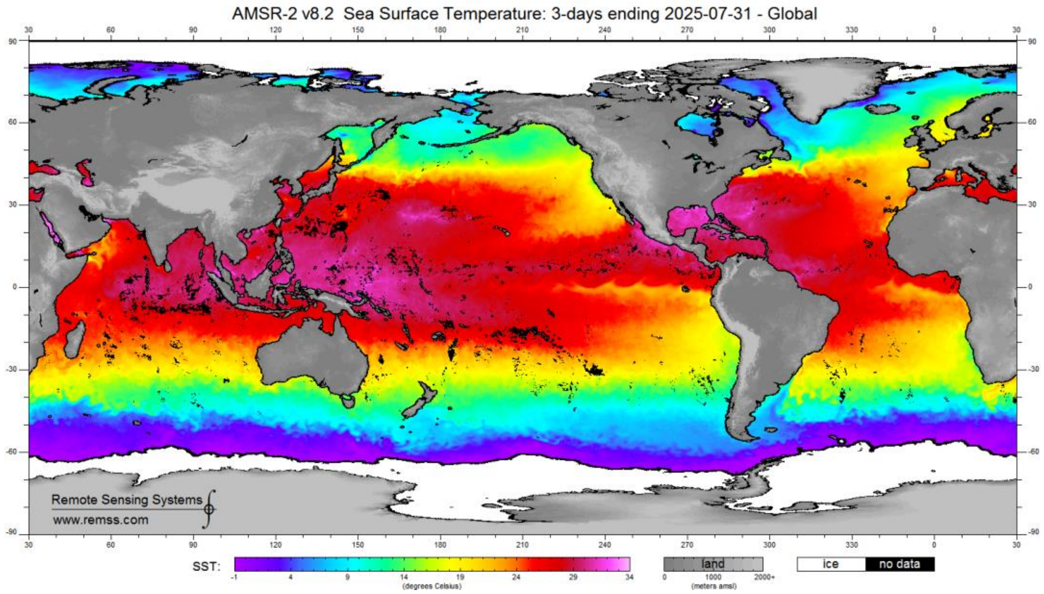
CIMR L-band 3dB footprint is 43 x 73 km

But we **gain in radiometric accuracy** & **spatio-temporal coverage**

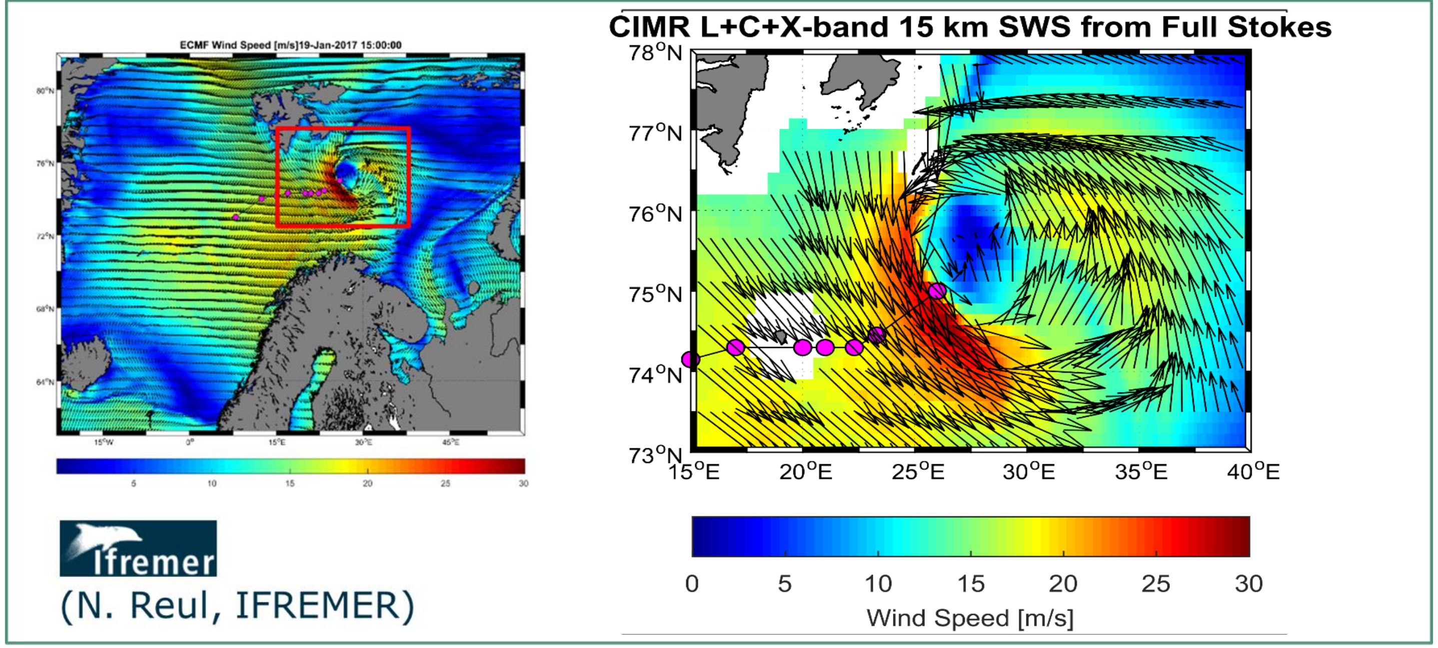
Instrument	Frequency(GHz)	Spatial resolution [km x km] (3-dB footprint size)	Earth Incidence angle (∘)	NeΔT*(K)	Polarizations	Swath Width (km)
CIMR	1.4 (L-band)	43 x 73 km	52°	0.3	H, V, 3rd & 4th Stokes	>1800 km
SMAP	1.4 (L-band)	39 x 47 km	40°	1.3	H, V, 3rd & 4th Stokes	~1000 km
SMOS	1.4 (L-band)	37=>60 km (synthetic beam)	0°-60°	1.5-4 K	H, V, 3rd & 4th Stokes	~1500 km

And we **gain colocated key auxiliary data for the SSS algorithm co-localized &retrieved from CIMR**

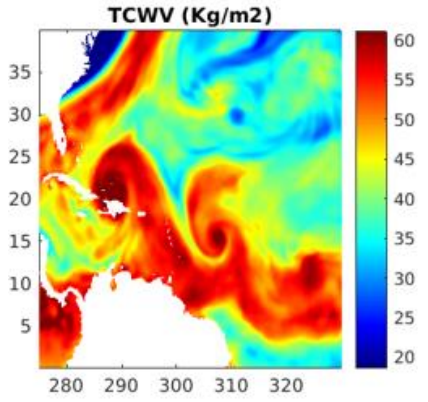
SST @ 60 to 15 km resolution



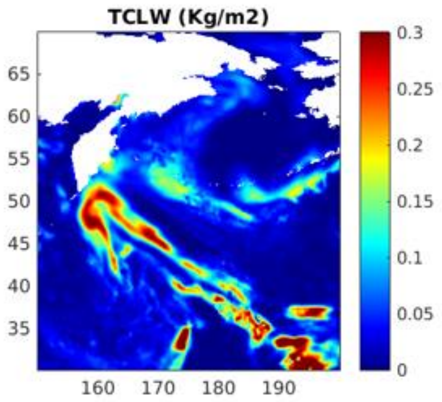
Surface wind vector @ 60 to 15 km resolution



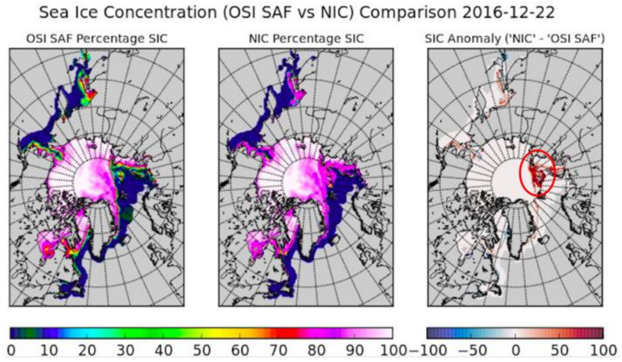
Total Column Water Vapour



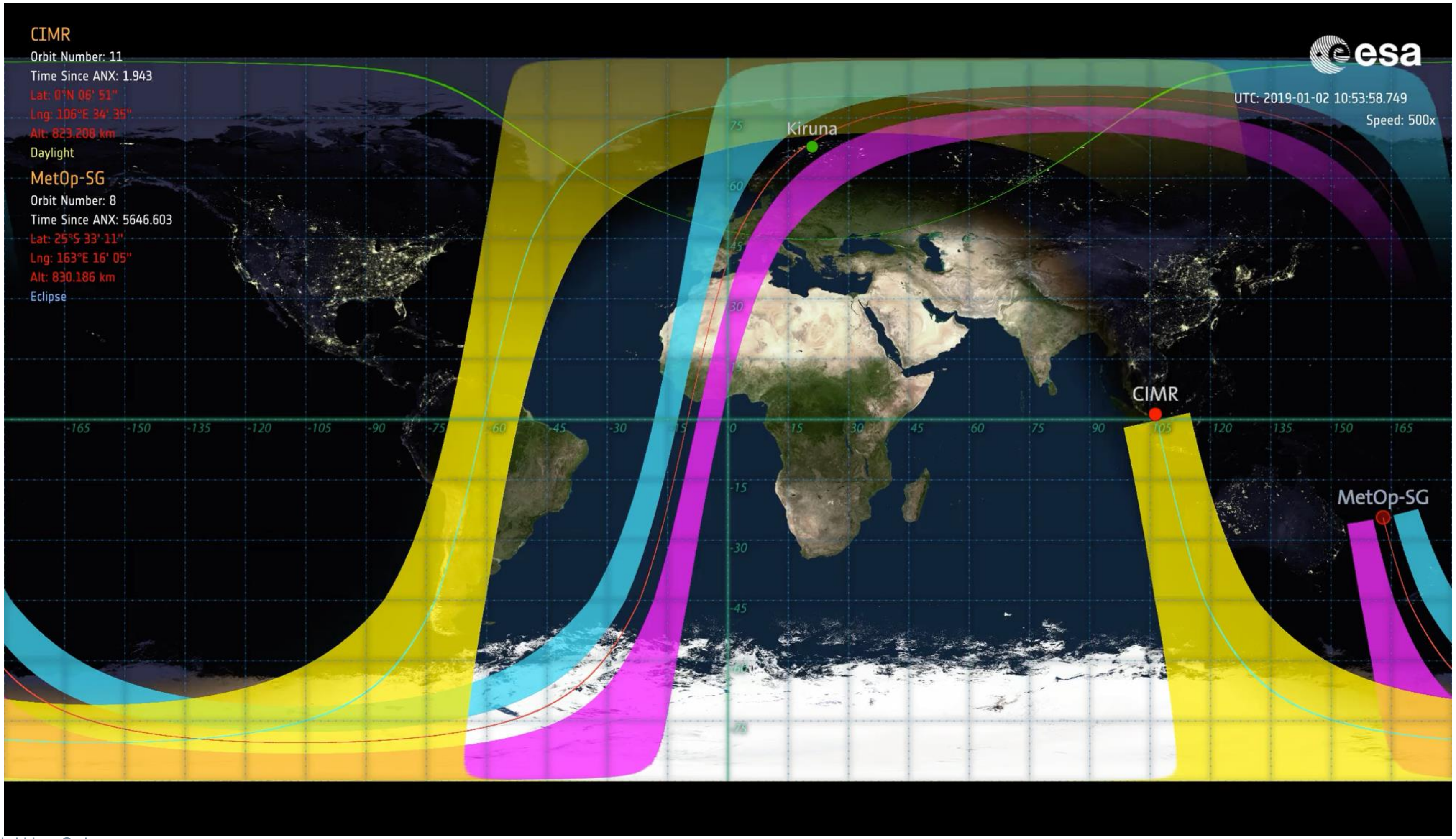
Liquid Water Path



+ Sea ice parameters (SIC, SIE, Drift, thickness, type, etc..)



Interleaved CIMR and MetOp-SG(B) orbits to support ocean wind vectors coverage in 1 day: less than 10 min around CIMR Tbs in the poles

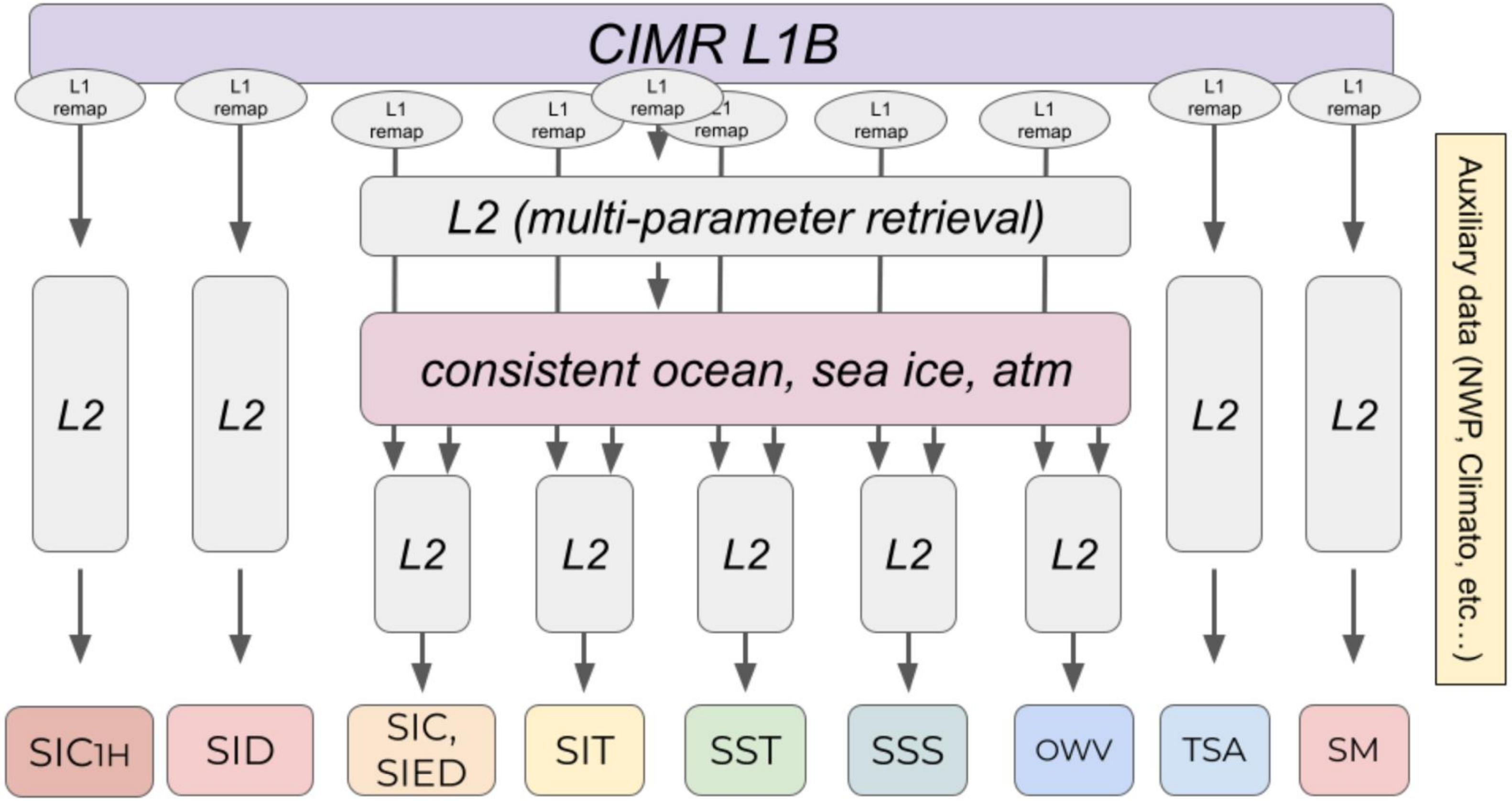


RFI: ITU issues and approach

- **L-band:** Important to have a very well defined channel selectivity (bandpass and receiver) centered in the Earth Exploration Satellite Service(EESS)passive band 1400-1427 MHz (SMOS/SMAP experience show RFI from strong radars in adjacent bands).
- **C-band:** ***EESS(passive) is weak and we cannot claim protection***. AMSR-xx shows significant RFI
- **X-band:** heavily used by the GEO/NGEO Fixed Satellite Service (FSS) on a primary basis and European video links.
- **Ku-band:** sharing regulatory constraints of EESS(passive) and the FSS downlinks. FSS (s-E) has allocation in the range 17.3 to 21.2 GHz, allocation to EESS(passive) falls in the middle.
- **Ka-band:** Powerful RADARS (e.g. KREM) operating in the lower adjacent band. can blind, even damage, the receiver. The FSS(downlinks) operate above 37.5 GHz and are target for development of future LEO mega-constellations.
- **Solution: Channel selectivity is important with detection and mitigation using on-board processors.**

CIMR Products Consistency

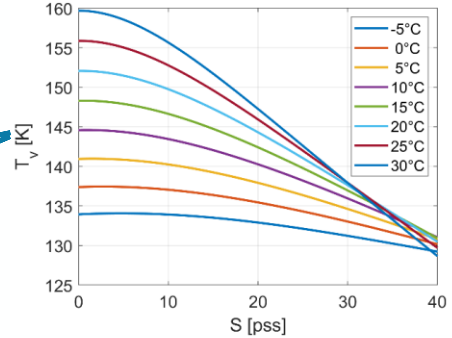
- The Multi-Parameter-Retrieval (MPR) is adapted for CIMR
- Several ATBDs for L1B to L2 are written
- Plan: each individual parameter retrieval can access the consistent MPR results as prior if needed



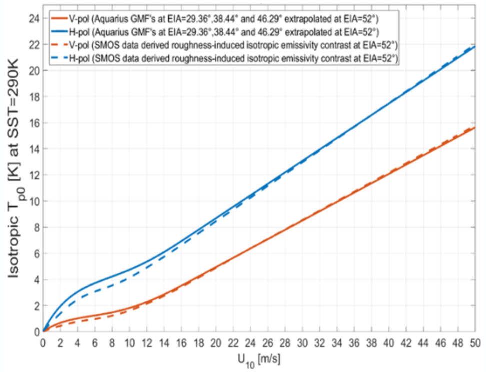
Norwegian Meteorological Institute, University of Bremen, Ifremer, Universitat de València, DMI, Finnish Meteorological Institute

SSS retrieval algorithm for CIMR

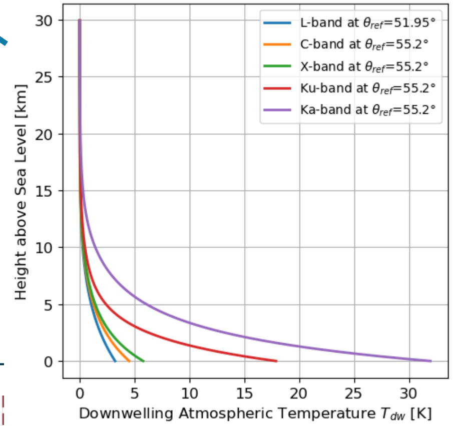
Sea water dielectric cst
Boutin et al (BVZ,2023)



GMF from SMOS data @ 52°



Atmospheric impacts (MPM 1993)



Auxilliary Data (first guess):
Surface Wind vector, SST, SSS,
Atmospheric parameters:T(z), …

L2 SST^p
SSS^p

Seawater L-band dielectric constant estimate

Flat sea surafce Brightness Temperatures
T_{Flat} (h,v,U,V)

L2 U^p_{10},Φ^p_w

Add Surface Roughness Effects

Sea-Surface Total Brightness Temperatures
T_{Surf} (h,v,U,V)

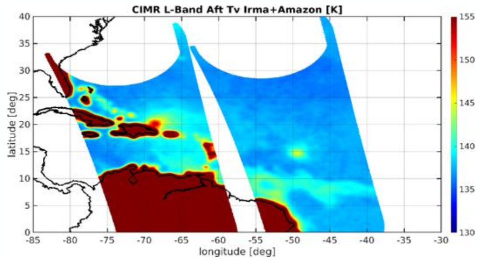
ECMWF P_{surf}, Tair, CWV

Add atmospheric contributions
(O_2, cloud and H_2O Absorption)

Sum of the Forward model solutions
Four Stokes L-band parameters aft and fore views

Top of the Atmosphere RTM
(surface pol basis)

Iterations



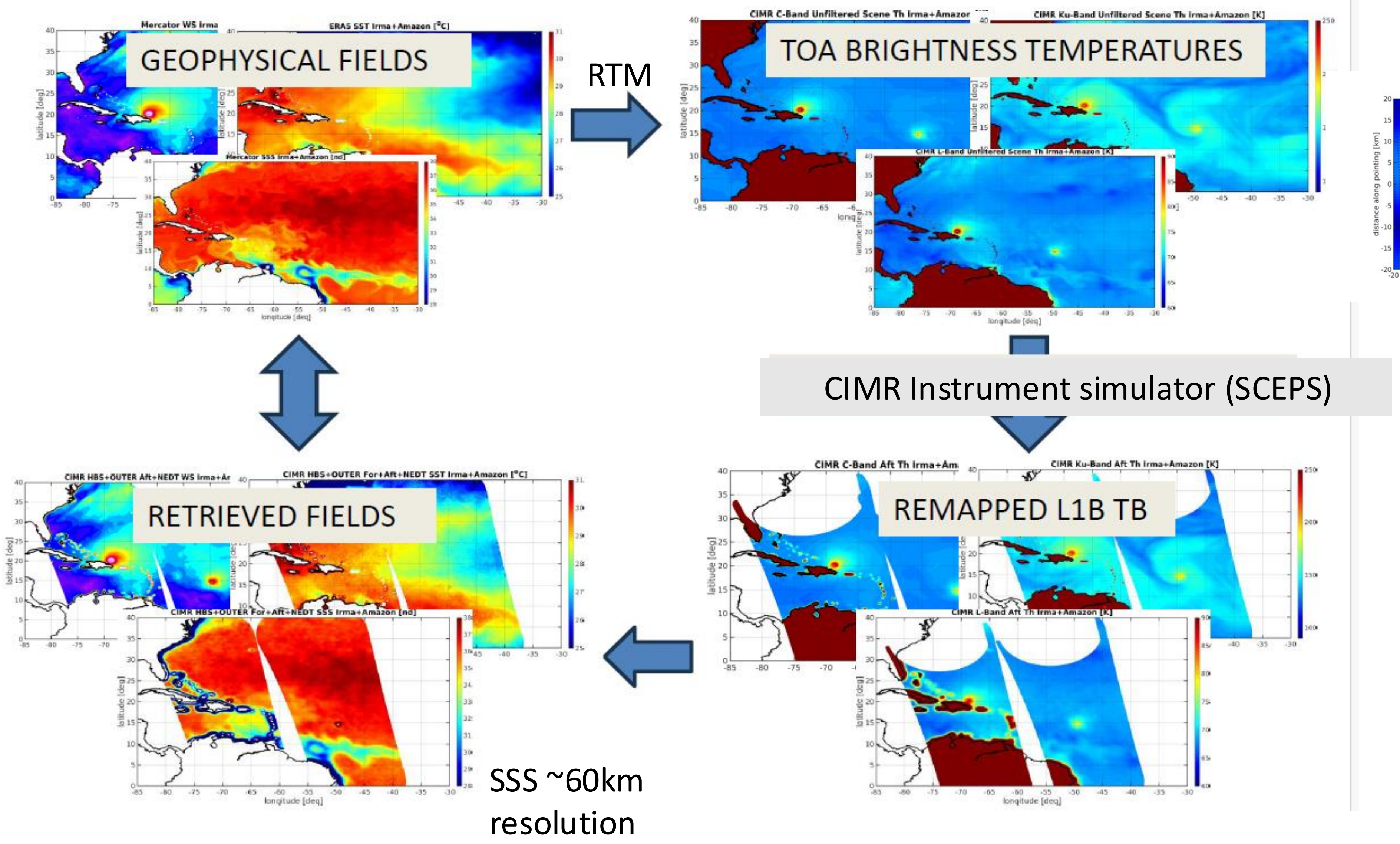
CIMR Level 1C resampled TOA
Four Stokes L-band parameters
aft and fore views
(surface pol basis)

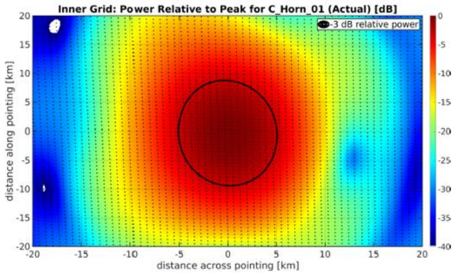
Maximum Likelihood
Inversion Method

L2 SSS
aft and fore views

Corrected for solar & Sky radiations
& Faraday rotation & RFI filtered

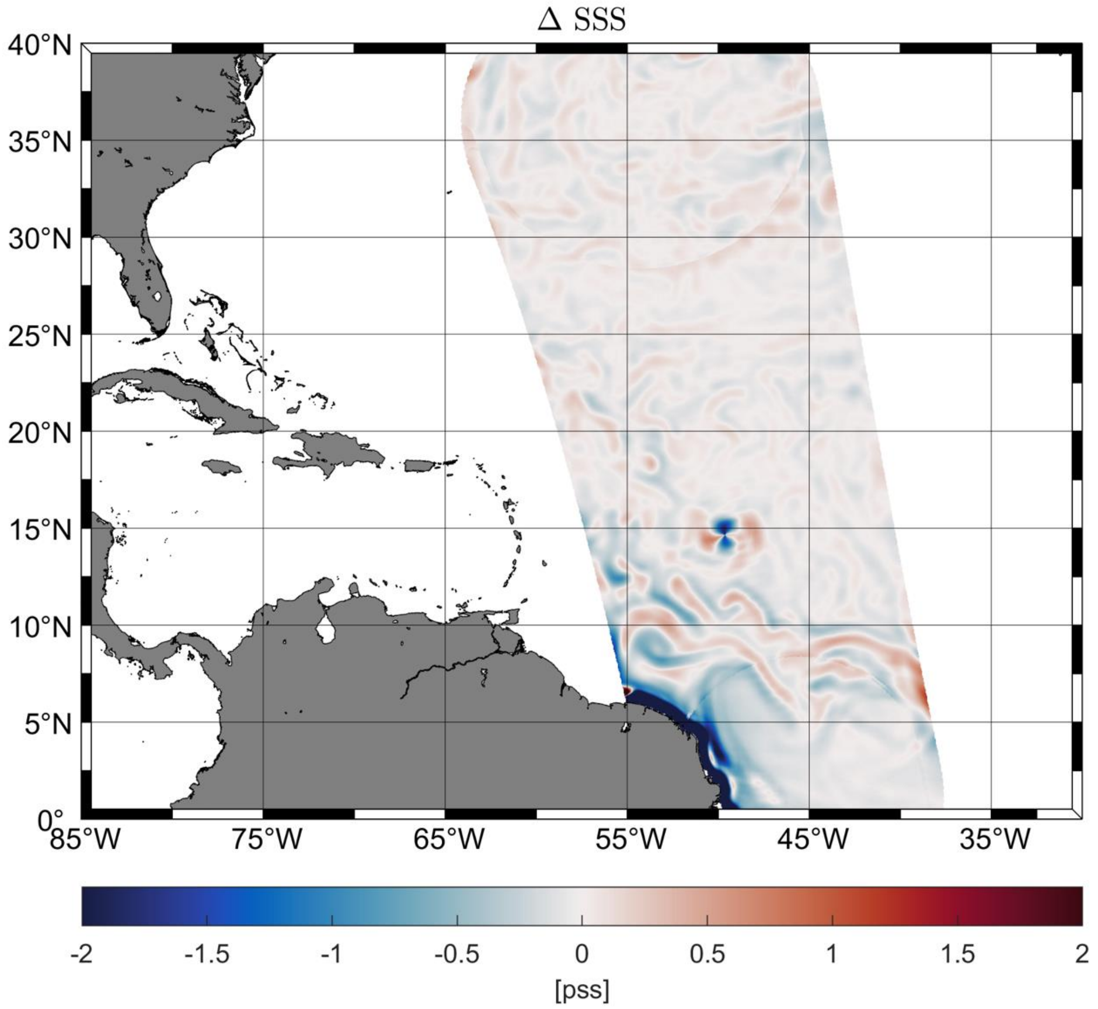
SSS retrieval simulations for CIMR

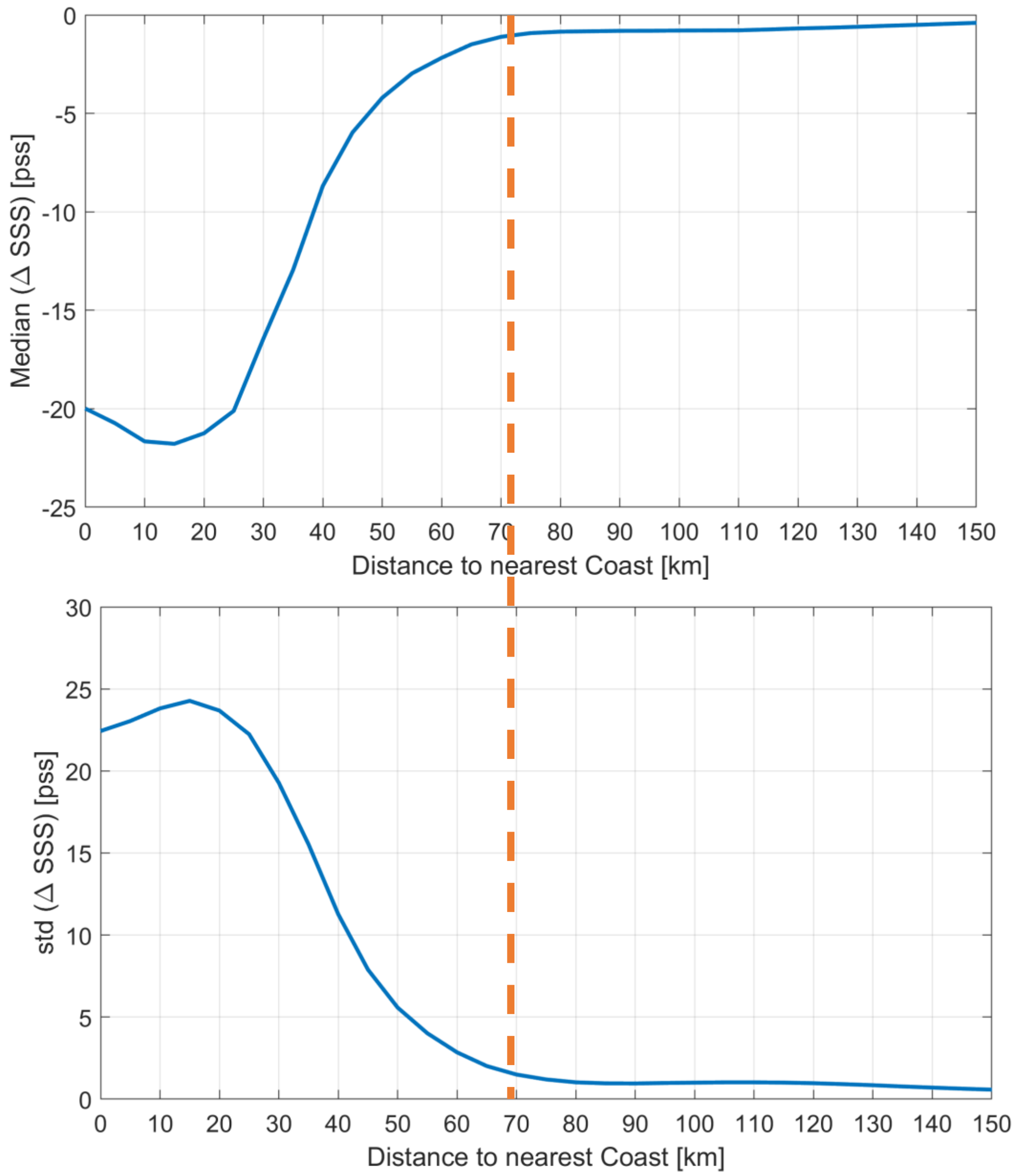




Integrated over
full antenna patterns
+ NEDT
+resampled
Aft & Fore views

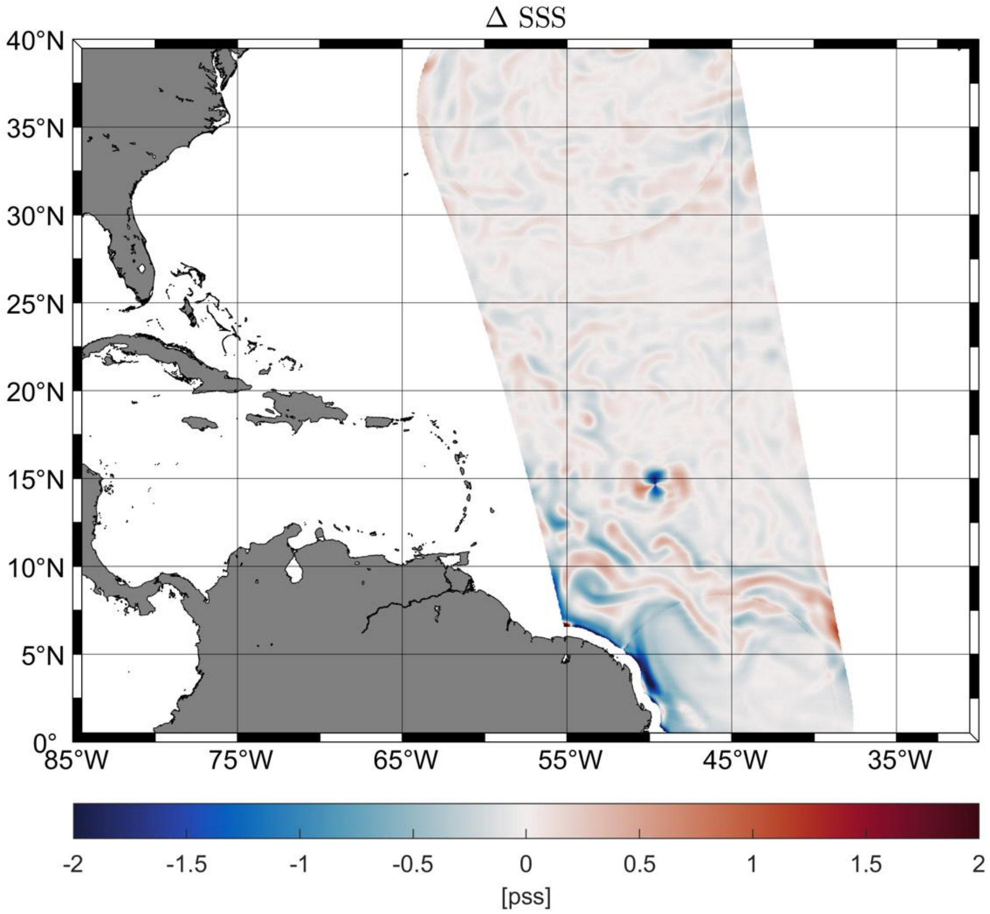
SSS Retrieval: land Contamination

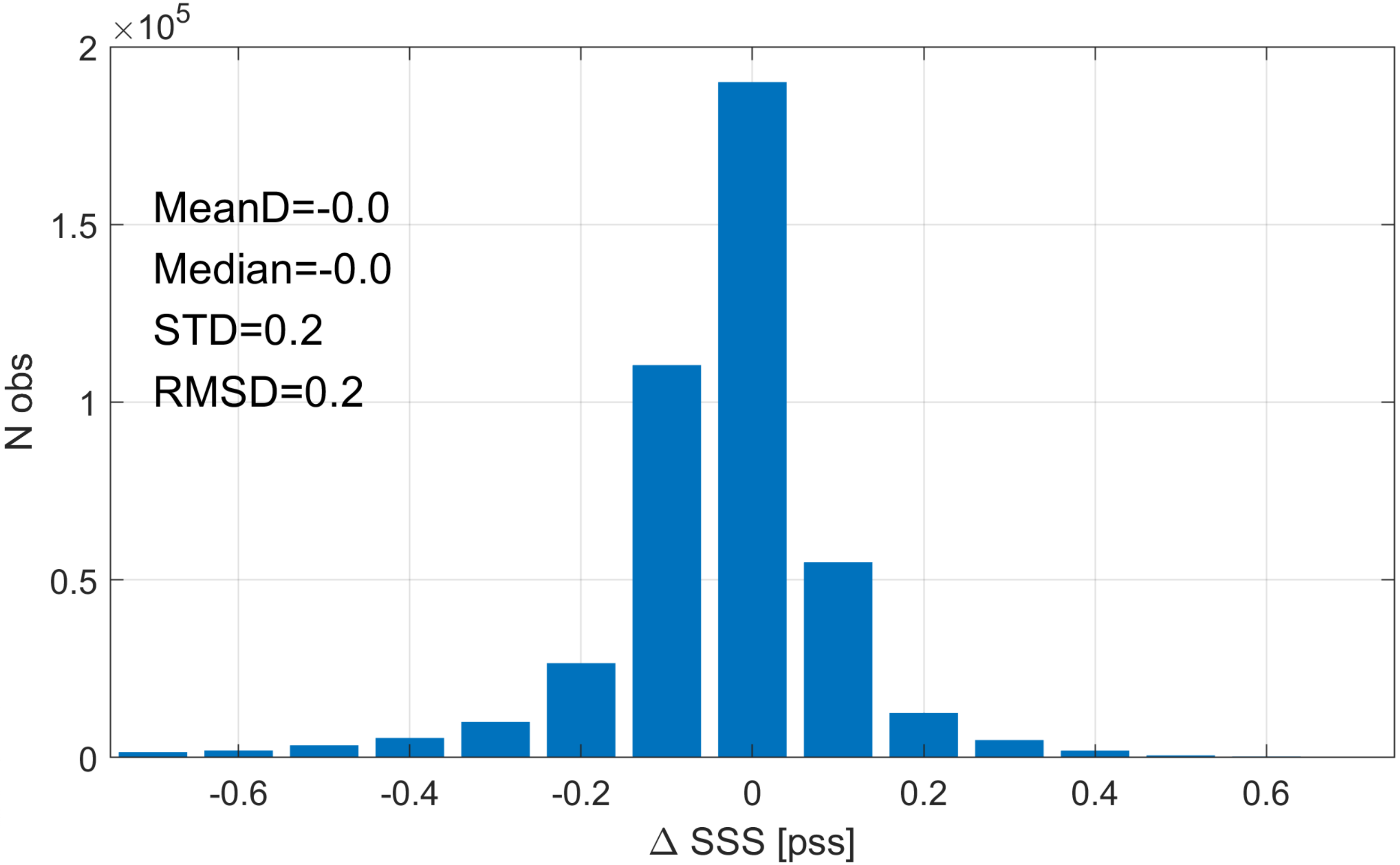




Significant Land contamination observed within ~70 km from coasts => impact of land Tbs in sidelobes & main lobe

Step 6 :SSS Retrieval: after land Contamination Filtering (distance to coasts > 70 km)





High resolution features (North Brazilian current induced SSS fronts and TC center) not well resolved by the ~60 km resolution L-band footprint

Major souces of SSS retrieval errors in cold waters

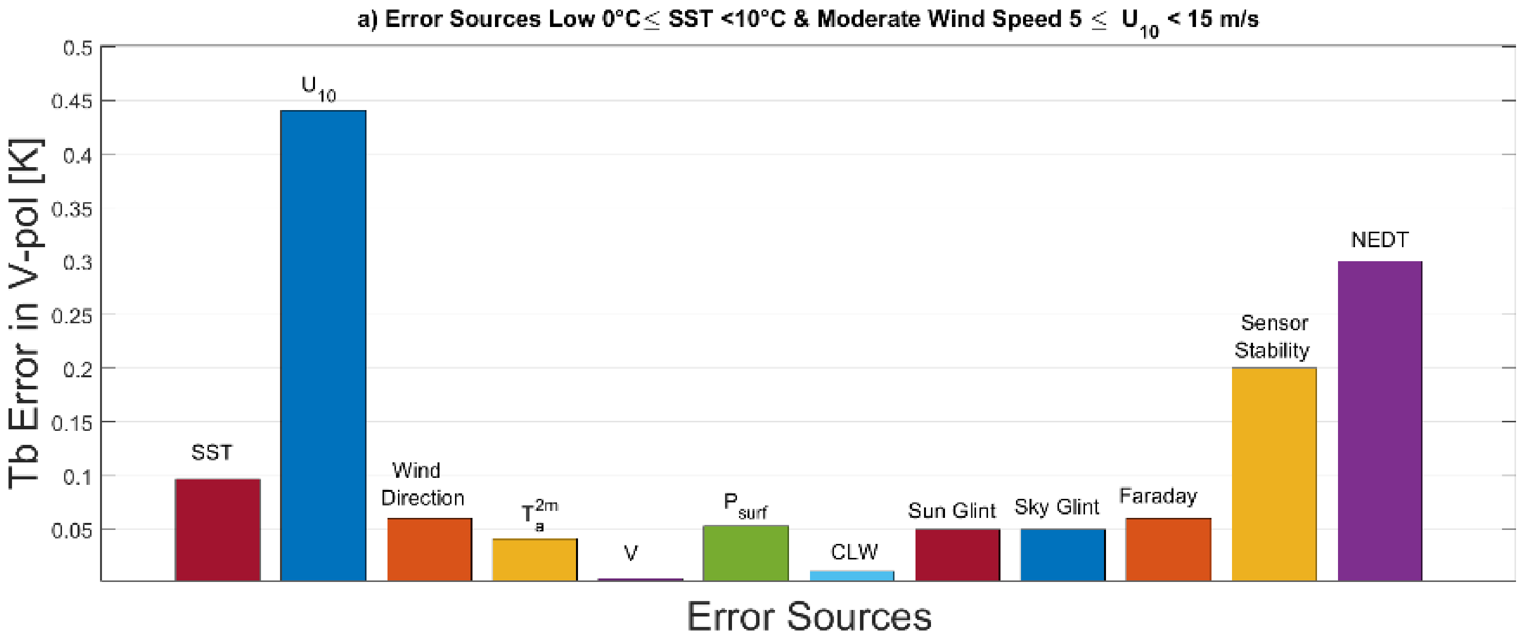


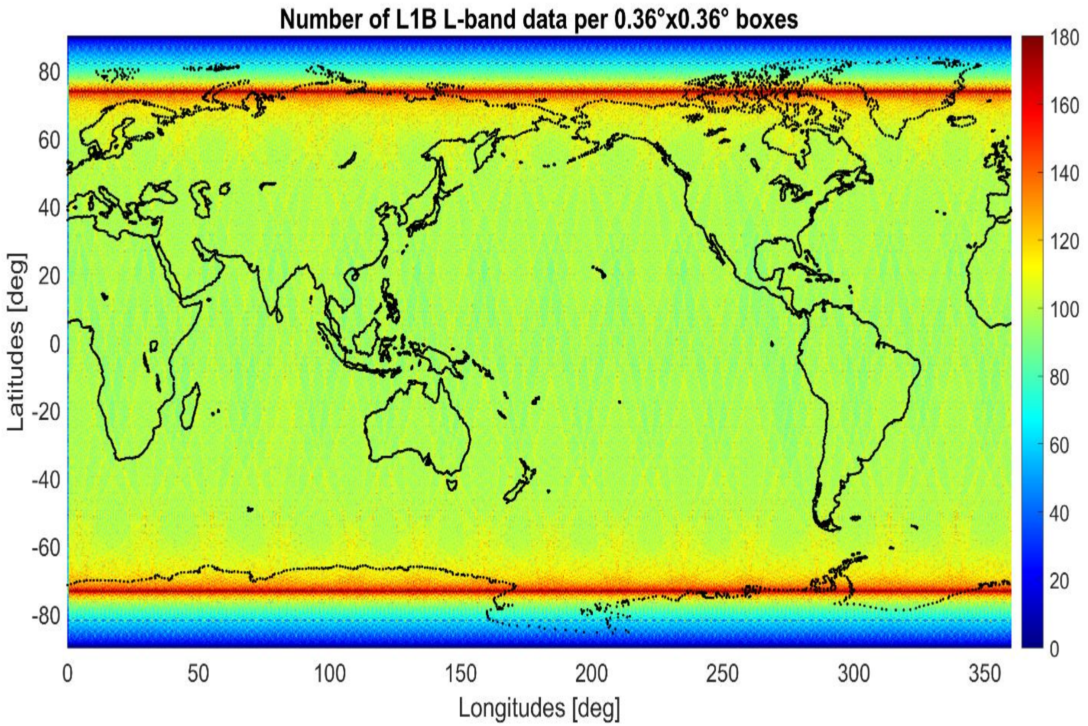
Figure 34: *Distribution of uncertainties in the modeling of the V-polarization L-band Tbs at incidence angle of 52° in a) cold sea condition and b) warm sea conditions. The wind speed is moderate with 5 m/s* $\leq U_{10} < 15$ *m/s.*

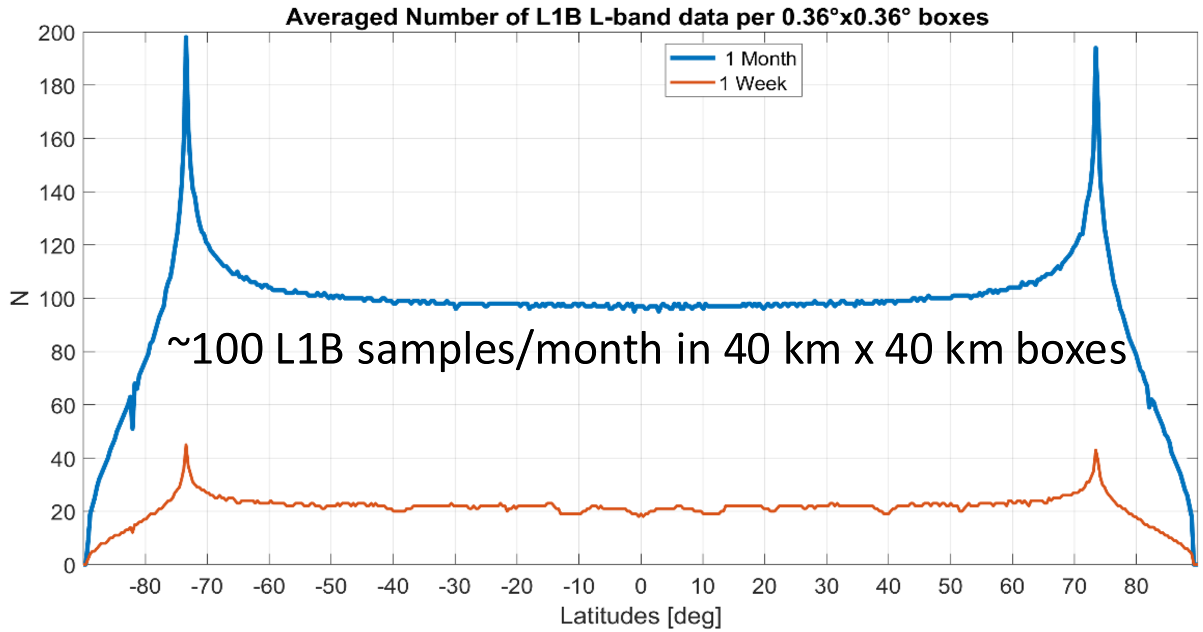
In reality, uncertainties on auxilliary data and corrections will be source of retrieved SSS errors

In V-polarization, the **expected accuracy of instantaneous retrievals ranges from ~0.9 pss to ~3.5 pss in polar waters** depending on wind speed and SST conditions.

Far away from coasts & ice-edges, dominant sources of errors are uncertainties in **wind speed, NEDT and sensor stability**

Monthly Number of L1B data in 40 km^2 boxes





The number of independent L1B samples required to reduce the error to 0.3 pss after temporal averaging has been evaluated

⇒ It is about 50 for very cold waters (with V-polarization data) and

⇒ diminishes to ~5 passes for Tropical regions.

One month sampling with the CIMR polar-orbiting L-band instrument results in about 100 passes.

This suggests that a monthly averaged SSS of 0.3 pss is clearly achievable at distances > 70 km from coasts and ice edges

Summary:

- The **CIMR mission will provide a unique set of wide swath (1900 km) data** having global coverage and no hole at the pole with near daily (95%) coverage.
- **Spacecraft is now in phase PHASE CD**
  - ✓ Space Segment is **composed of 2 spacecraft (A & B)** and **1 optional (C)**
  - ✓ **CIMR-A is set to be launched in 2029**
- The mission focus in on **Polar Regions where up to 8 daily passes** covering the European regions above 60Deg N are available.
- **Ensured continuity of L-band passive measurements of the ocean surface**
- **Improved SSS retrievals in weaker sensitivity high latitudes thanks to high repetitivity and concomittant measurements of SST, Surface wind vector, SIC**, etc..
- **15-40 km resolution wind vector capability**
- Air-sea interaction studies: first instantaneous & concomittant measurements of spaceborne surface density, wind and ice estimator
- Will have **limitations because of**
  - ➢ **moderate spatial resolution** from ~40 km (L3 monthly) to 60 km (L2)
  - ➢ **land/ice contamination** (~70 km and ~30 km from land/ice borders for sss and wind, respect)

    => Can be mitigated using side-lobe corrections (Olmedo et al 2017; Meissner & Manaster, 2021)
  - ➢ **sun & sky glint** will be an issue at high latitudes in the Northern hemisphere for SSS retrievals,
  - ➢ Sky & sun glint can be mitigated thanks to aft/fore view differences
- **Continuity of many products from SMOS, SMAP, AMSR2/3 is assured until 2045+ using two satellites to be launched sequentially CIMR-B will be launched after CIMR-A**

Spare slides

EUMETSAT L2 algorithms for Global Products

Courtesy: Robin Ekelund, Eumetsat

A “cascade” multi-parameter, multi-frequency, multi-scale algorithm, using a physically-based Optimal Estimation retrieval Method (OEM)