Impact of the RFI on Weather Forecast and Climate Studies

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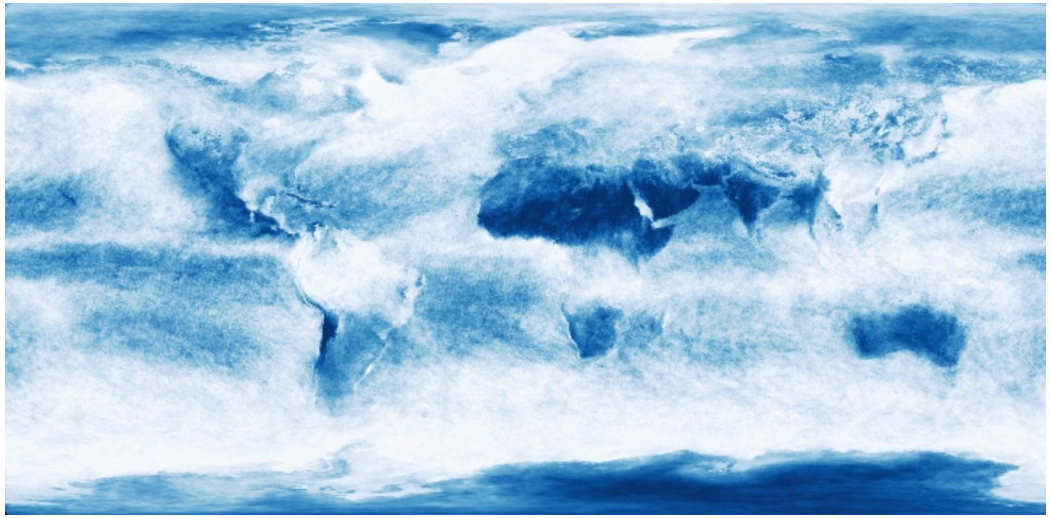
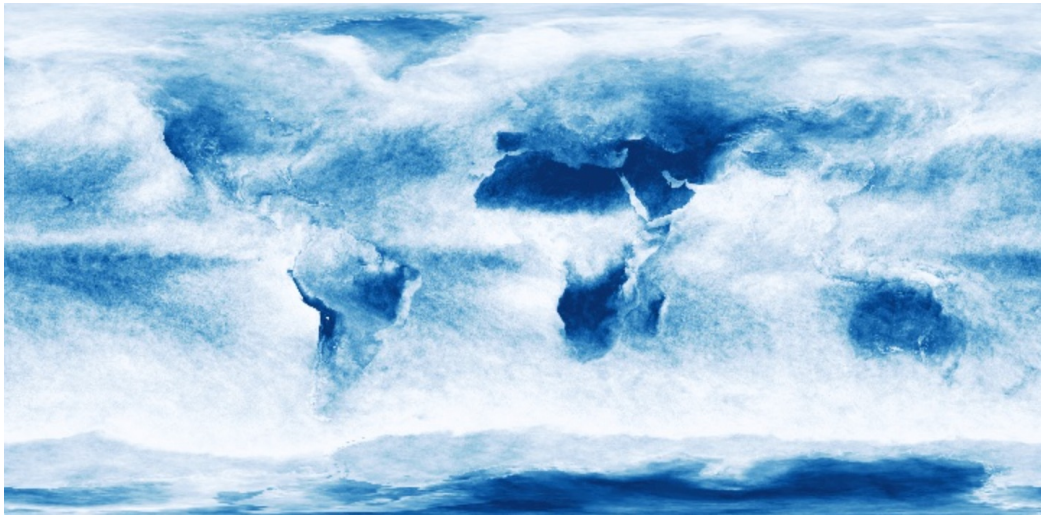
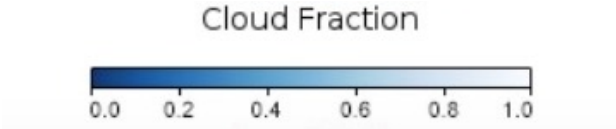
The cloud cover on Earth



February 2022
(Terra / MODIS)

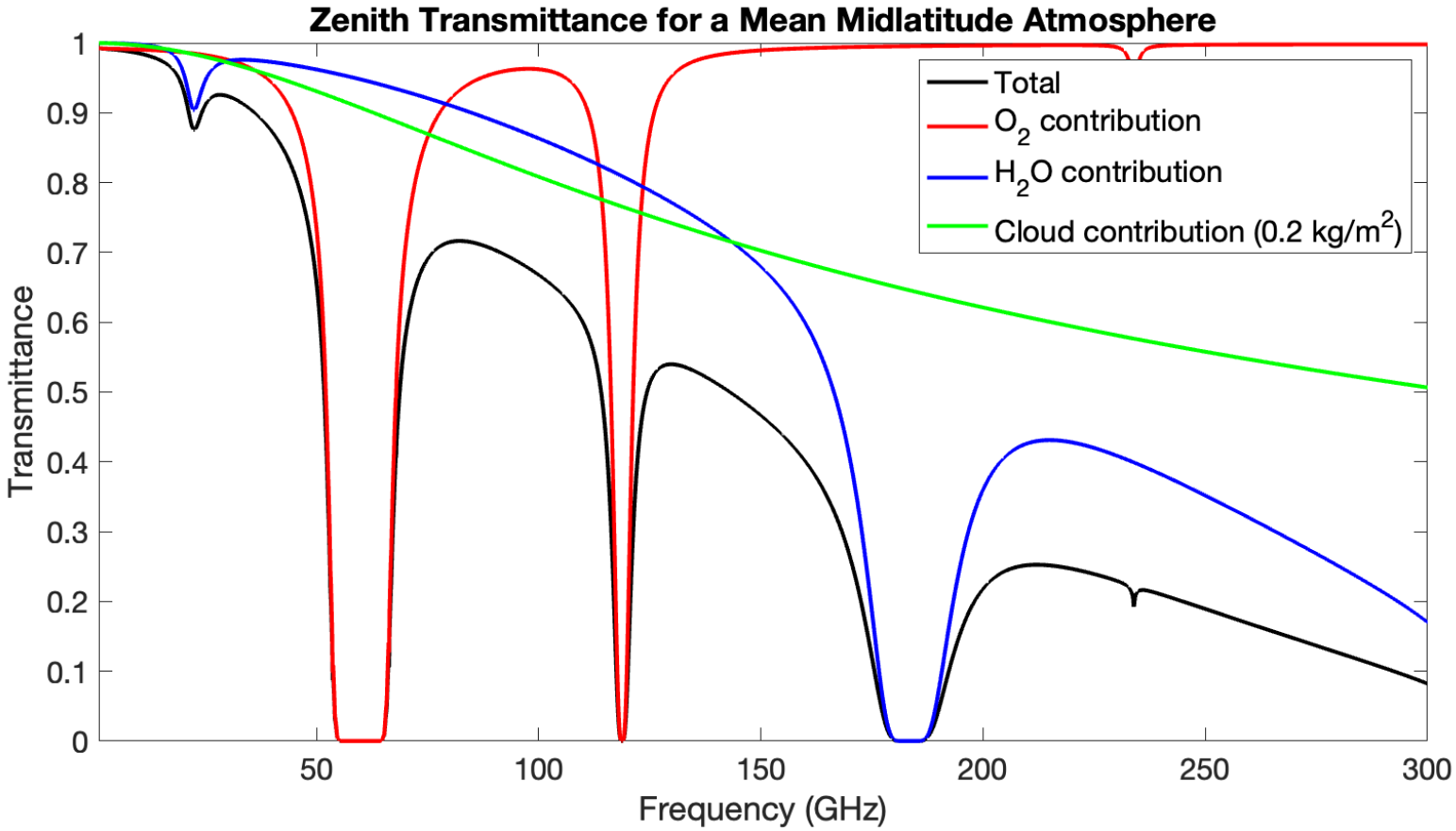


August 2022
(Terra / MODIS)



~70% in average

The atmospheric transmittance in the microwaves



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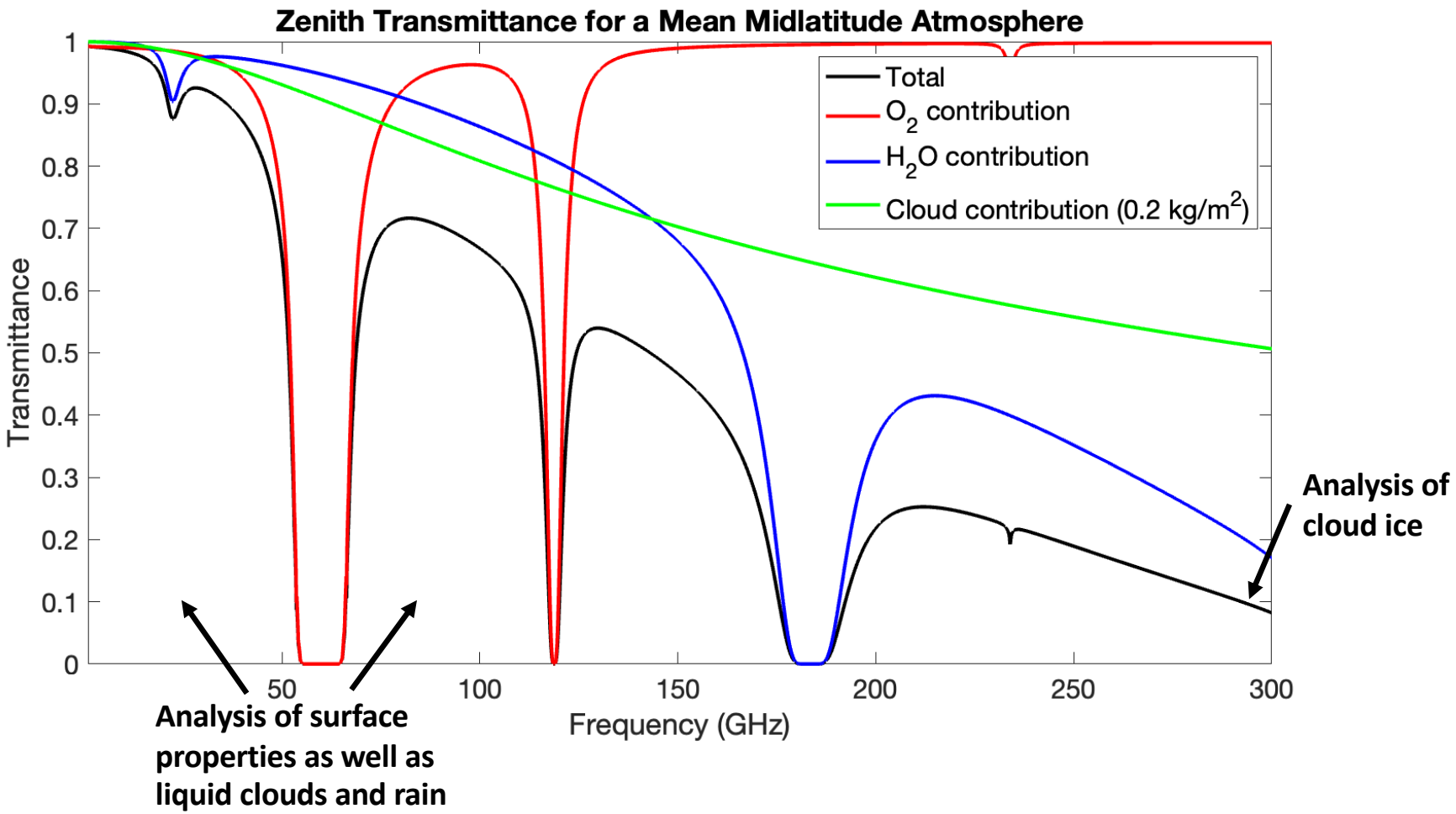

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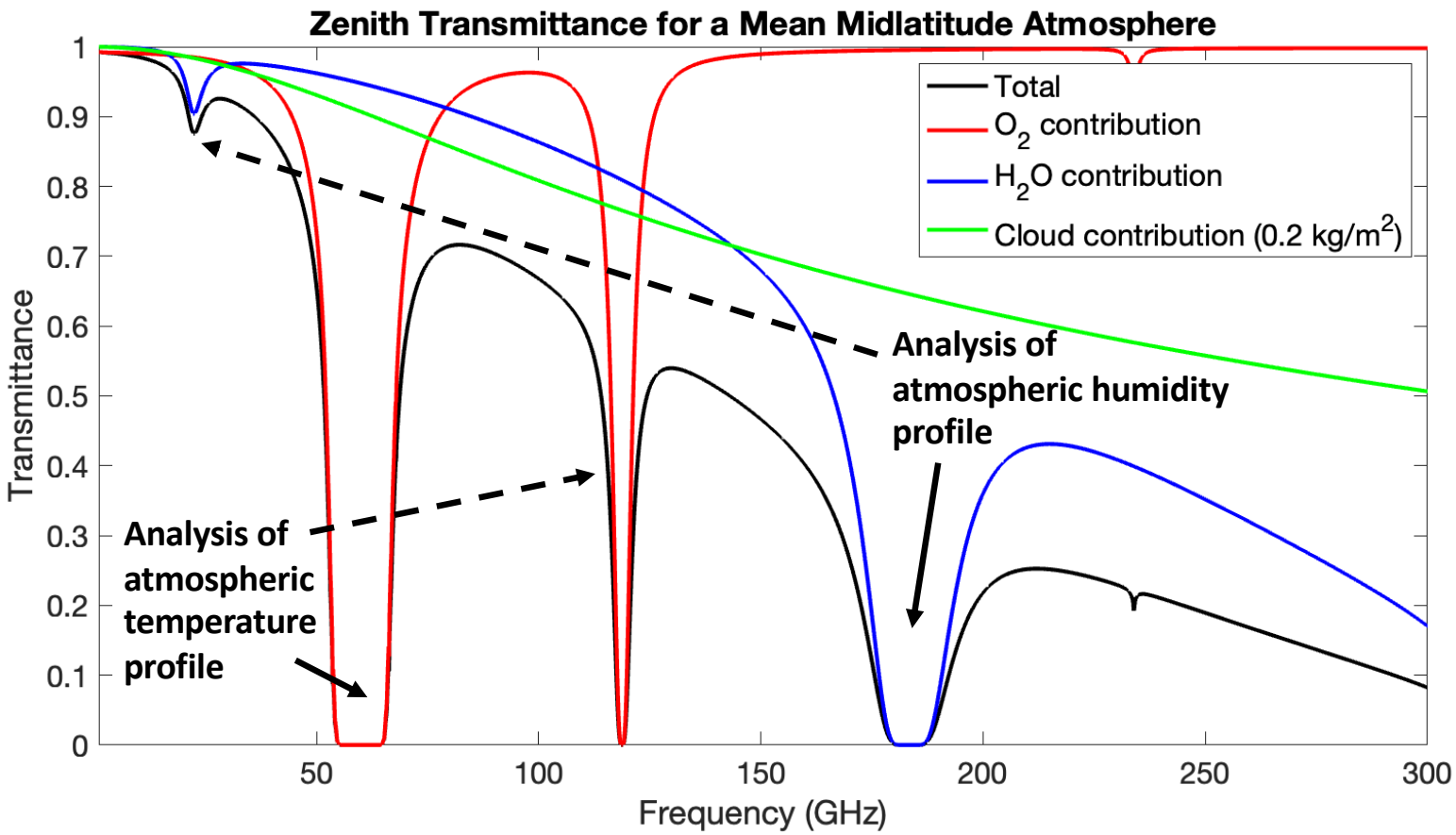
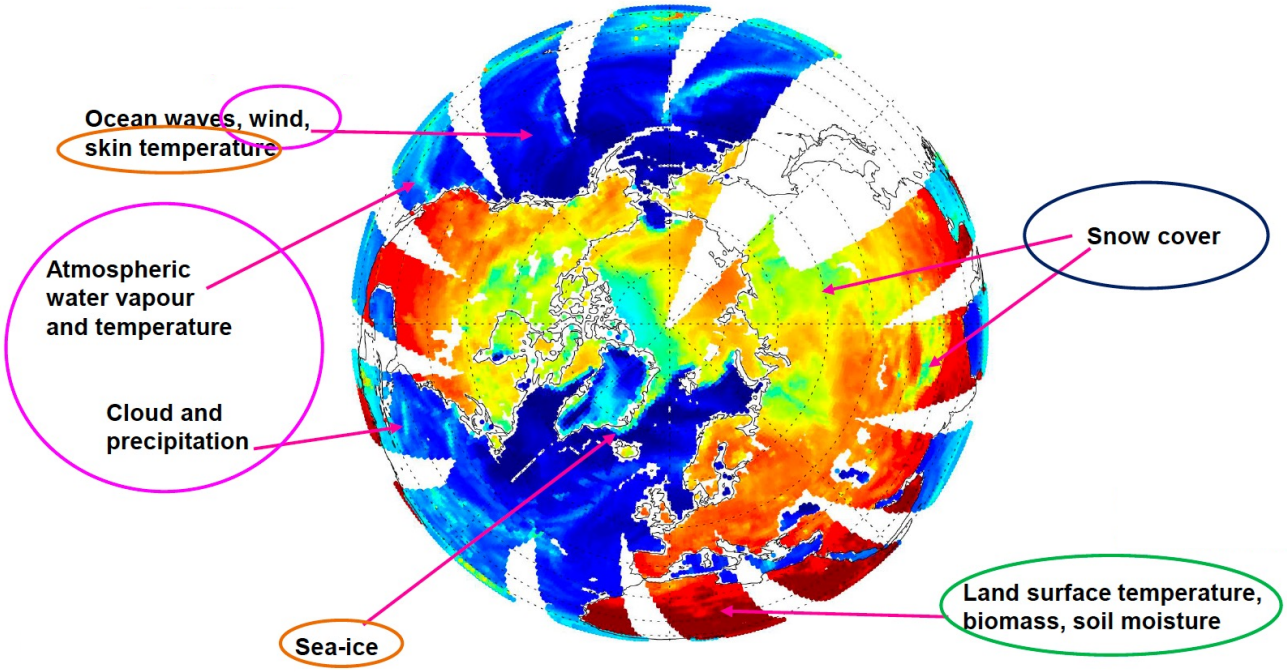


Microwave sensitive to many Earth parameters

19 GHz V polarization (SSMIS) for one day (03/12/2014)



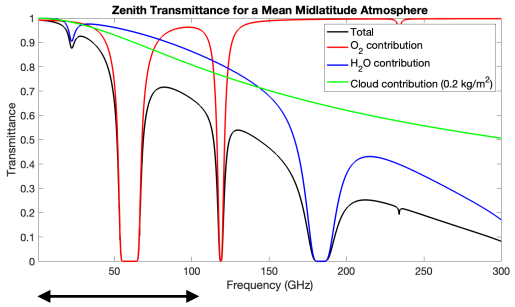
ECMWF

From Alan Geer

Frequency selection and their bandwidth, dictated by:

- **Physics**
  - **spectral lines of O_2 and H_2O (usually narrow bandwidth required)**
  - **sensitivity to surface, cloud and rain (large bandwidths if possible)**

- **ITU regulation**



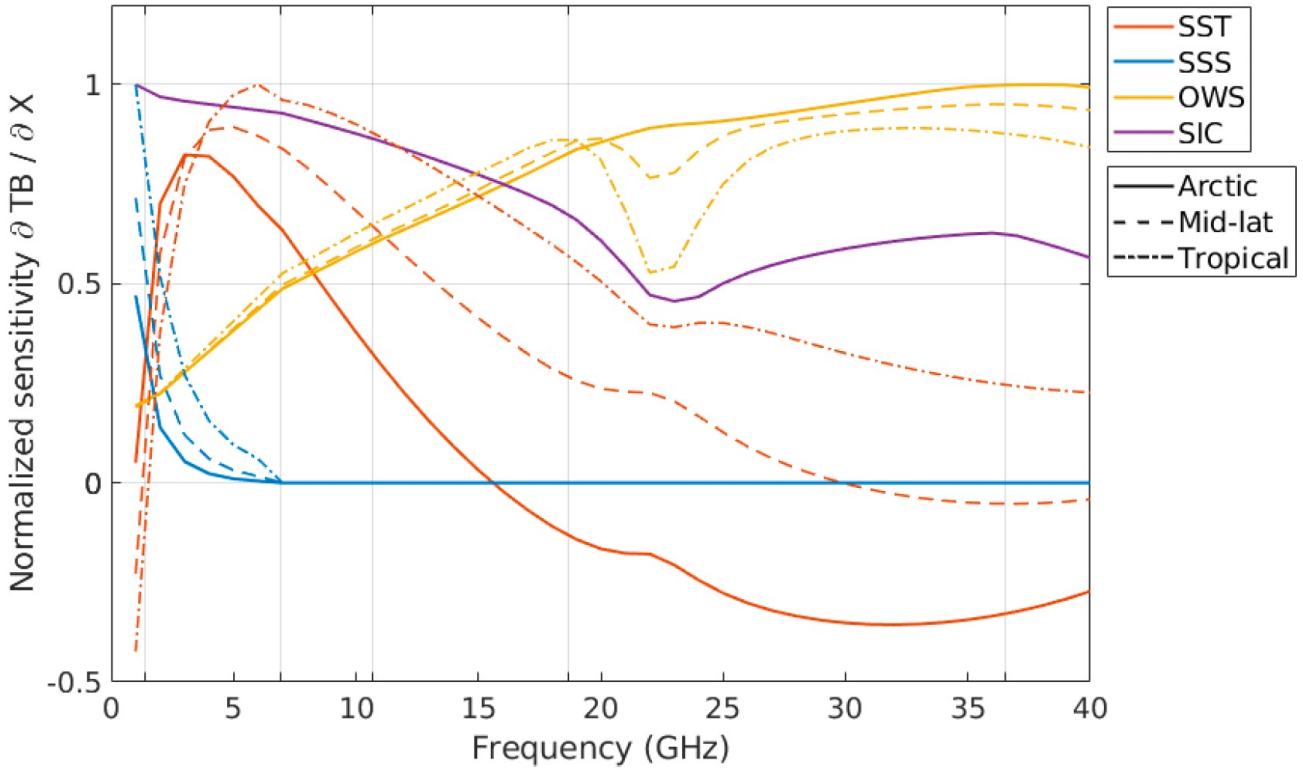
Frequency bands used for Passive Earth Exploration up to 100 GHz
(more at higher frequencies)

Band name	**Frequency (GHz)**	**Main retrieved information**	**Instrument and Center Frequency (GHz)**
L	1.4-1.427	Surface properties (soil moisture, sea surface salinity)	SMOS, SMAP, CIMR: 1.4135
C	6.425-7.25	Surface properties (sea surface temperature)	AMSR2: 6.925, 7.3 CIMR: 6.925
X	10.6 - 10.68 10.68 - 10.7	Surface properties	AMSR2, GMI, MWRI, CIMR: 10.65
Ku	18.6 - 18.8	Surface and atmospheric properties	AMSR2, GMI, MWRI, MWI, AMR-C…: 18.7
K	23.6 - 24.0	Atmospheric properties (integrated water vapor)	AMSR2, GMI, MWRI, AMSU-A, ATMS…: 23.8
Ka	31.3 - 31.8	Surface and atmospheric properties	AMSU-A, ATMS, MWI, MWS: 31.4
Ka	36.0 - 37.0	Surface and atmospheric properties	AMSR2, GMI, MWRI, CIMR: 36.5 SSMIS: 37.0
V	50.2 - 50.4	Surface and atmospheric properties	AMSU-A, ATMS, SSMIS, MWI, MWS: 50.3
V	52.6 – 59.3	Atmospheric properties (temperature profile)	AMSU-A, ATMS, MWS: 52.8, 53.6, 54.4, 54.9, 55.0
W	86.0 - 92.0	Surface and atmospheric properties	ATMS: 88.2 AMSU-A, AMSR2, GMI…: 89.0 SSMIS: 91.65

Inspired by Duncan et al., 2024

Sensitivity of the radiometric signal to the surface and atmospheric parameters over ocean

Some parameters only measurable at selected frequencies



Kilic et al., 2021

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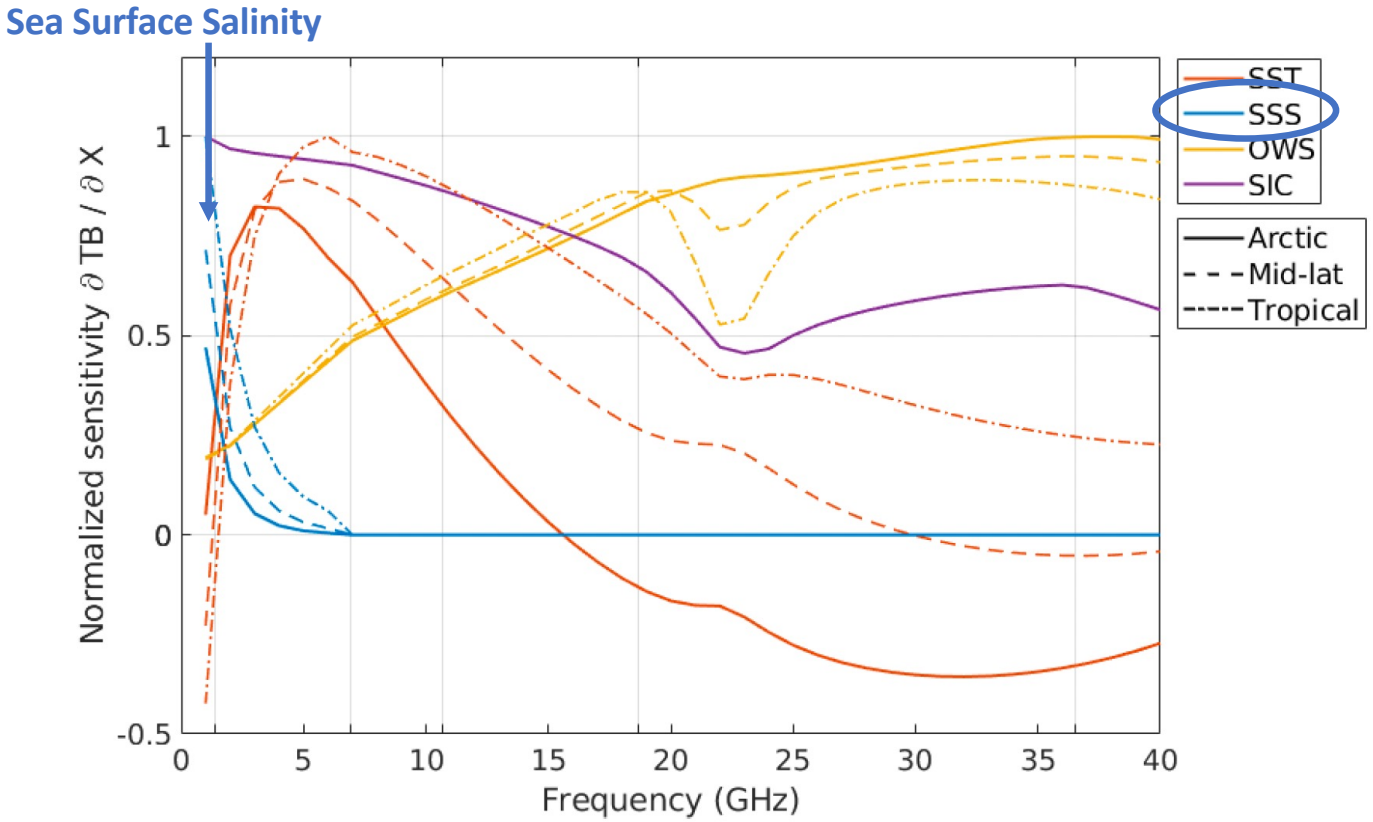
Some parameters only measurable at selected frequencies such as:

- Salinity (around 1.4 GHz)



Kilic et al., 2021

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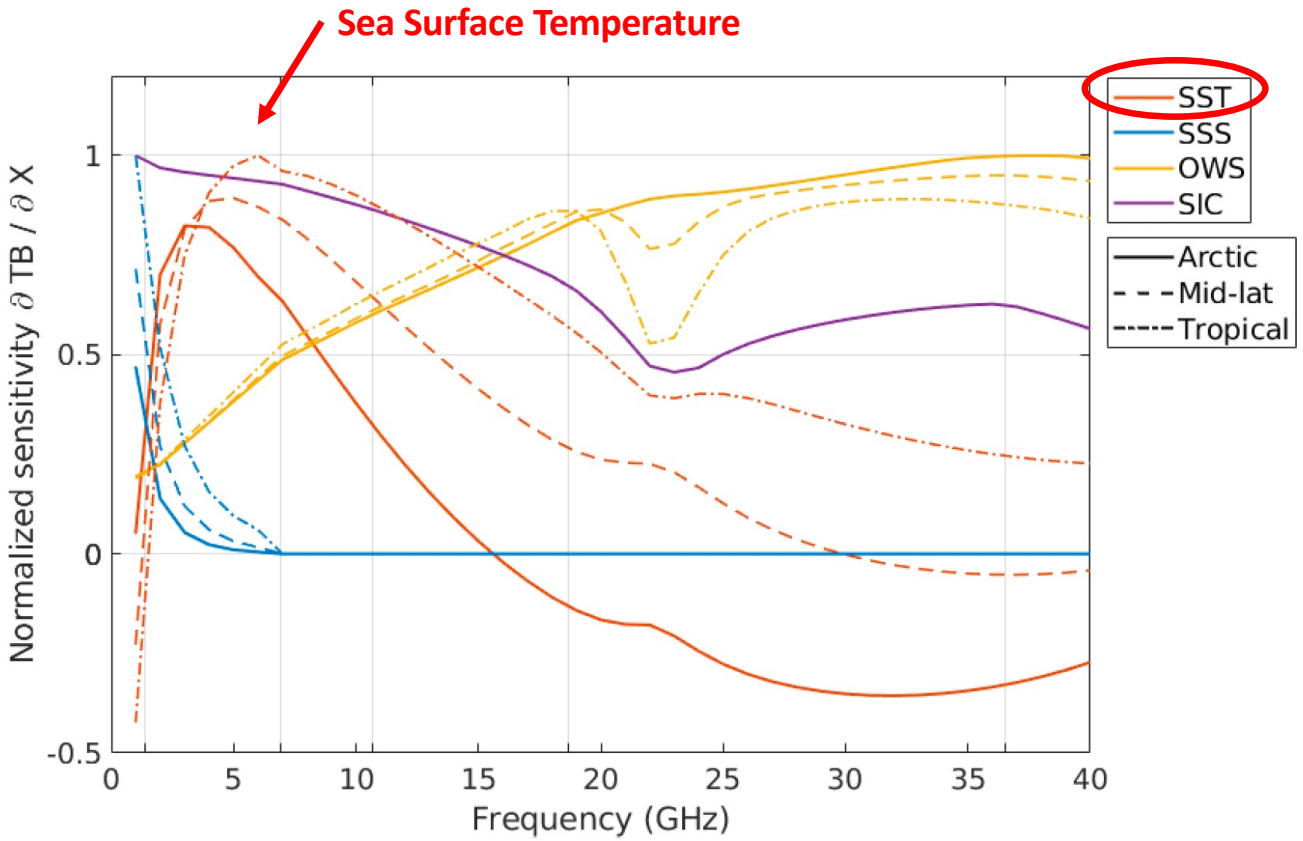

Kilic et al., 2021

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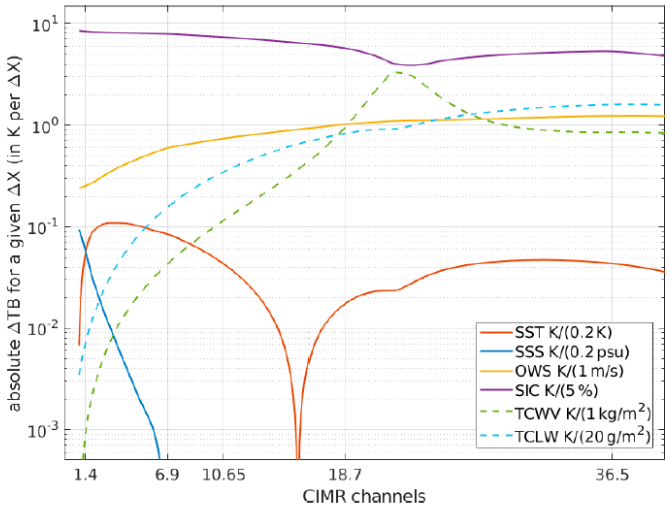
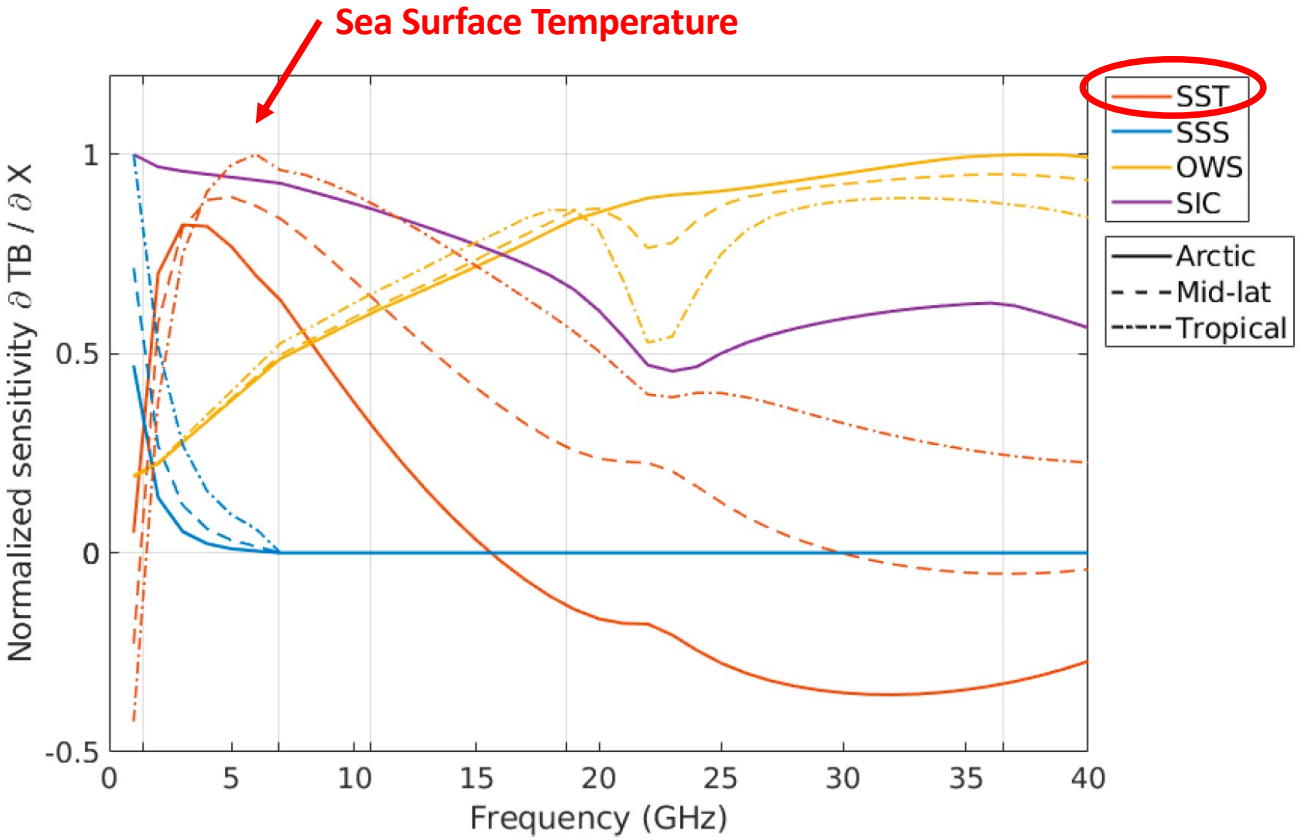
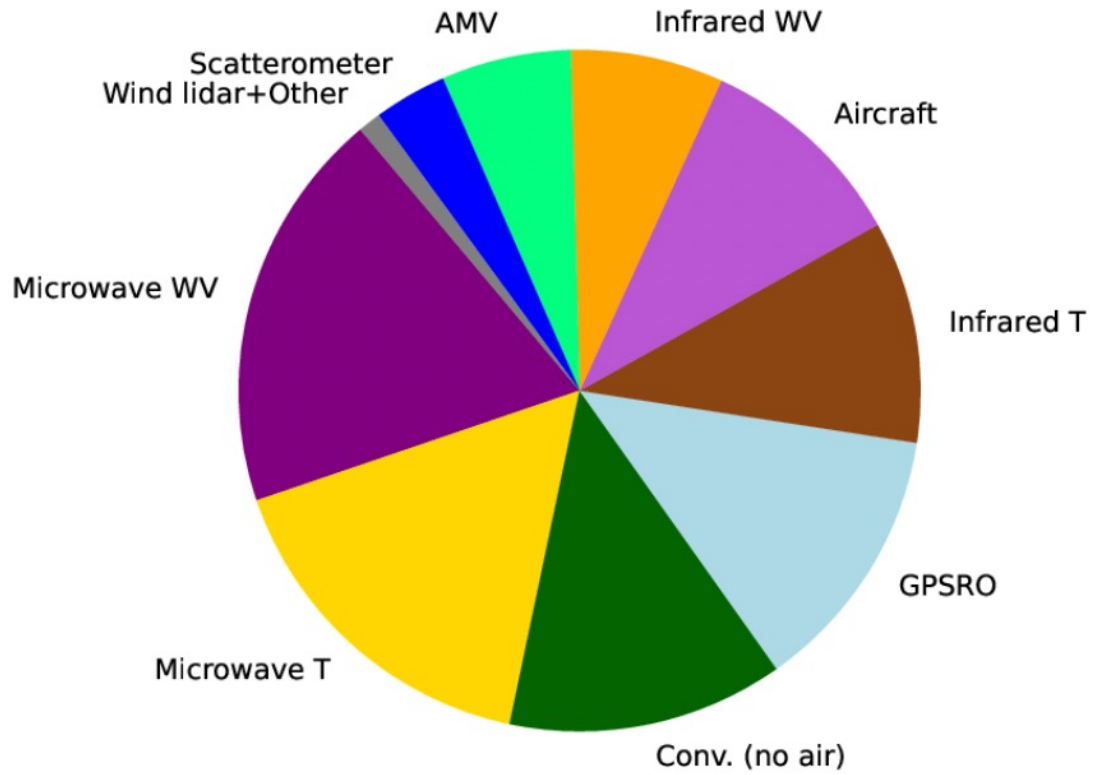


Kilic et al., 2021



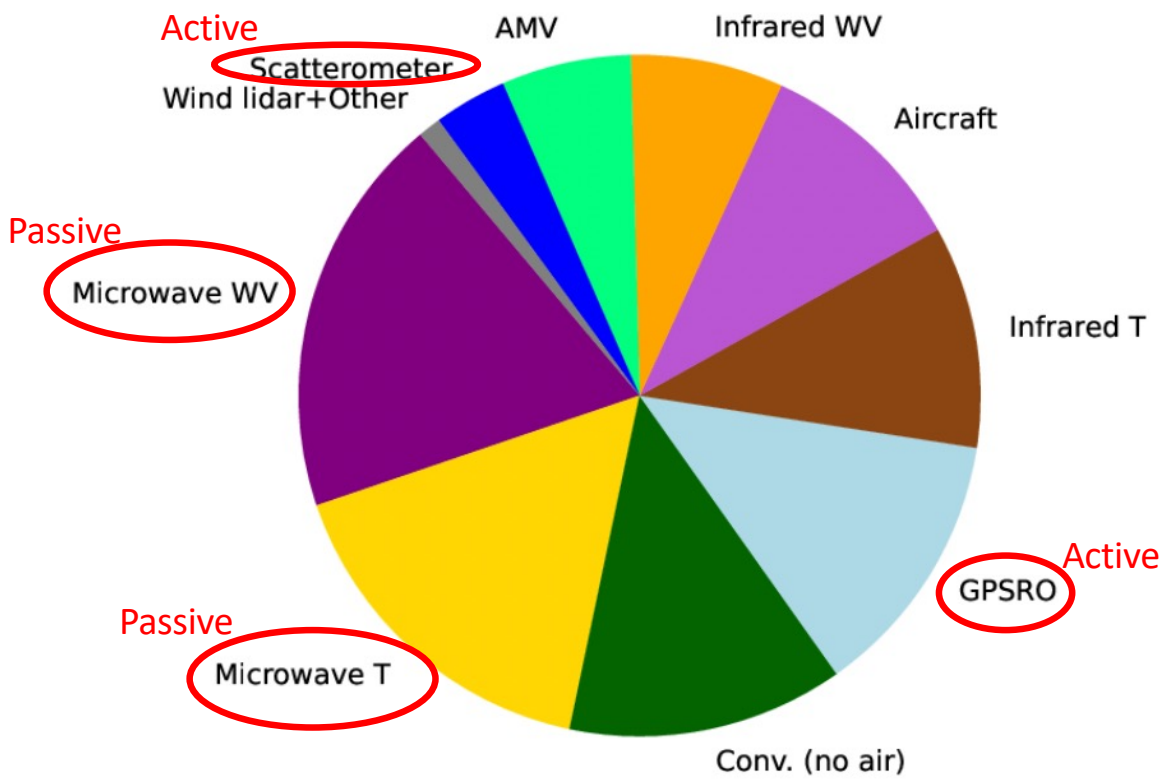
Unique role of the microwaves in operational weather forecast



English et al., ECMWF, 2024

Contributions of different observation types at ECMWF to the skill of short-range weather forecasts

Unique role of the microwaves in operational weather forecast



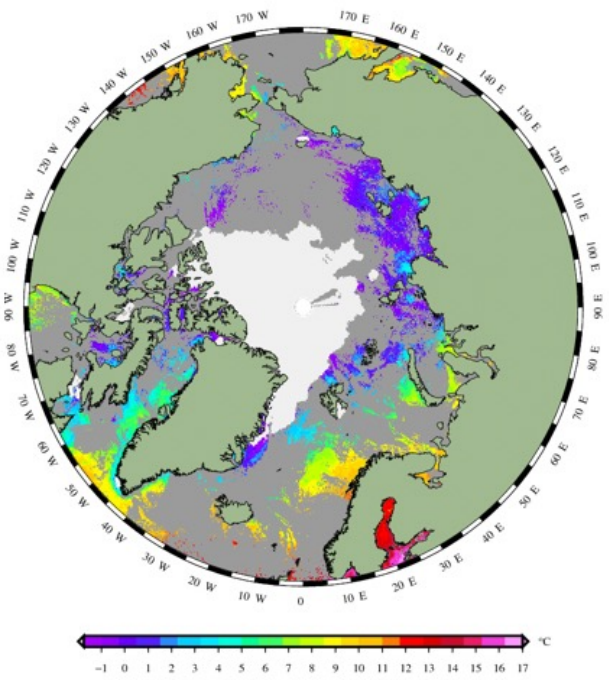
English et al., ECMWF, 2024

Current impact of main observing systems at ECMWF: more than 50% from microwaves

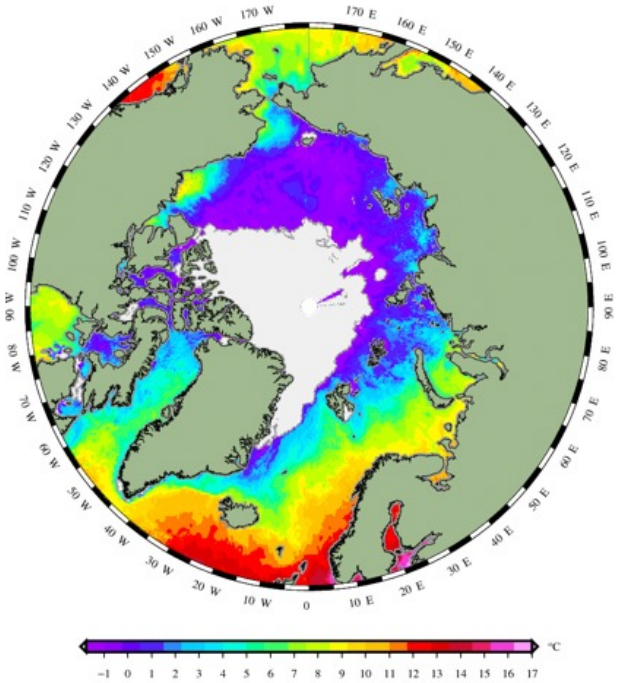
Estimation of the sea surface temperature: to complement infrared estimates under clouds

(key frequency: around 6 GHz)

With multiple infrared satellites in one day



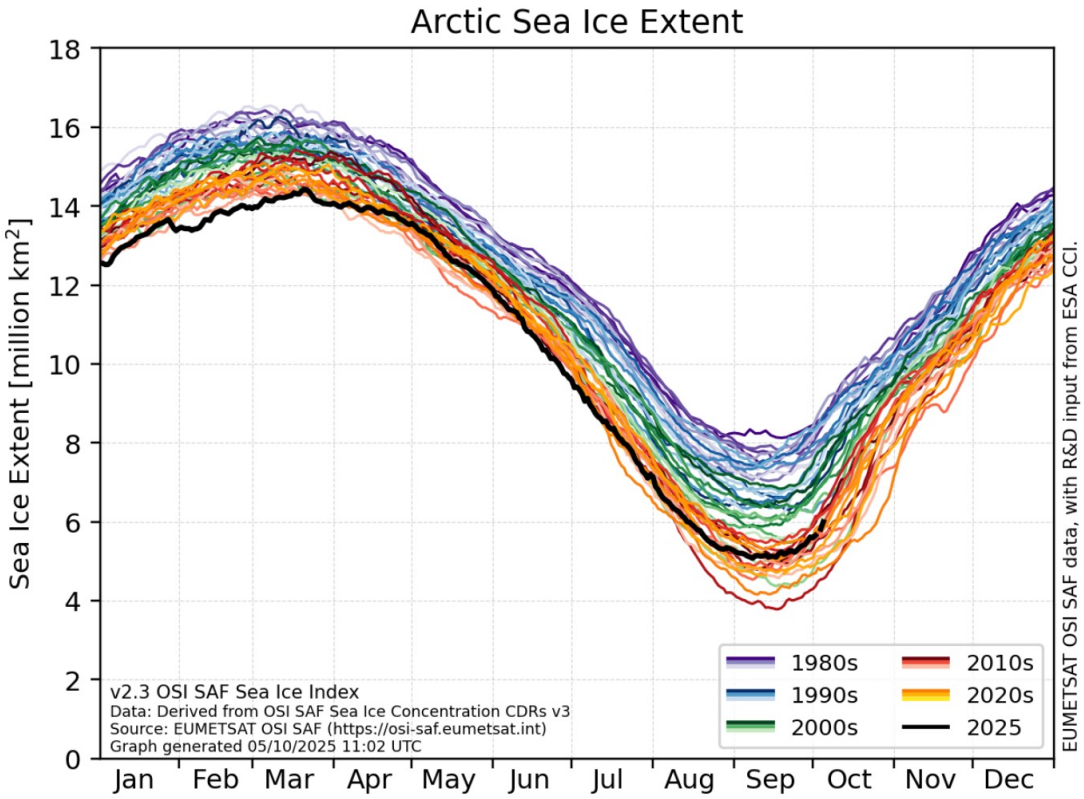
With one microwave satellite in one day



From Copernicus Marine Environmental Services (CMES)

Estimation of the sea ice extent (here over the Arctic): one of the longest series of satellite climate data

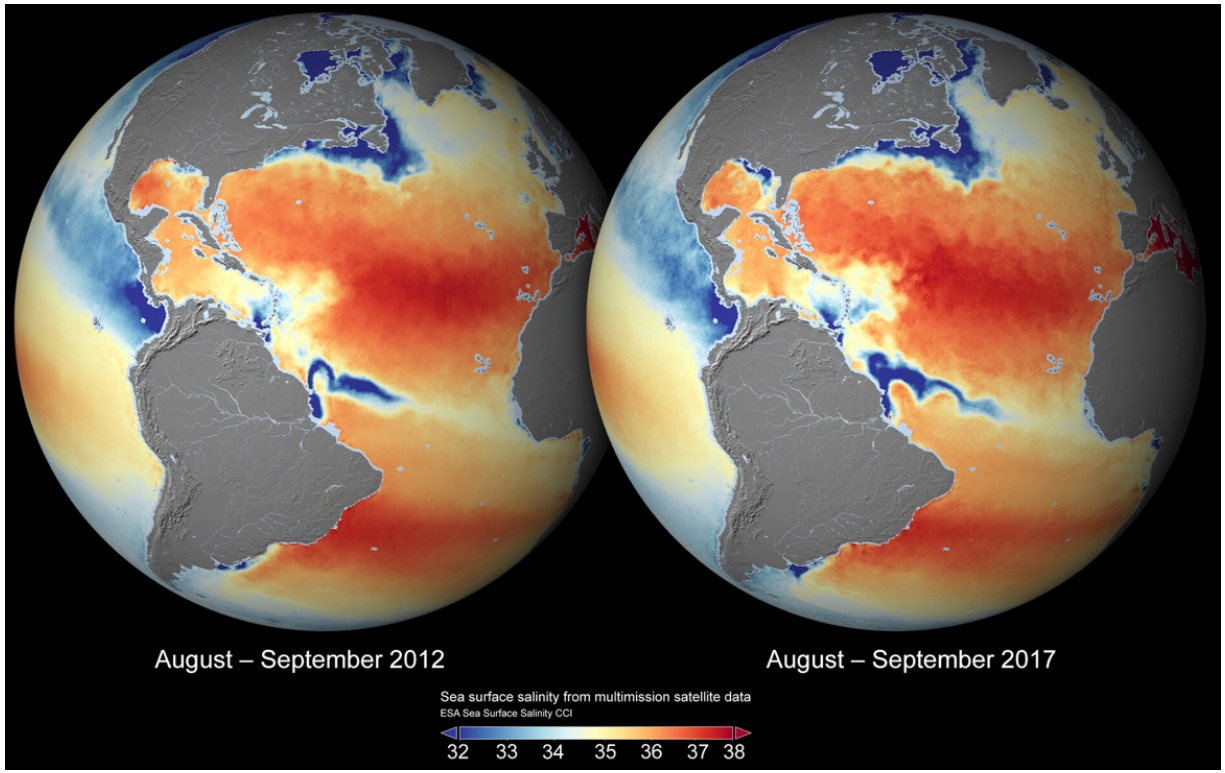
(key frequencies: 18 and 36 GHz)



From OSI SAF

Estimation of the ocean salinity

(key frequency: around 1.4GHz)

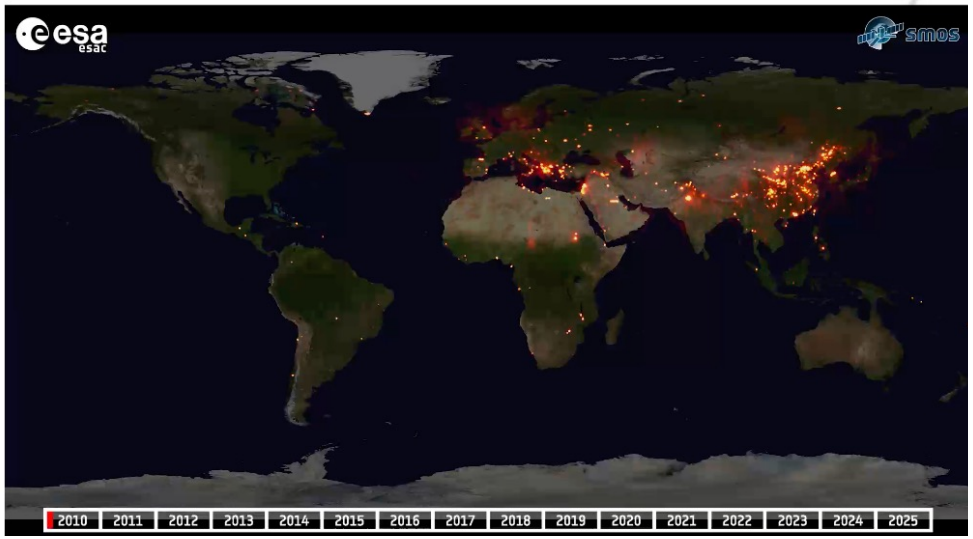


ESA Sea Surface Salinity CCI

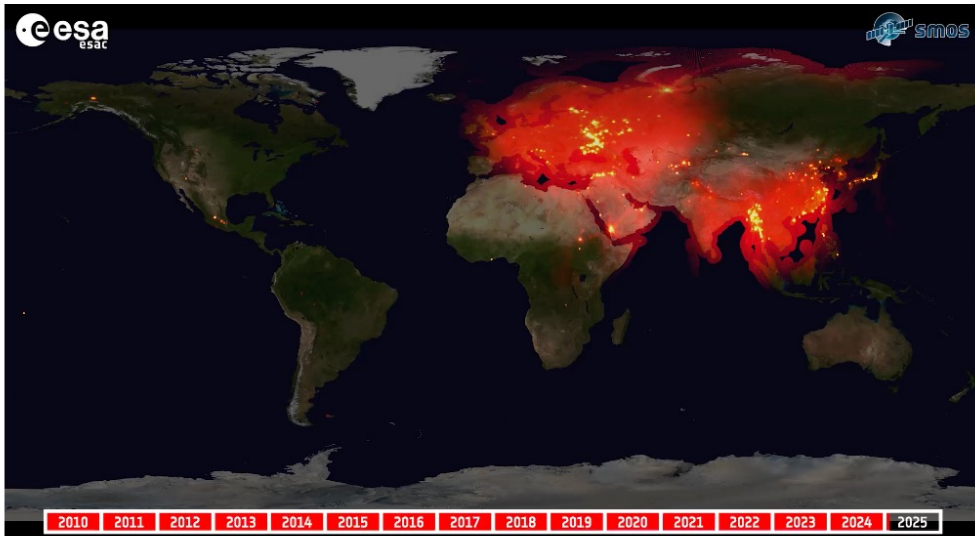
Over land and ocean

At 1.4 GHZ

In 2020



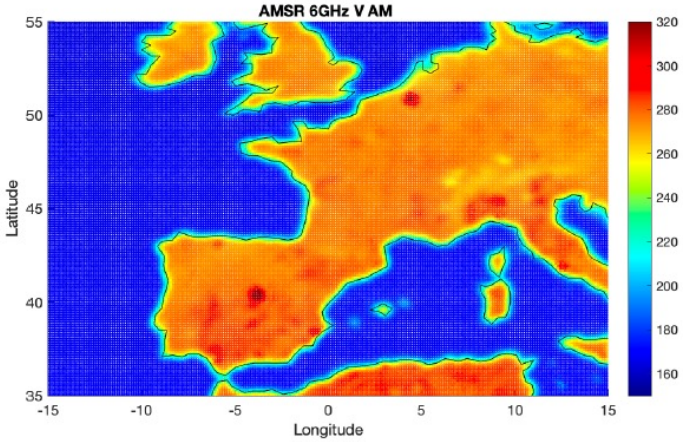
In 2025



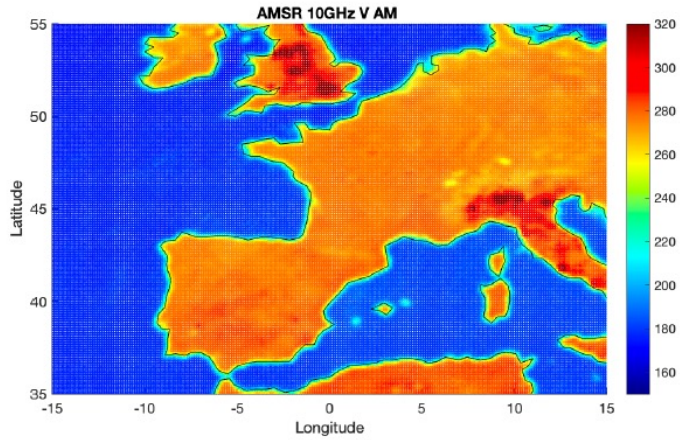
The 1.4 GHz RFI presence probability, in 2010 (left) and in 2025 (right)
(from the ESA RFI Monitoring & Information Tool, ERMIT)

Over land

Very strong RFI contamination around some cities, at specific frequencies



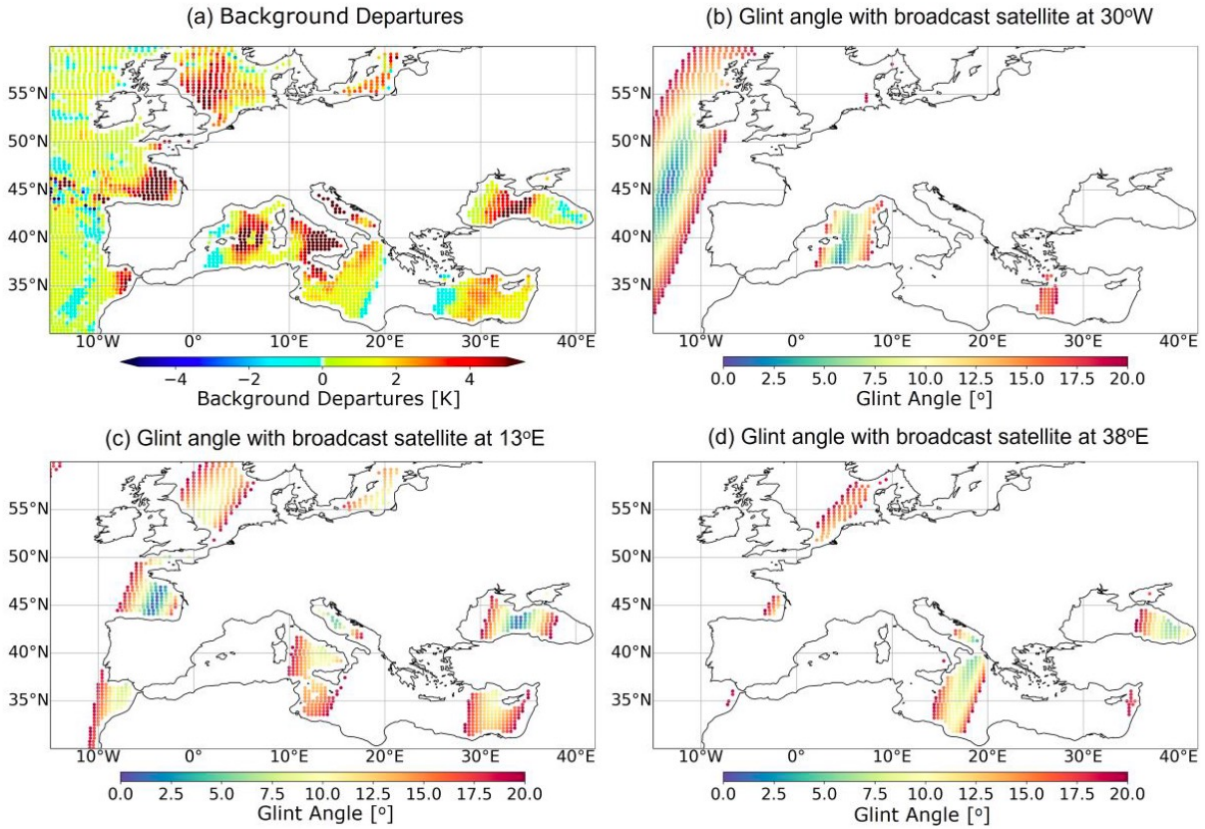
6 GHz
(secondary allocation)



10 GHz
(primary allocation)

Over ocean

At 10.65 GHZ

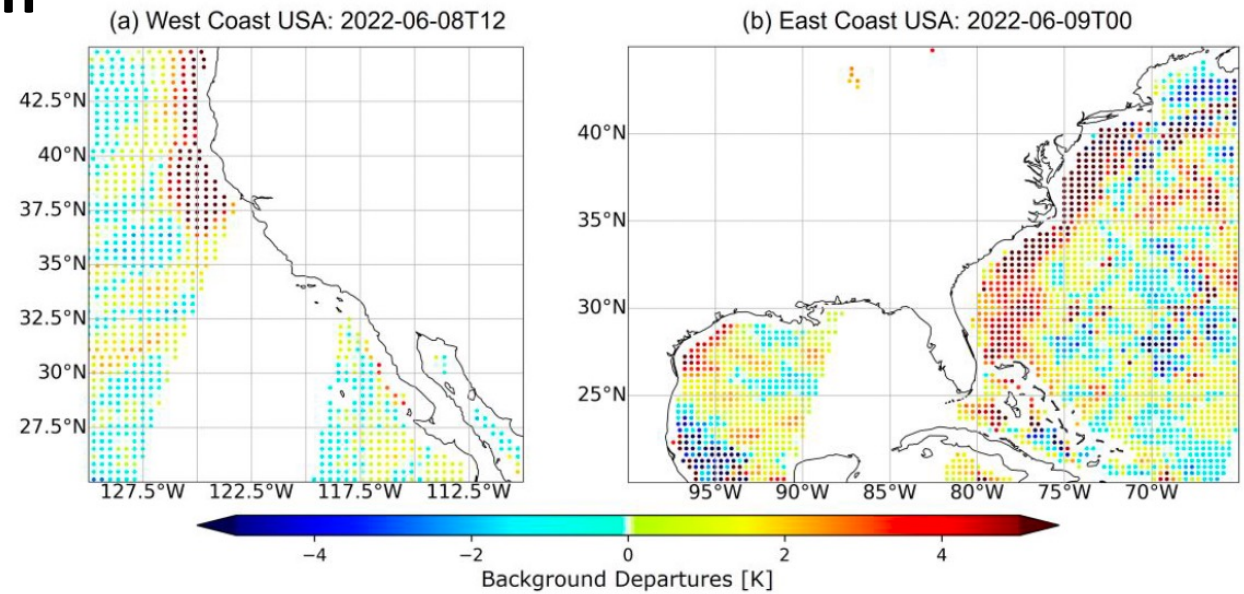


Maps for 2022-07-15T00 for (a) background departures at 10.65V with AMSR2 and the glint angles of the observations with geostationary satellites placed at (b) 30°W, (b) 13°E, and (c) 38°E.

Scanlon et al., ECMWF, 2024

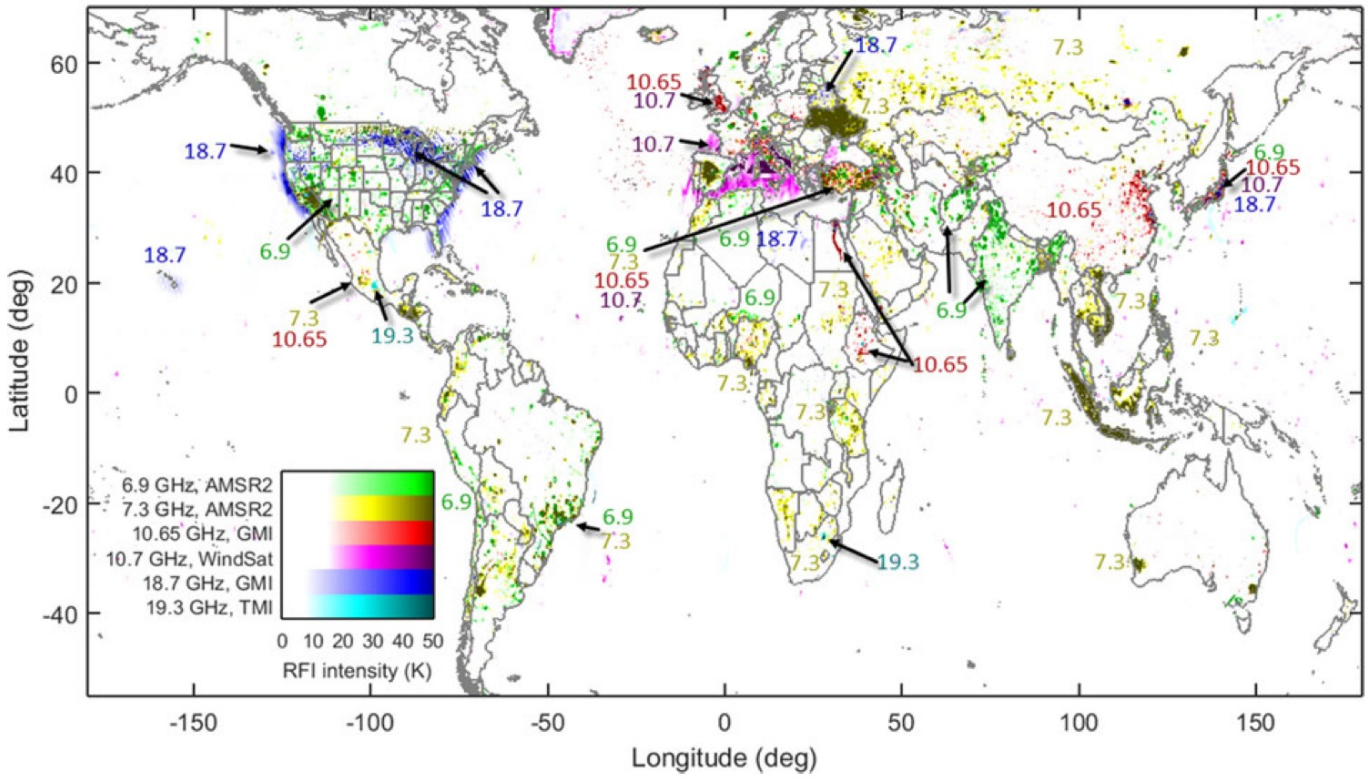
Over ocean

At 18.7 GHZ



Maps of background departures at 18.7 V with AMSR2, for two dates.
RFI most likely caused by a geostationary satellite at 102°W.

Scanlon et al., ECMWF, 2024

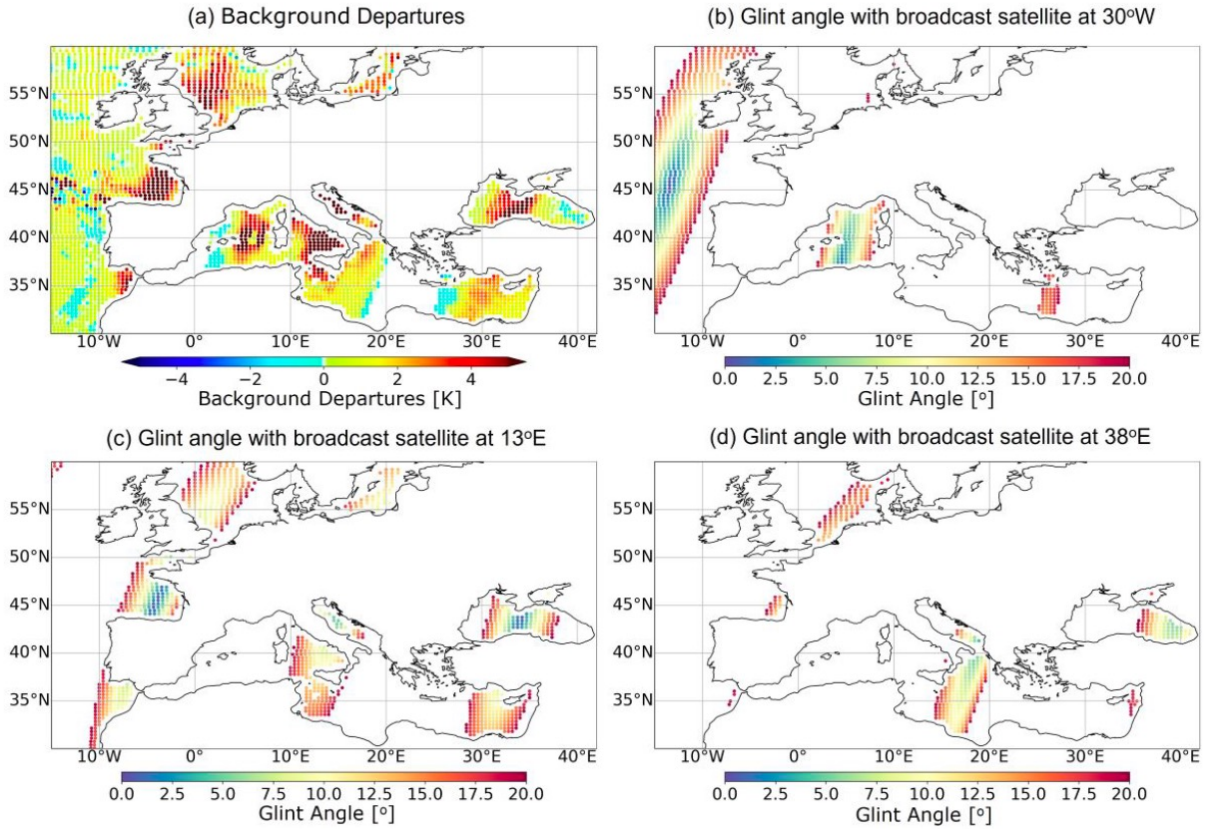


Draper et al., IEEE TGRS, 2018

Depending on the locations, RFI at different frequencies, and changing with time

Impact of the RFI on Weather Forecast

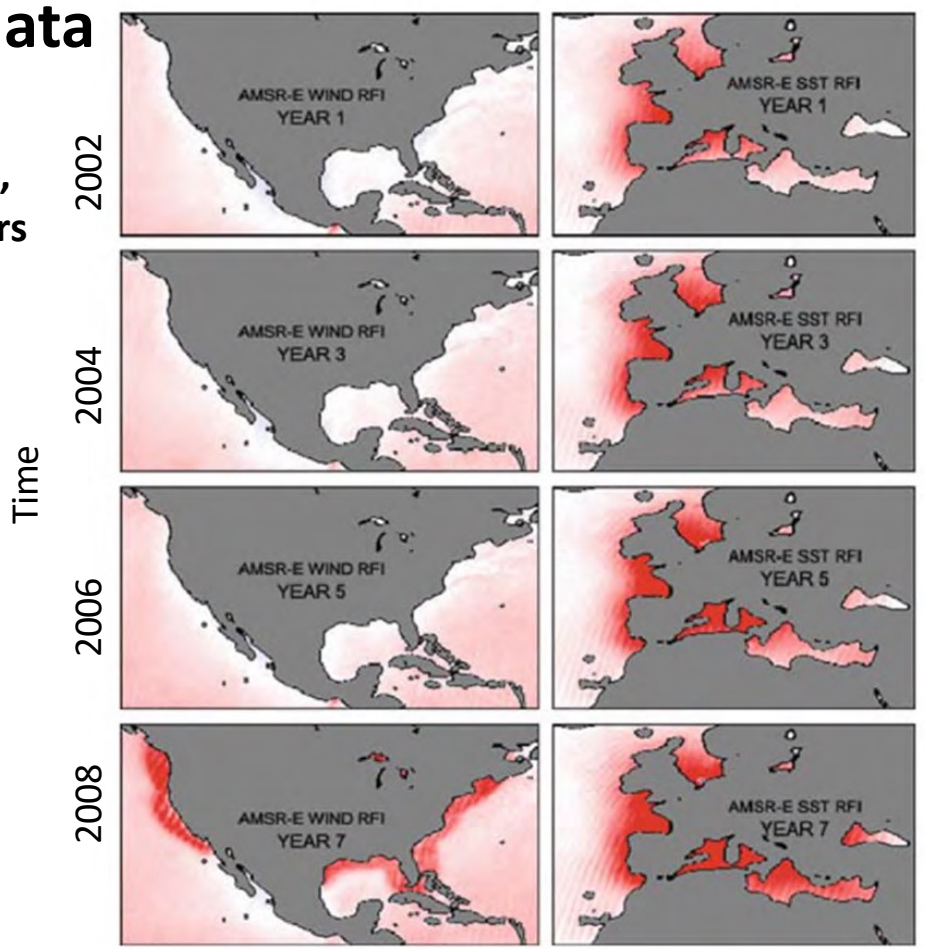
- **Masking of all the areas that can be possibly contaminated (very significant percentage in some areas)**
- **Spurious results that might be difficult to detect in some areas**



Scanlon et al., ECMWF, 2024

Impact of the RFI on environmental data

- **RFI signal translates into erroneous geophysical products,**
- **Here, RFI increase in coverage and intensity over the years**



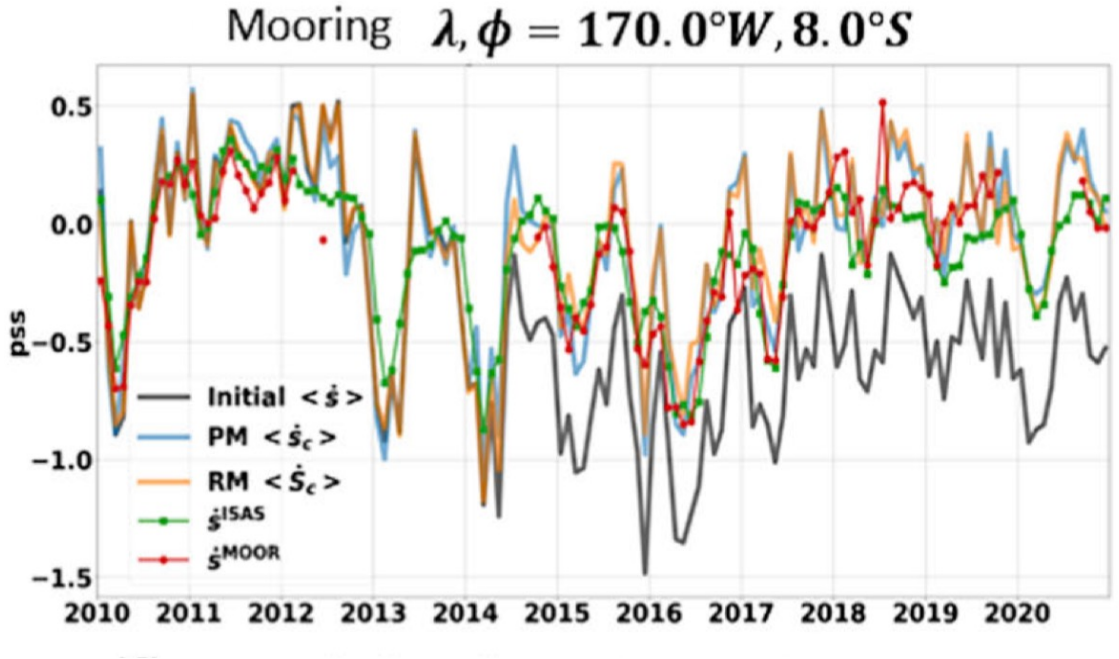
RFI induced Wind errors

RFI induced Surface Temperature errors

Gentemann et al., 2010

Impact of the RFI on climate records

- **Subtle RFI can affect climate records**
- **Strategies to mitigate them**



Mooring
SSS from SMOS (before correction)

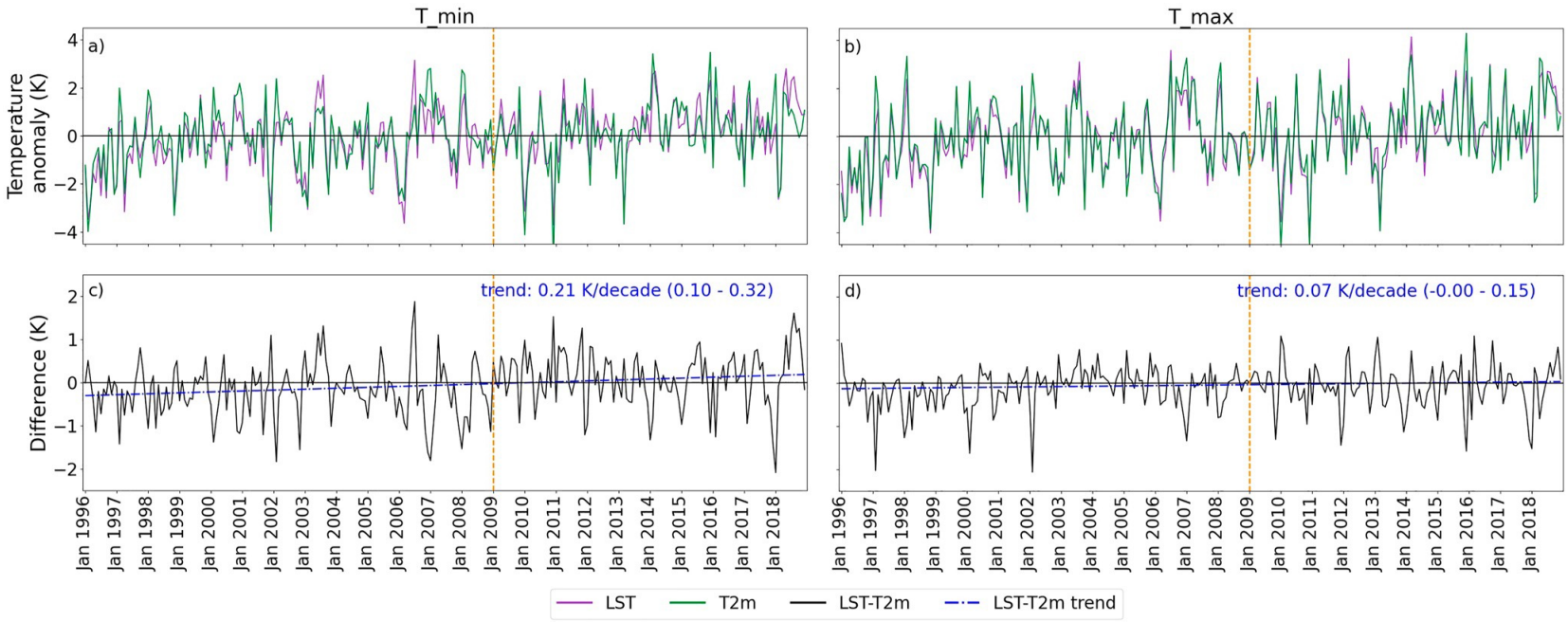
Sea Surface Salinity time series, affected by RFI at 1.4 GHz, in the middle of the Pacific Ocean

Bonjean et al., IEEE TGRS, 2024

Impact of the RFI on climate records

- Looking for small signals… that can be easily contaminated…

Land Surface Temparature from passive microwaves (18 and 36 GHz), as compared to ERA5



Jimenez et al. (2024), Good et al. (2022)

Conclusions

- **Weather foreacst and climate analysis strongly depend upon microwave observations**
- **Increasing evidence of RFI contamination in the data, even in protected bands, below 20 GHz**
- **Masking significant percentage of data in the contaminated bands**
- **But still possibility to miss some RFI, with confusion with real signal and errors in forecast or climate records**
- **The 6.9 Ghz band for SST…**

- **Necessity to monitor and filter the data, at different steps in the process**
- **Necessity to regulate and protect bands … as much as possible… even at higher frequencies**

For more information:
https://www.esa.int/Applications/Observing_the_Earth/FutureEO/Preparing_for_tomorrow/ESSEO_European_Scientists_on_Spectrum_for_Earth_Observation