

Recent experience with RFI in data assimilation for global Numerical Weather Prediction

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WMO-ITU Global Seminar on Spectrum Use for Meteorology

September 2026



Outline

- **Summary up front**
- **Current exploitation of spectrum**
 - Can we identify possible RFI?
 - Can we mitigate possible RFI?
- **Where we are going**
 - Higher and lower – Sub-mm bands and L-band
- **Conclusions**

Summary up front

Weather forecasts **save lives, property and livelihoods.**

Weather forecasts **rely on numerical weather prediction (NWP) models**, especially several days in advance.

NWP **relies heavily on satellite data.**

The most critical satellite data for medium range weather forecast are microwave observations that **need clean radio frequency spectrum.**

So meteorological spectrum allocation (EESS) saves lives, property, and livelihoods.

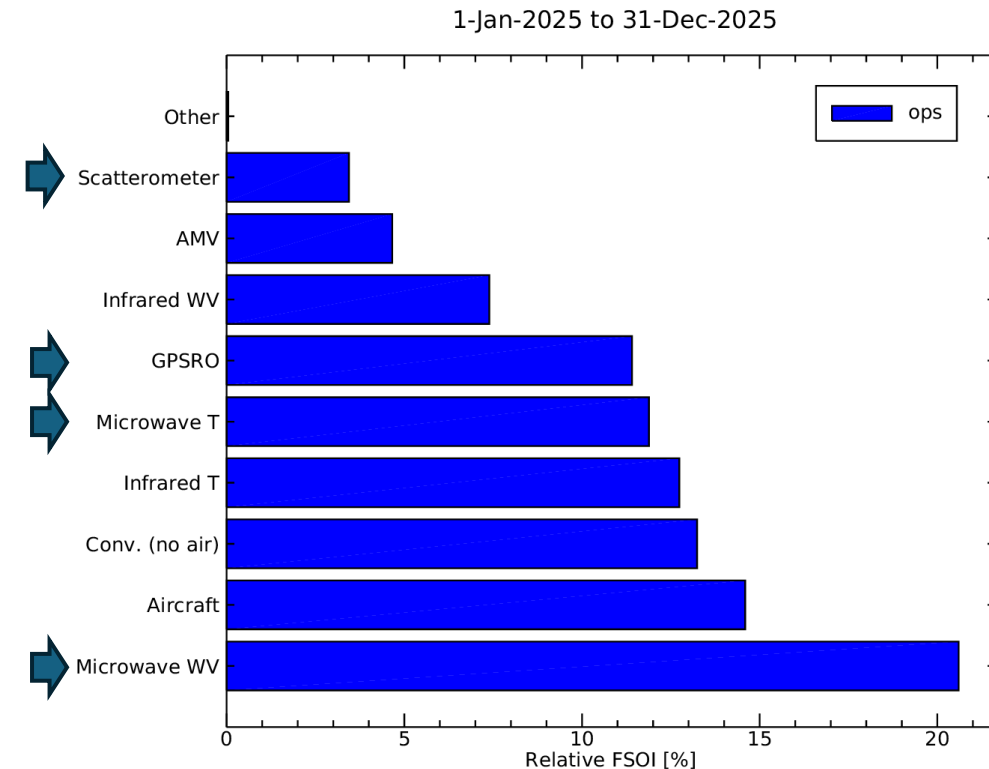


Fig.: A. Geer (ECMWF)

Summary up front

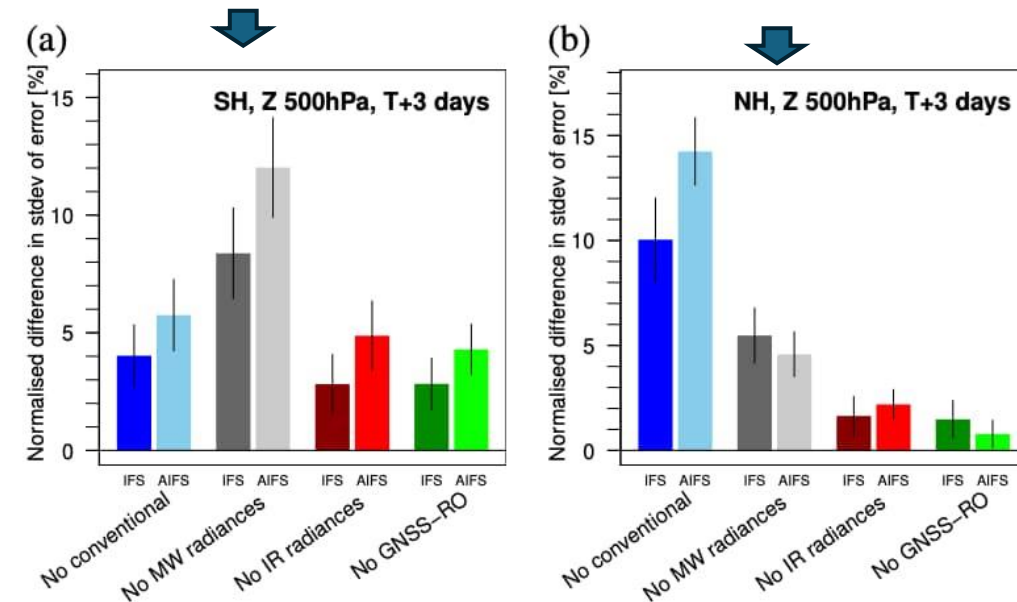
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→ MW radiances are crucial for physics-based and ML-based systems' forecasting skill

From Bormann et al. (2026)

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Current exploitation of MW spectrum in NWP

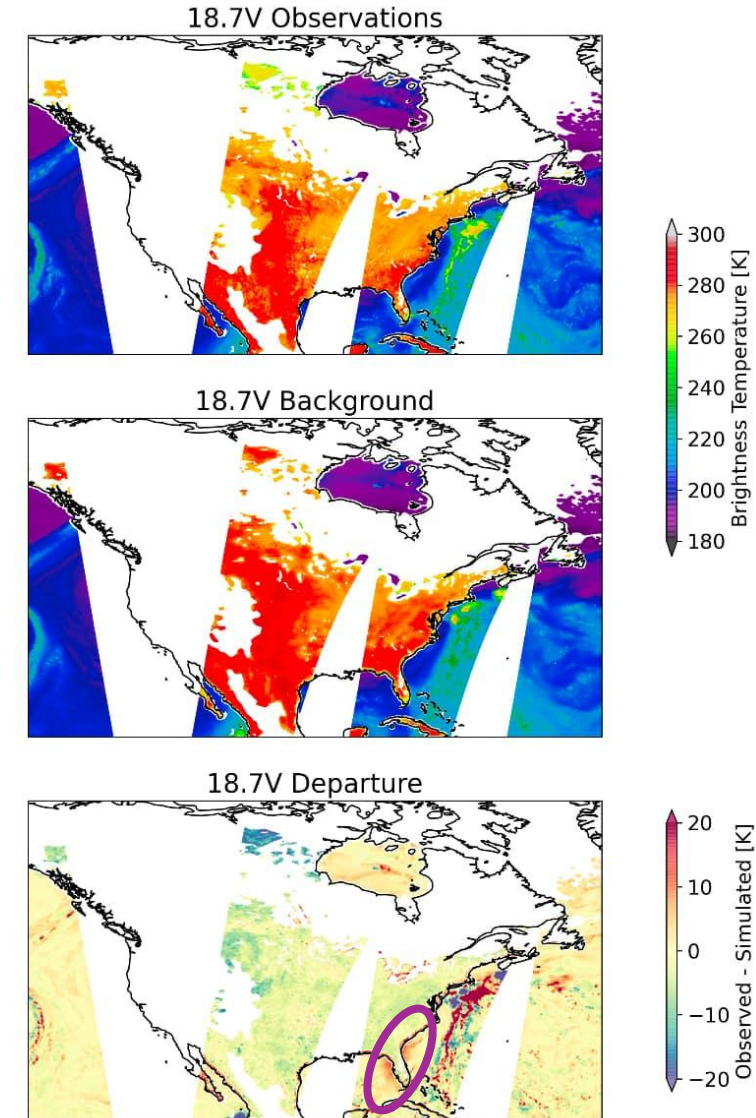
Microwave data affects NWP forecasts almost exclusively via direct radiance assimilation

- Simulate radiances in all conditions
 - Atmospheric gases – oxygen, water vapour, ozone
 - Clouds & precipitation
 - Surface emission
- Data assimilation updates our knowledge of the Earth system state by comparing observations with the short-range forecast
 - Observations vs. Simulations
 - Millions of comparisons with NWP model daily in MW spectrum

Unnatural emission is not simulated in NWP models

→ *Valuable for RFI detection*

→ *Undetected RFI (either a new source or below our detection limit) can be dangerous in NWP for aliasing signals*



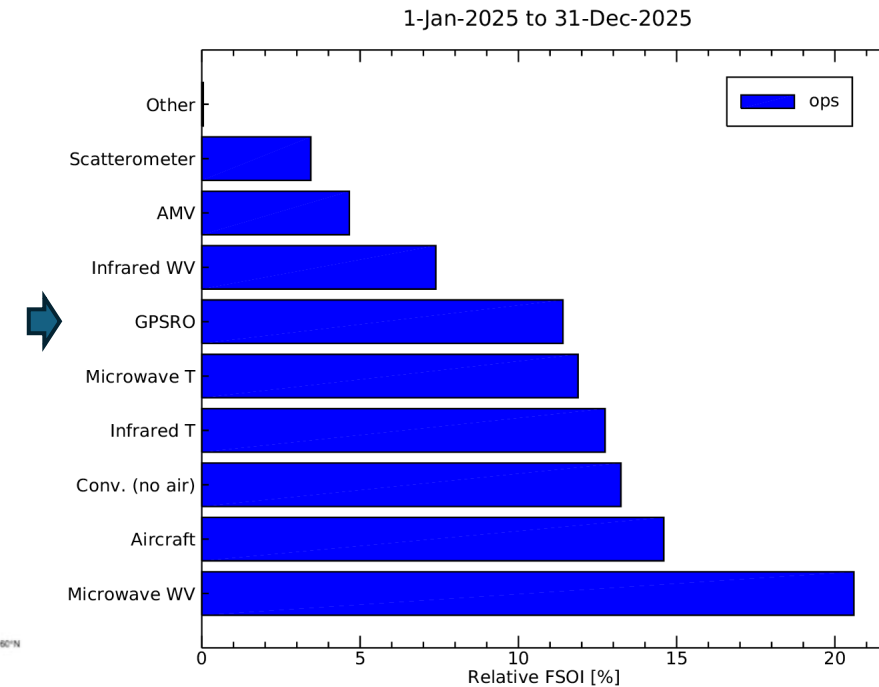
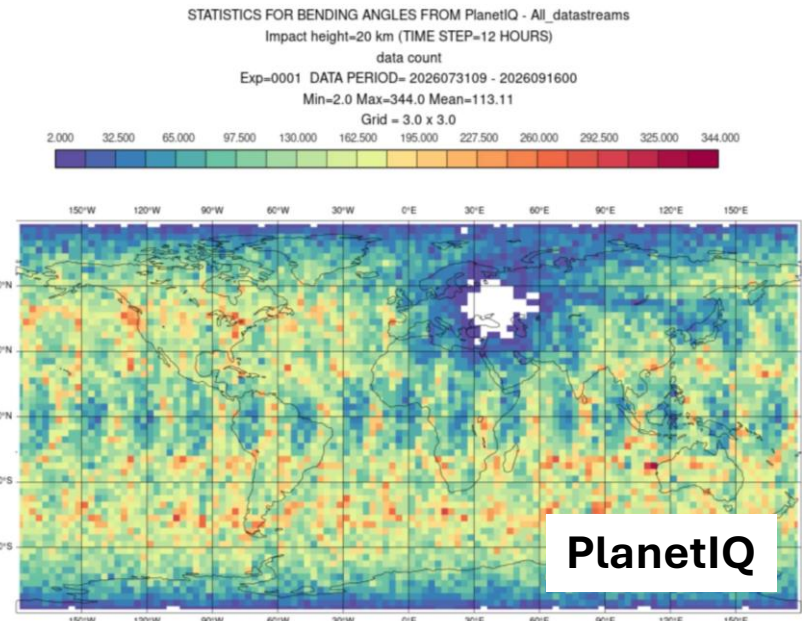
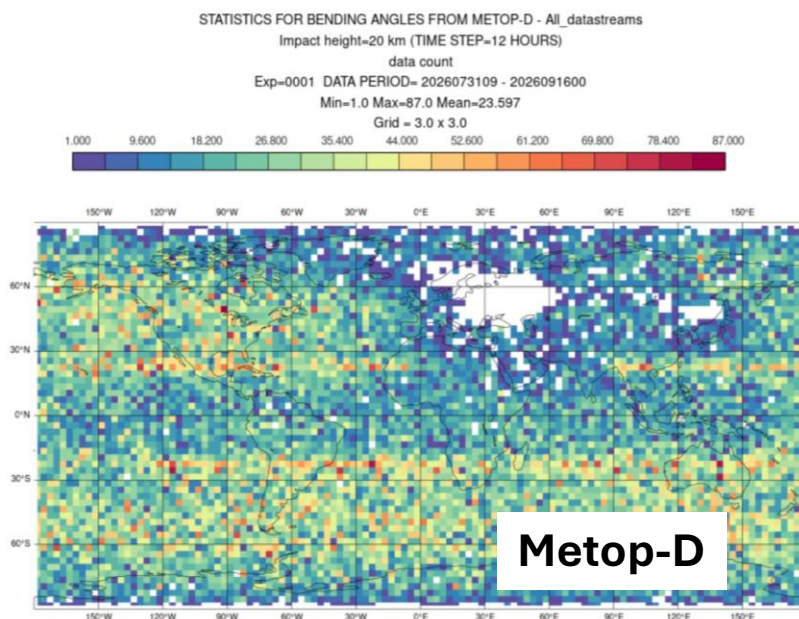
From Onrubia et al. (2026)

Current exploitation of MW spectrum in NWP

Which channels and instruments do we use?

We cannot forget Radio Occultation!

GPS jamming and spoofing over some regions (notably Eastern Europe) causes loss of RO data



<https://charts.ecmwf.int/catalogue/packages/obstat/>

Current exploitation of MW spectrum in NWP

Which channels and instruments do we use?

In Sept. 2026, there are **9 MW radiometers** assimilated from **13 different satellite platforms** at ECMWF:

- **2 AMSU-A** (Metop-B/C)
- **2 MHS** (Metop-B/C)
- **3 ATMS** (SNPP, NOAA-20/21)
- **2 MWHS-2** (FY-3D/E)
- **2 SSMIS** (F17/18)
- **MWS** (Metop-D)
- **AWS MWR** (AWS)
- **GMI** (GPM)
- **AMSR3** (GOSAT-GW)

These span frequencies from:

6.925 GHz (AMSR2 / AMSR3)
to
325 ± 4.1 GHz (AWS)

Compare this to a few years ago:

18.65 GHz (AMSR2, GMI, SSMIS)
to
190 GHz (MHS, MWHS-2, ATMS, etc.)

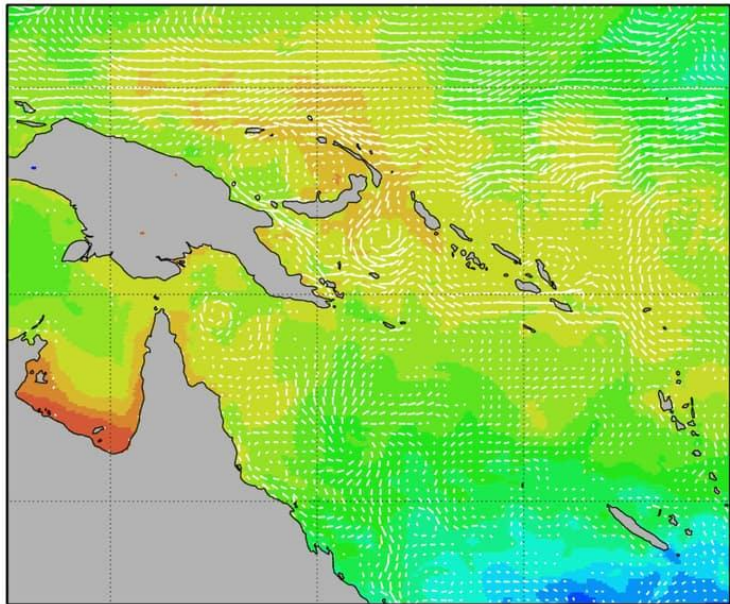
In addition, we now assimilate EarthCARE radar at 94 GHz!

Current exploitation of MW spectrum in NWP

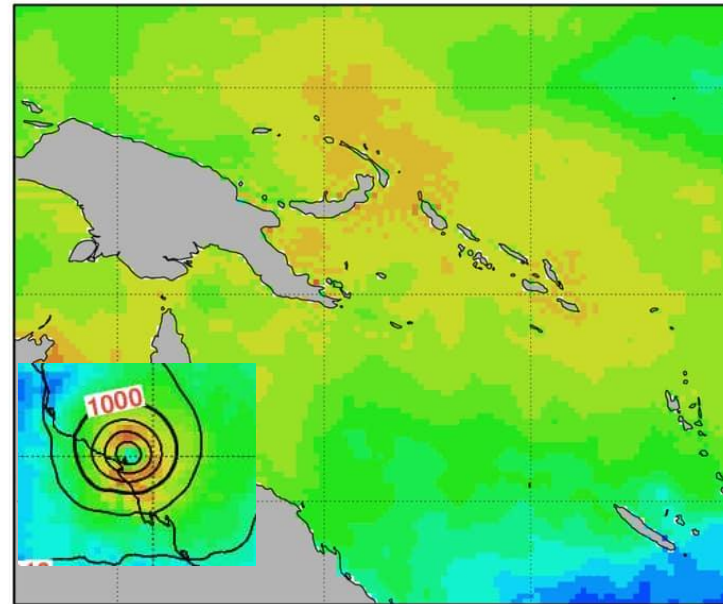
Coupled data assimilation relies on low-frequency MW radiances

SST informed by 6.925 GHz and 10.65 GHz on AMSR2/AMSR3 & GMI – bands with known RFI

ERA6, 25 March 2017, 00 UTC



ERA5, 25 March 2017, 00 UTC



ERA6 has hourly SST + currents from its ocean component and benefits from coupled DA – ocean and atmosphere coupled together

Tropical Cyclone **Debbie**:

- Winds reported up to 120 mph
- Damage: ~ €2 billion

Extracts energy from the ocean:

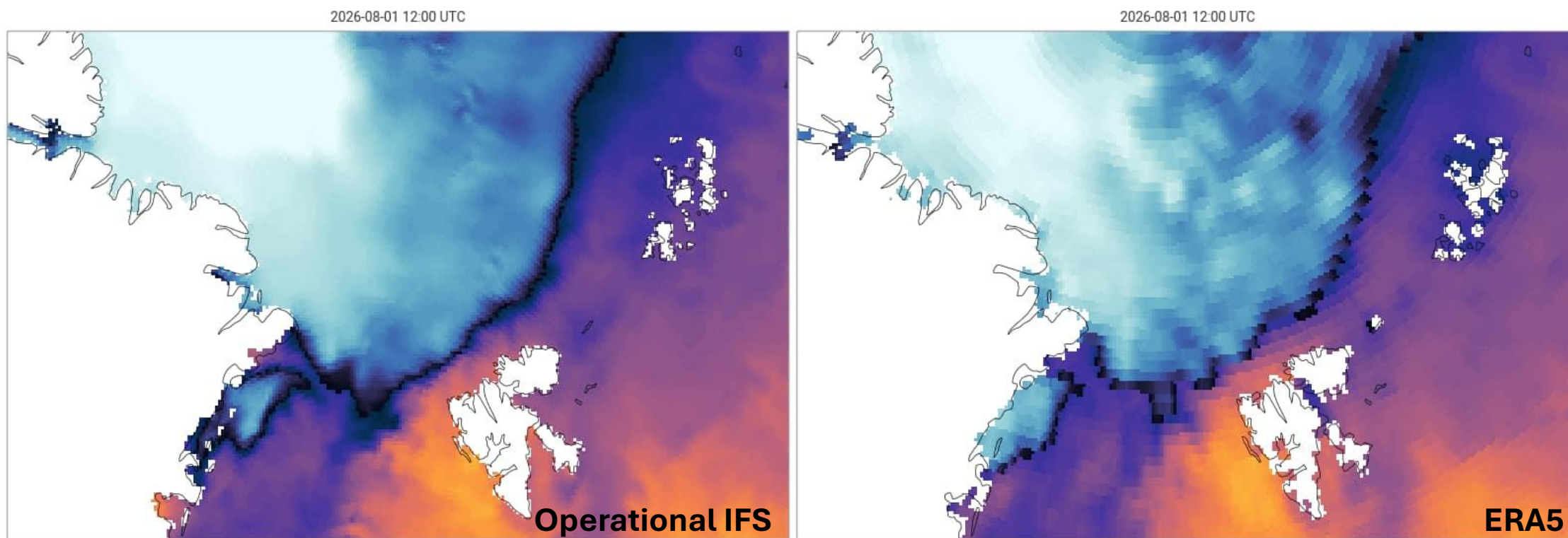
- Cooling of SST
- Induced ocean currents

More realistic ocean-atmosphere processes

Current exploitation of MW spectrum in NWP

Coupled data assimilation relies on low-frequency MW radiances

Sea-ice concentration informed by 10.65 GHz on AMSR2/AMSR3 & GMI



Sea ice concentration and sea surface temperatures

Current exploitation of MW spectrum in NWP

Coupled data assimilation relies on low-frequency MW radiances
– can we identify potential RFI?

Coupled Earth System assimilation includes observations sensitive to atmosphere & surface

Low-frequency MW is ideal for surface measurement.

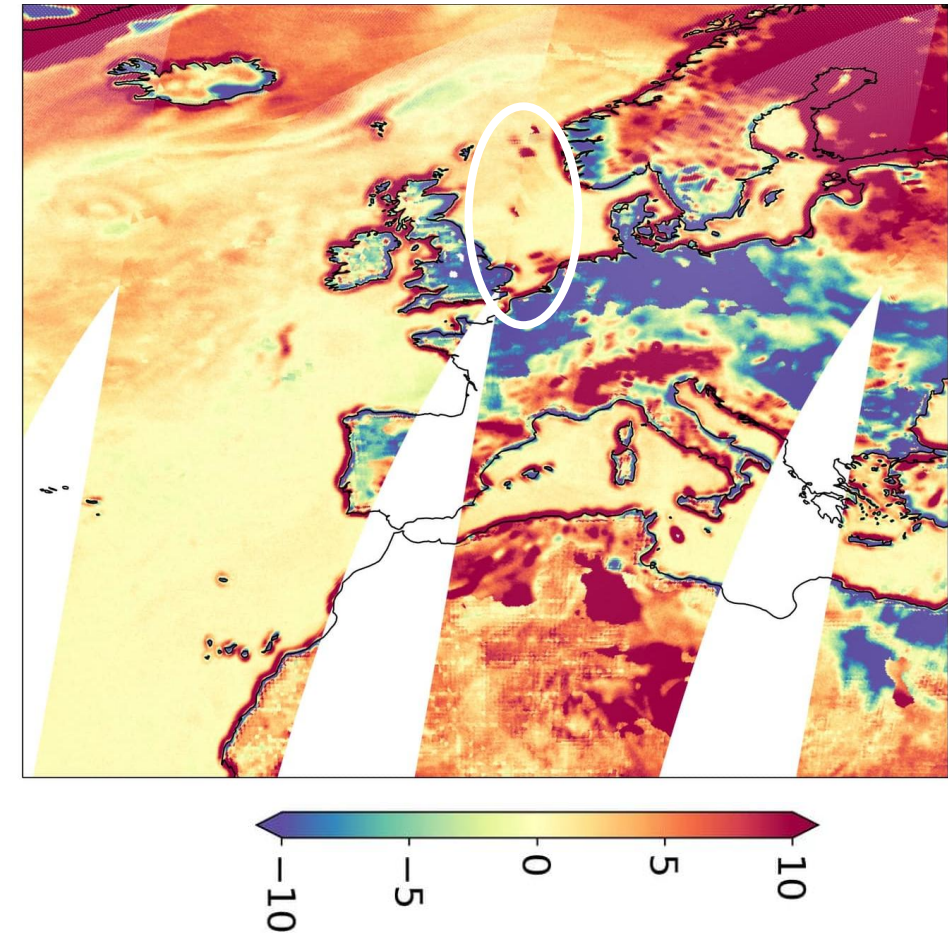
EESS allocation in:

- L-band
- C-band
- X-band

SST measurements need to be very accurate – more susceptible to low levels of RFI

- Reflected signals
- Stationary emitters
- Ships

AMSR2 6.925v GHz



Background Departures

Current exploitation of MW spectrum in NWP

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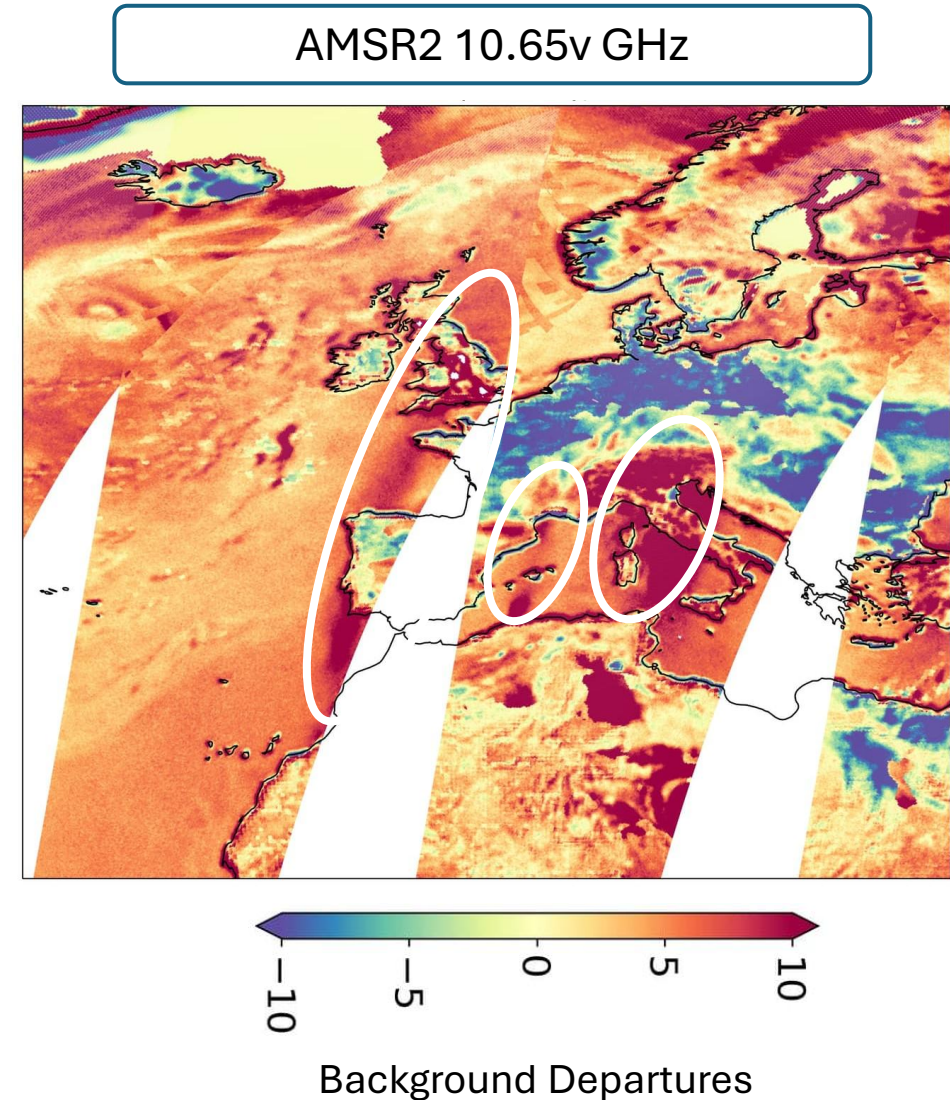
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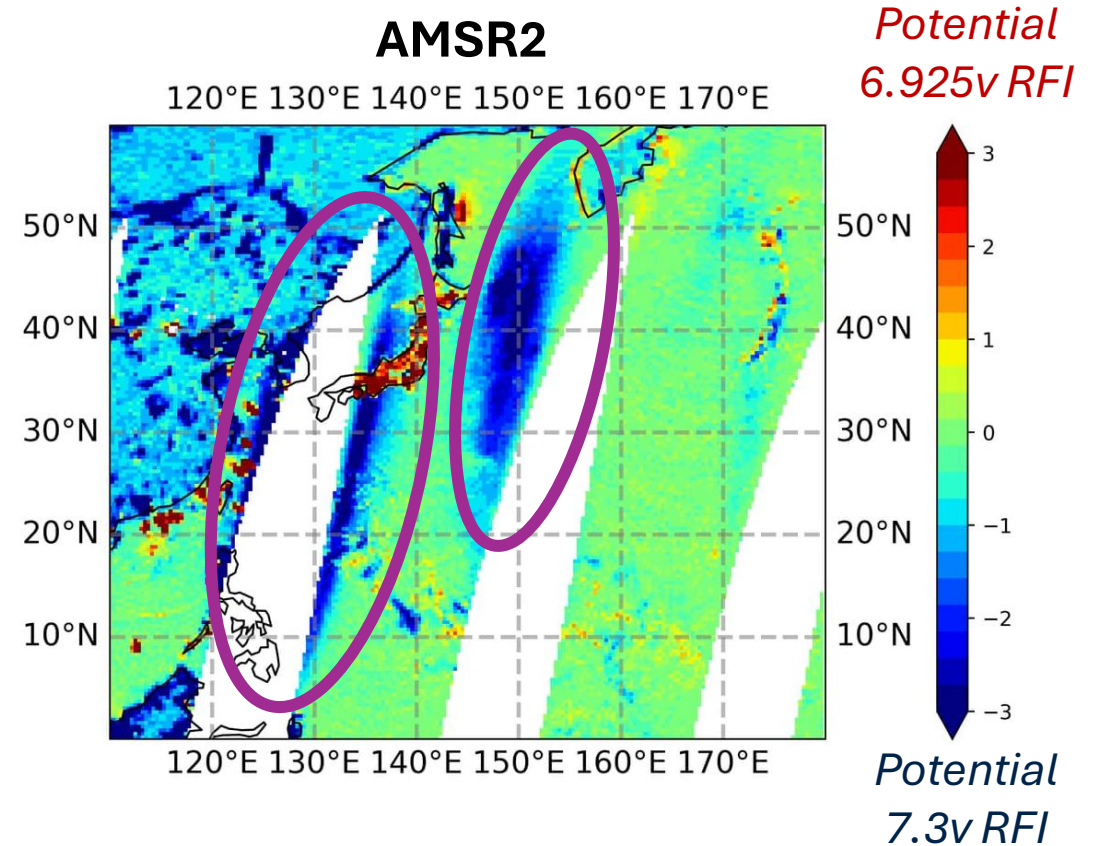
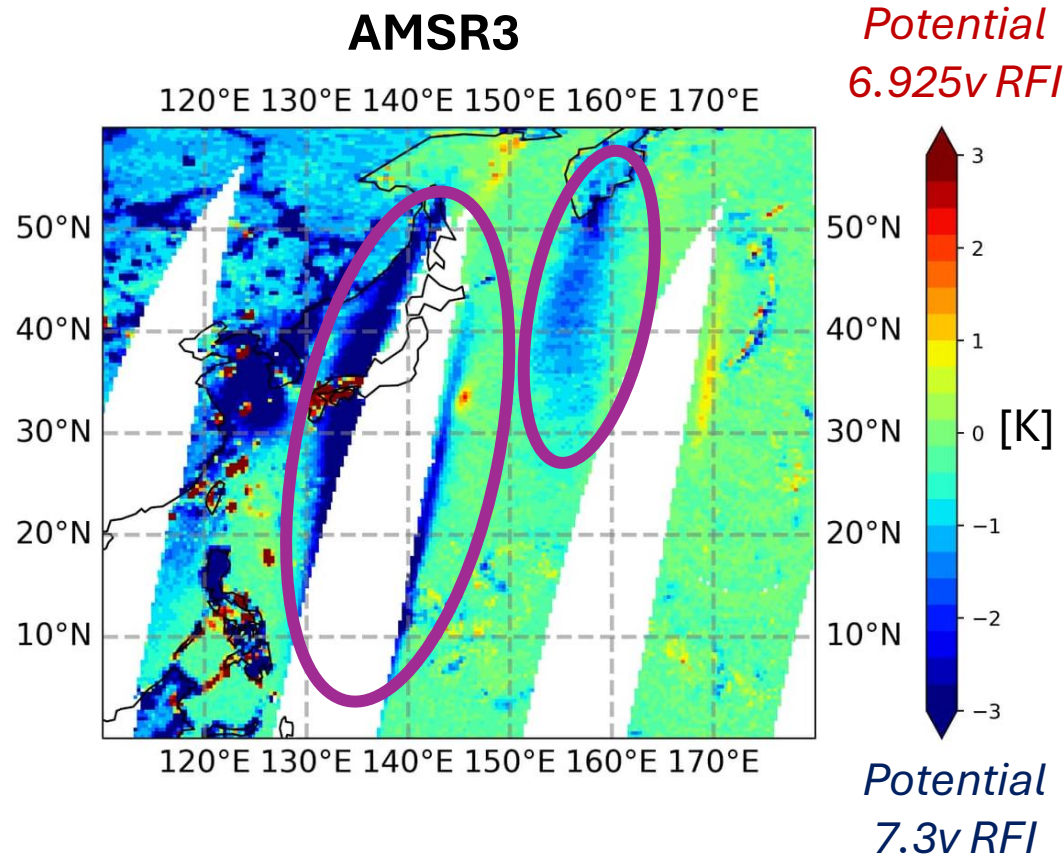
- Reflected signals
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Current exploitation of MW spectrum in NWP

Coupled data assimilation relies on low-frequency MW radiances
– can we identify potential RFI?

Difference of background departures between 6.925v – 7.3v GHz
 $(O-B)_{6.925v} - (O-B)_{7.3v}$

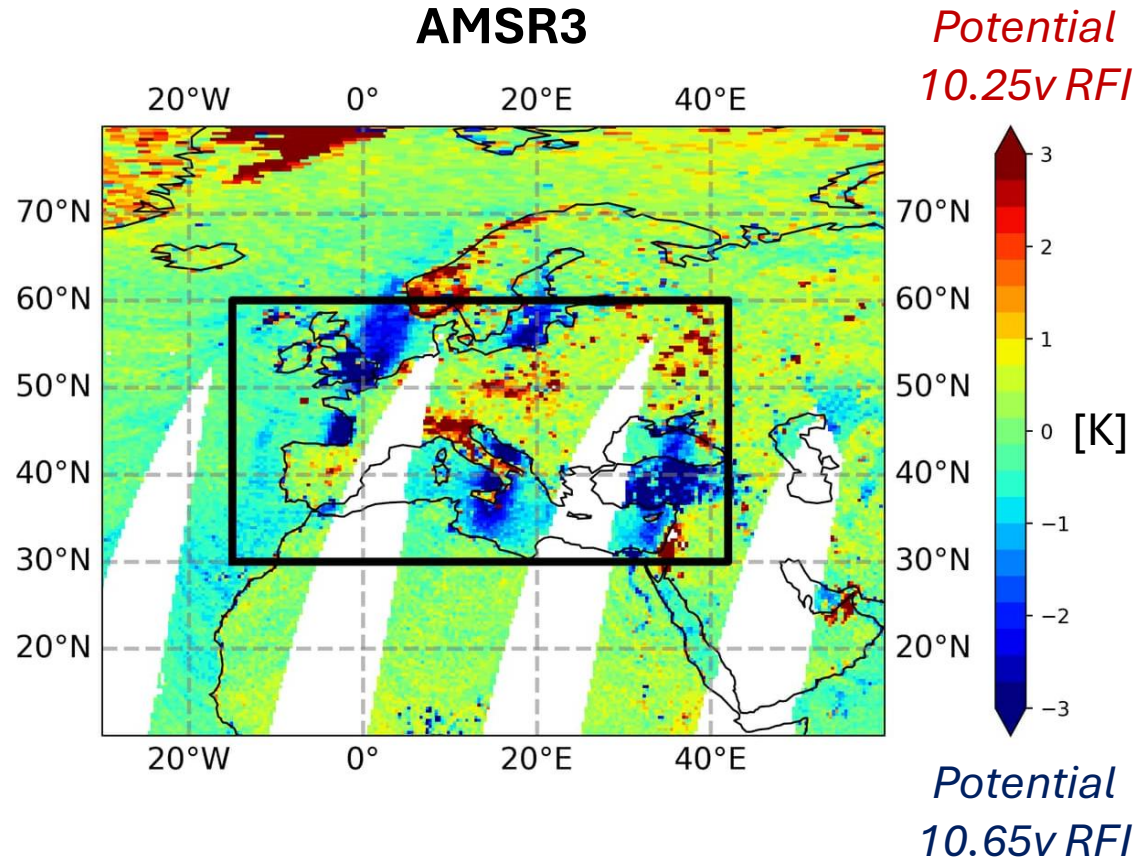


➡ The location and intensity of the RFI signals differ because the orbits of AMSR3 and AMSR2 are not identical.

Current exploitation of MW spectrum in NWP

Coupled data assimilation relies on low-frequency MW radiances
– can we identify potential RFI?

Difference of background departures between 10.25v – 10.65v GHz
 $(O-B)_{10.25v} - (O-B)_{10.65v}$



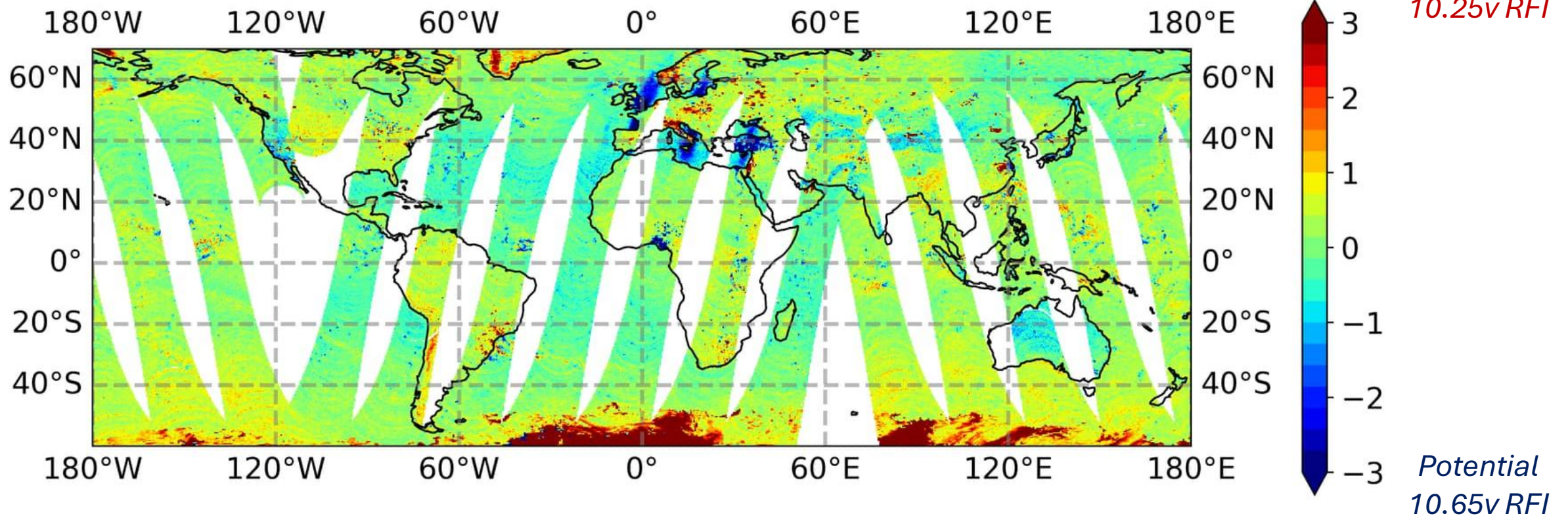
Can exploit new 10.25 GHz wide-band observations on AMSR3 to aid detection of RFI at 10.65 GHz

Current exploitation of MW spectrum in NWP

Coupled data assimilation relies on low-frequency MW radiances
– can we identify potential RFI?

Difference of background departures between 10.25v – 10.65v GHz
 $(O-B)_{10.25v} - (O-B)_{10.65v}$

AMSR3



10.25 GHz wide-band looks cleaner than 10.65 GHz?

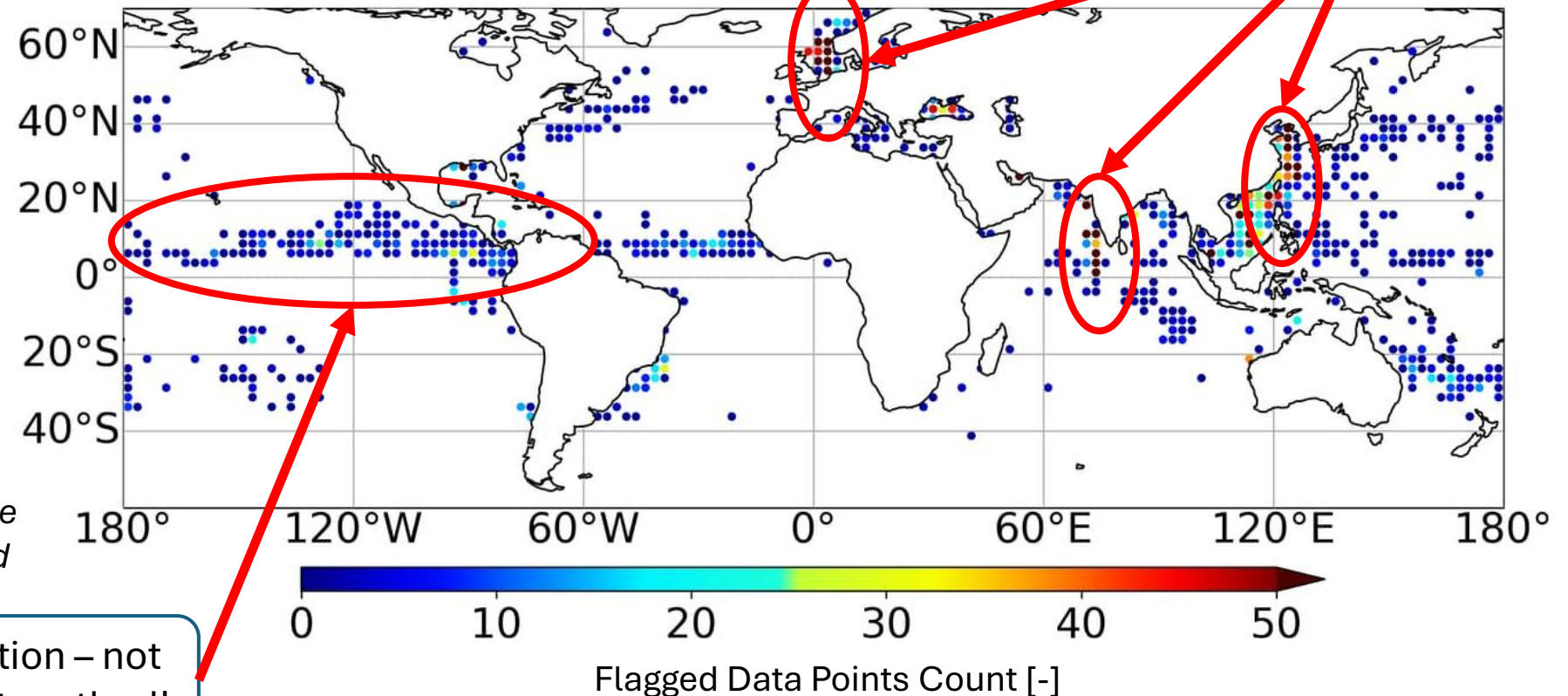
Current exploitation of MW spectrum in NWP

Can we mitigate known RFI at low frequencies?

6.925v GHz compare with 7.3v GHz

Method:

1. Find difference between O-B of 6.9 and 7.3 GHz.
2. Flag as RFI if difference ≥ 2.0 K.



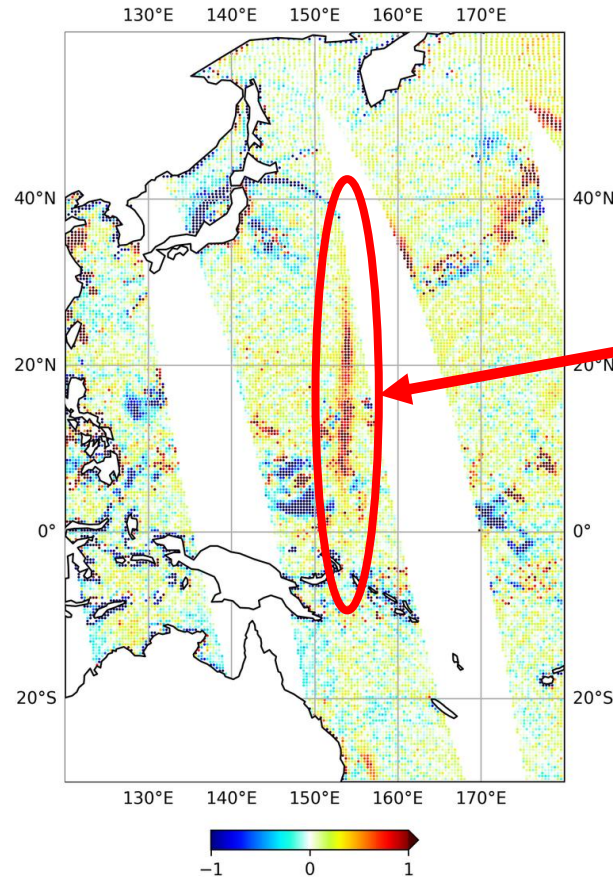
All mitigation methods throw out false positives (good data), even ML-based methods!

Current exploitation of MW spectrum in NWP

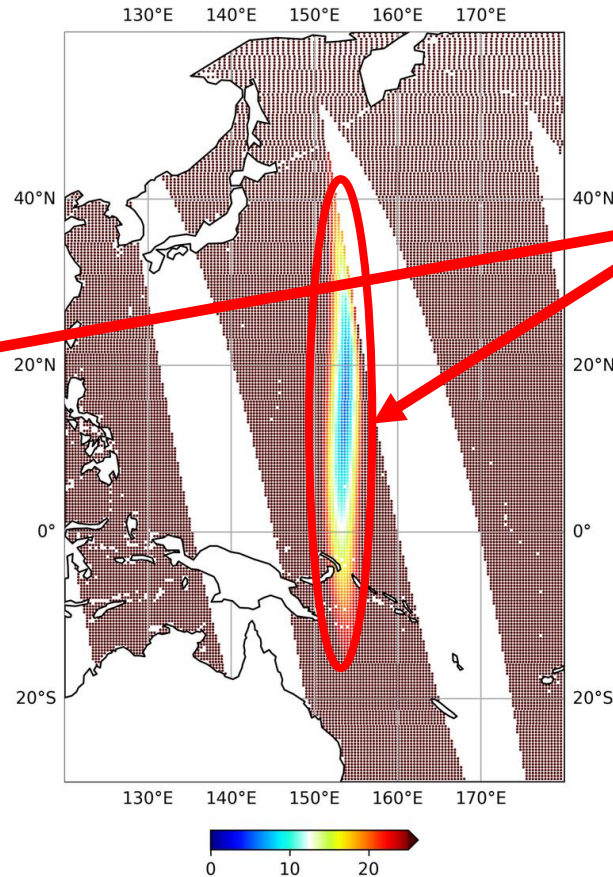
Can we mitigate known RFI at low frequencies?

6.925v GHz
LEO glint RFI

*Difficult to attribute to
single source; hard to
predict!*



Difference in Background Departures [K]
(AMSR2 6v GHz minus AMSR2 7v GHz)



Glint Angle Between AMSR2 and LEO Satellite

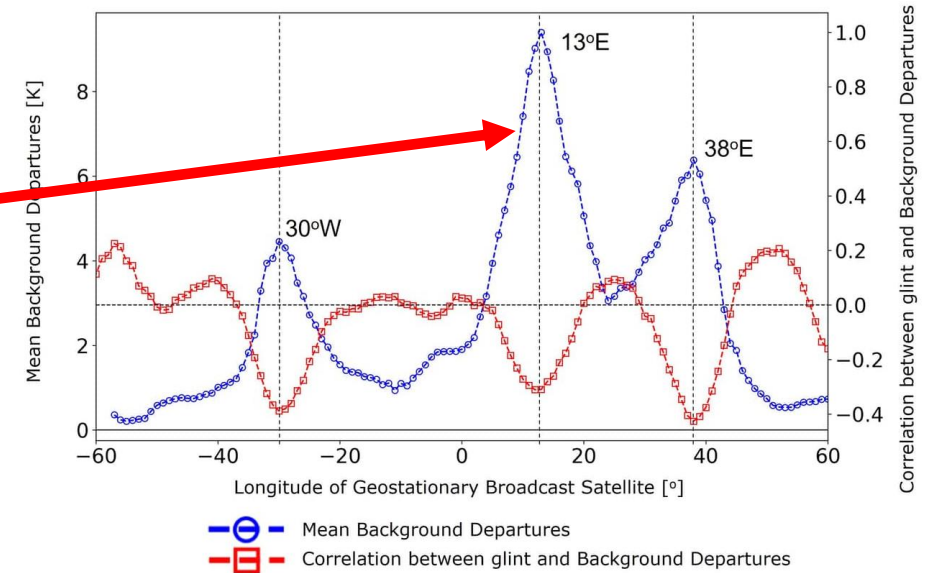
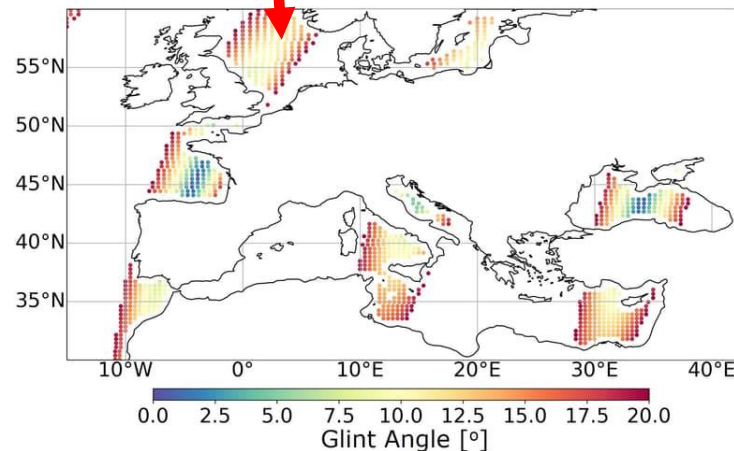
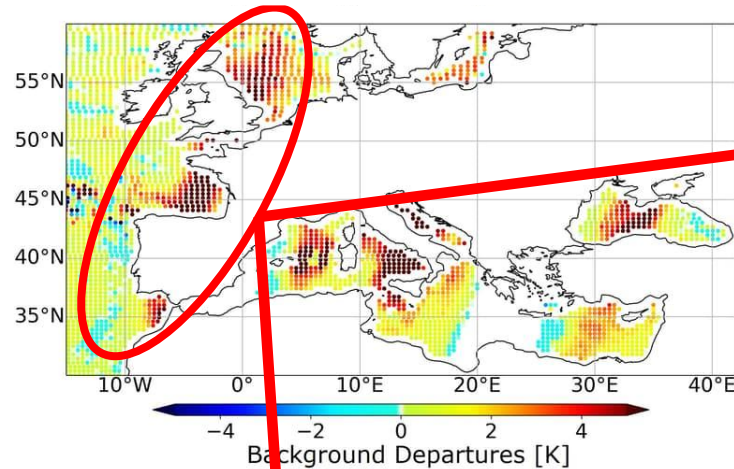
High difference in
background departures
(indicator of RFI) coincides
with low glint angle to
specific LEO satellites

Similar streak
patterns seen
throughout the past
few years.

Current exploitation of MW spectrum in NWP

Can we mitigate known RFI at low frequencies?

10.65v GHz
GEO glint RFI



Method:

1. Calculate glint angle between AMSR2 and theoretical satellites.
2. Calculate mean background departures.
3. Where there are peaks, there is likely a broadcast satellite.
4. Flag as RFI if glint angle with these satellites is $\leq 25^\circ$. This captures the RFI but also results in non-RFI affected observations being screened out.

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Where we are going

L-band and sub-mm radiances used in NWP models

Sub-mm (300+ GHz) radiances are now available for operational meteorology

Arctic Weather Satellite launched Aug 2024

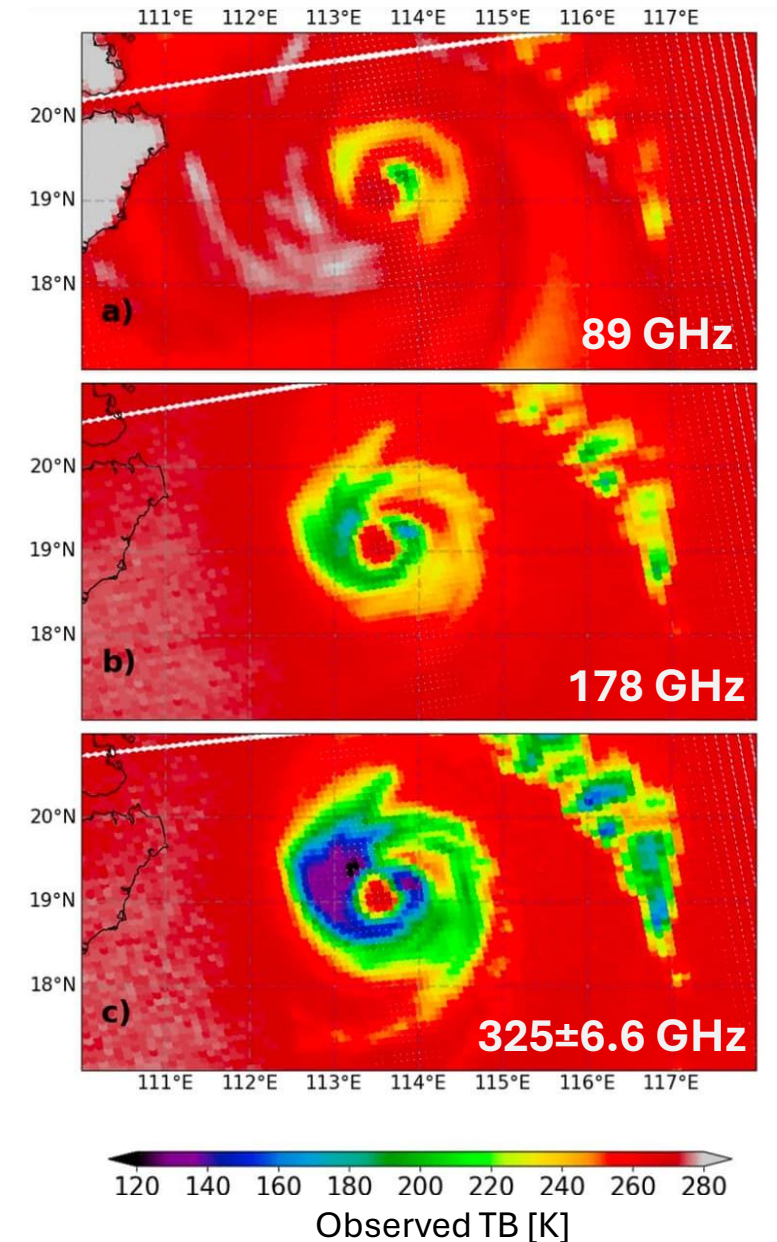
- 325 GHz band

Ice Cloud Imager launches end of 2026

- 325, 448, and 664 GHz bands

No RFI seen yet in 325 GHz

53 – 325 GHz from AWS assimilated at ECMWF since 2025

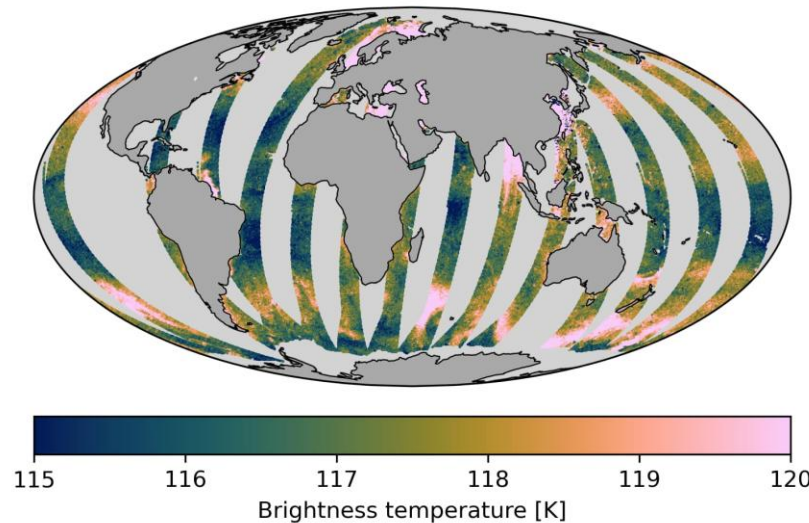


Where we are going

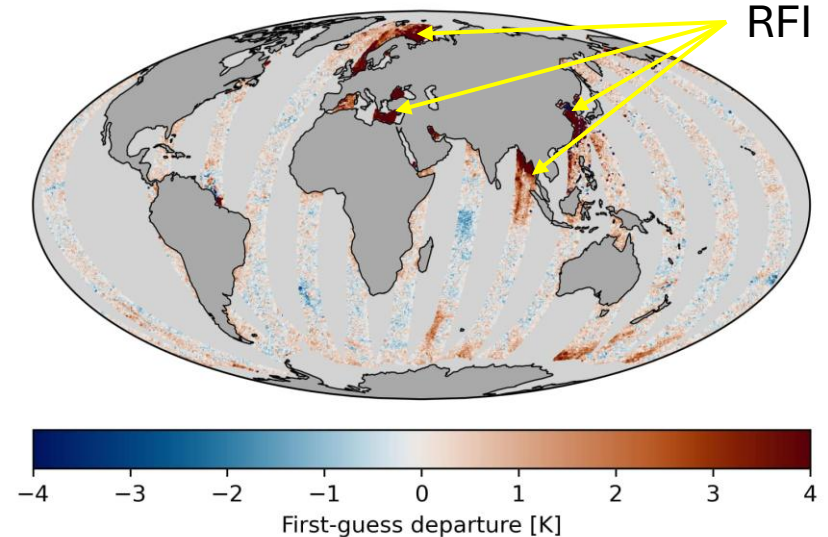
L-band and sub-mm radiances used in NWP models

- SMAP L-band (1.41 GHz) can be used to constrain sea surface salinity (SSS) in the coupled assimilation
- Land-based RFI sources contaminate observations in coastal areas *up to 1000 km* offshore
- These contributions are relatively weak and not reliably identified by RFI detection algorithm

Ocean
Observation



Ocean
Observation – Simulation



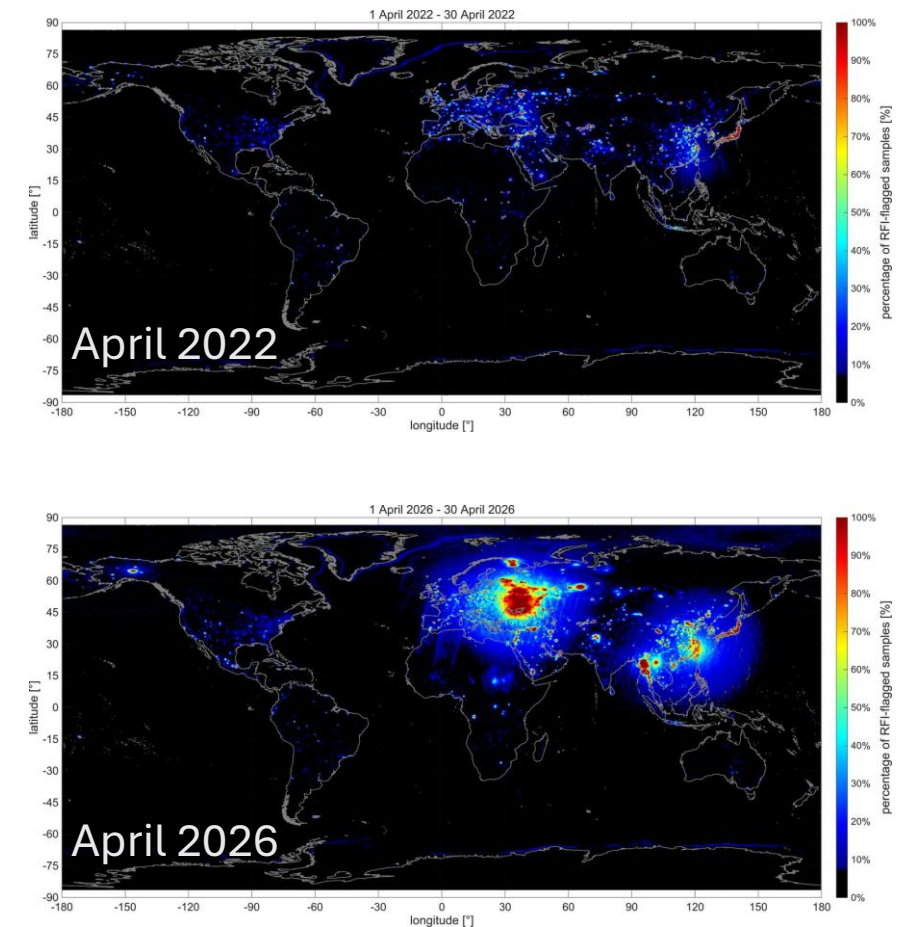
SMAP 22nd May, 2026

Where we are going

L-band and sub-mm radiances used in NWP models

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L-band RFI is clearly increasing globally



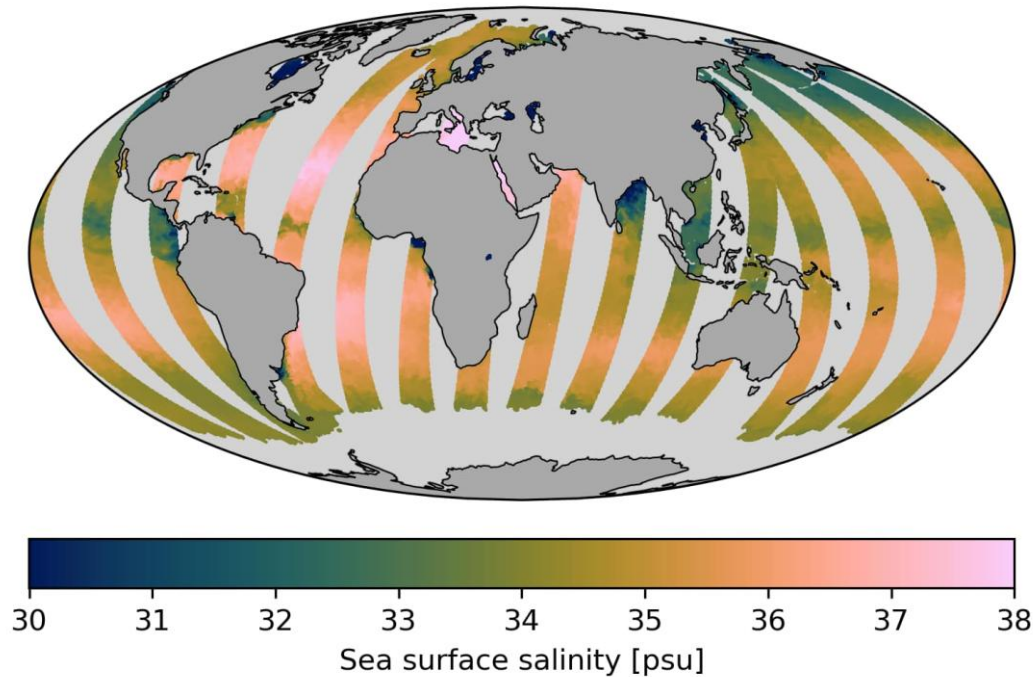
<https://salinity.oceansciences.org/smap-radiometer.htm>

Where we are going

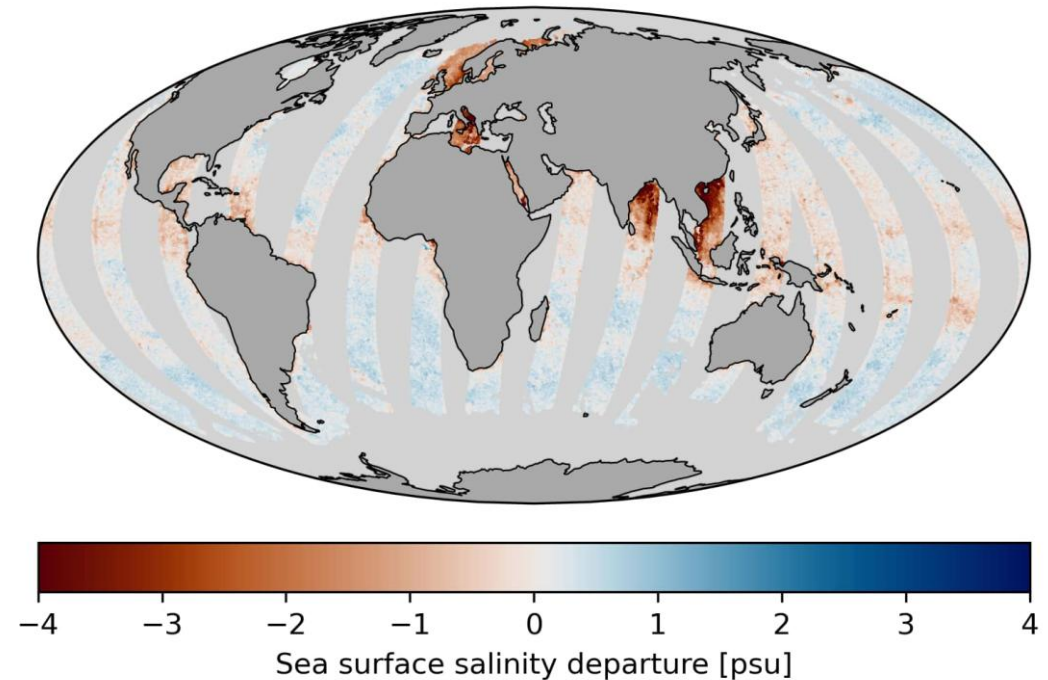
L-band and sub-mm radiances used in NWP models

- RFI contamination makes SMAP unusable for SSS estimation around Eurasia
- Without RFI screening, large and unrealistic changes are made to ocean model

Sea surface salinity (IFS-NEMO ocean model)



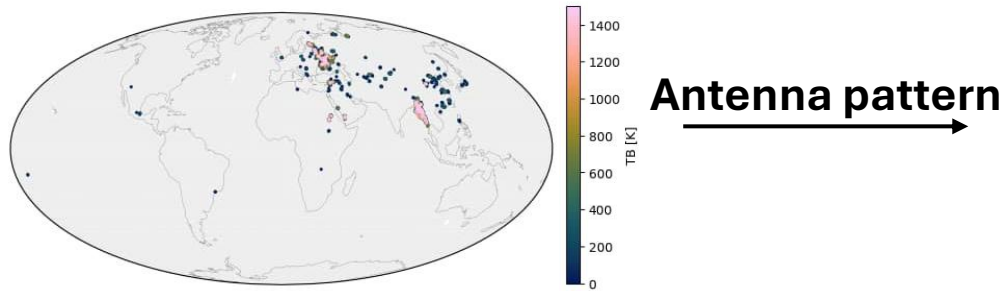
SMAP salinity departures



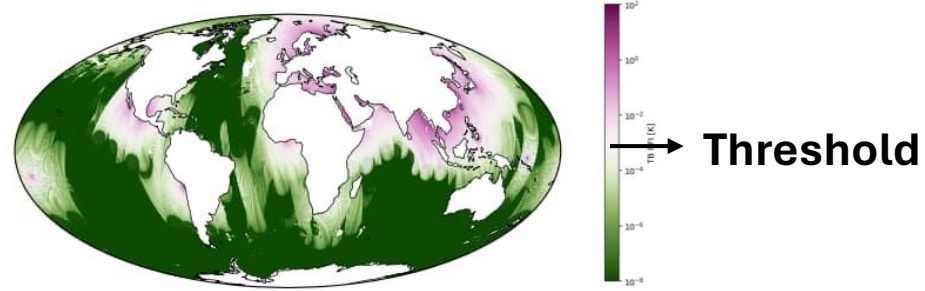
Where we are going

L-band and sub-mm radiances used in NWP models

1. RFI hotspots

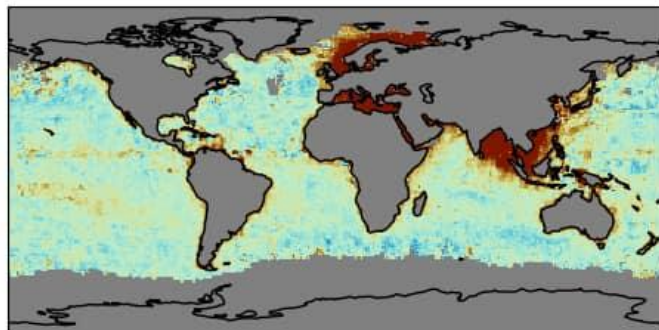


2. RFI contamination



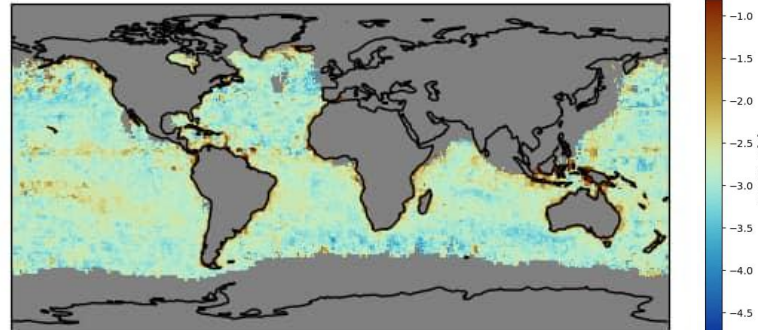
Mean background departures (29-31 Oct 2025)

1.4V GHz



RFI screening

1.4V GHz



Developing mitigation strategies for L-band RFI over sea

→ *Modelling of known sources does fairly well*

Trials to assimilate SMAP L-band radiances over sea are ongoing

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Conclusions

Exploitation of spectrum for NWP is expanding

This is driven by a push towards coupled Earth System models and utilizing surface-sensitive observations – many of these are bands that have been observed for many years already

Subtle signals (~ 1 K) over sea now require mitigation strategies (however imperfect) for effective use – we cannot reliably detect and screen all RFI

Thus we are actively exploring every angle for mitigation:

- Dual bands (e.g. 6.925 vs. 7.3 GHz)
- ML approaches
- Physical approaches (GEO/LEO glint, modelling known sources)
- Statistical approaches, etc.

Loss of data from GNSS-RO is also worrying, as RO is now a major component of the global observing system driving forecast skill improvements

The 23, 50, and 183 GHz bands remain the most critical for driving NWP skill, so we must be vigilant in protecting these parts of the spectrum

References

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