# Radio Technologies of Earth Observations – Passive sensing

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# Passive sensing principle

# Passive sensing: the target is the natural noise

Signal from transmitter

Active system:

Receiver

Passive system:

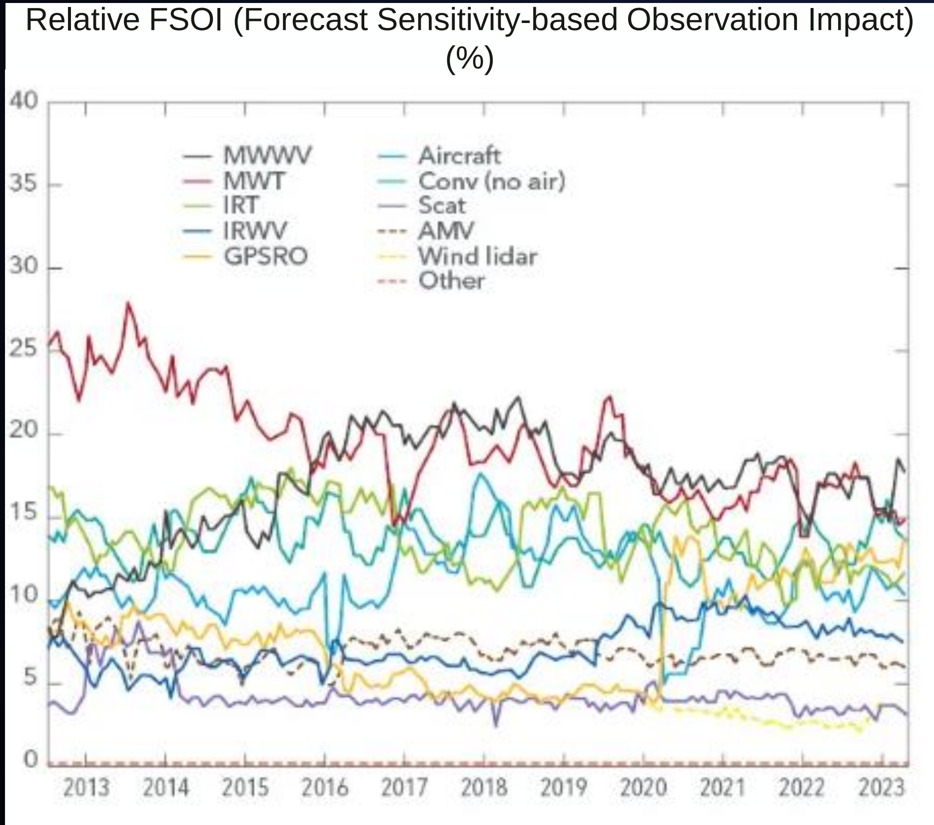
Receiver

Natural energy emitted from Earth

# Applications of passive sensing (examples)

# Weather forecast

## Main contributor to weather forecasting skill




English, 2023

**MWWV** = Microwave humidity sounders

**MWT** = Microwave temperature sounders

**IRT** = Infrared temperature sounders

**IRWV** = Infrared humidity sounders

**GPSRO** = GNSS radio occultation

**Aircraft** = *In situ* observations on aircraft

**Conv** (no air) = Other *in situ* observations

**Scat** = Scatterometers (currently all C-band)

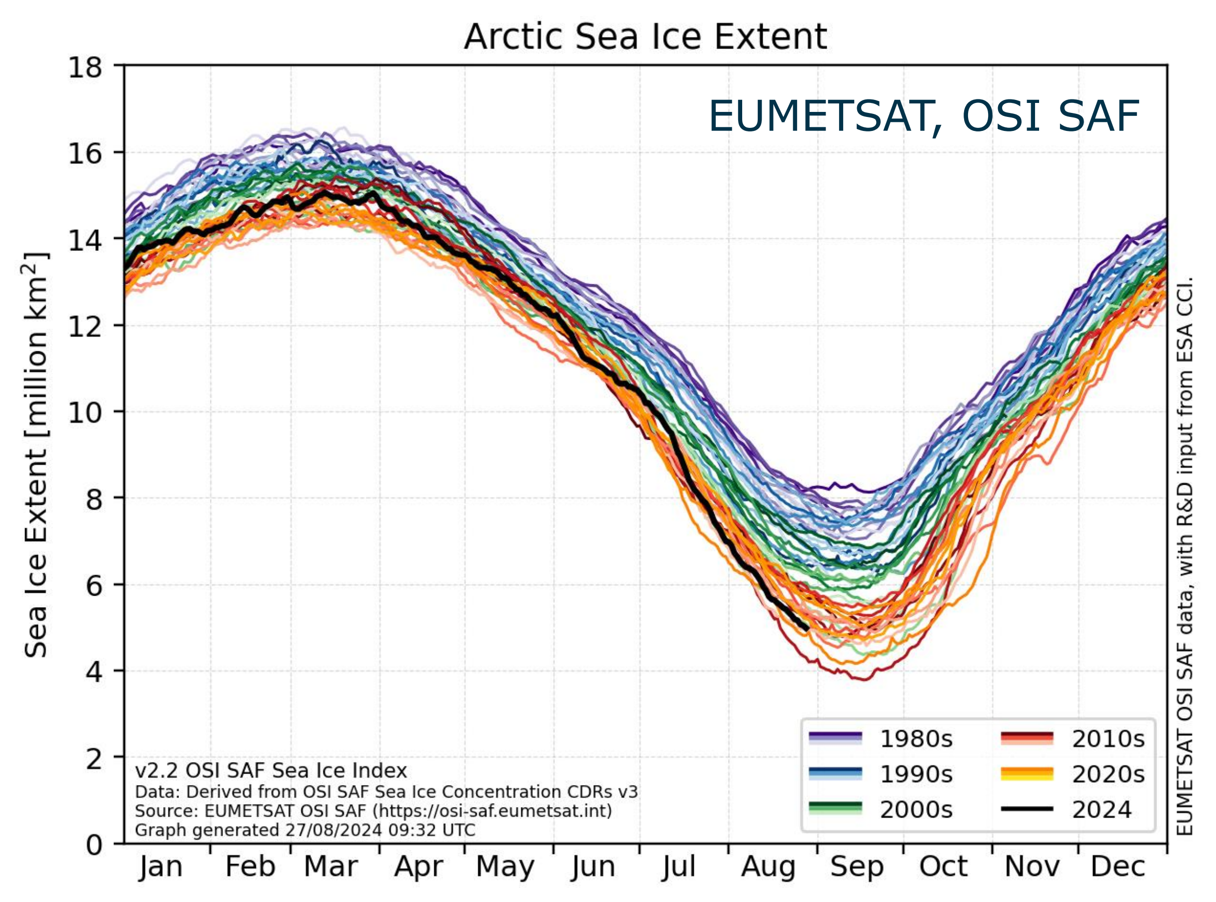
**AMV** = Atmospheric motion vectors (from satellite image sequences)

**Wind lidar** = UV doppler wind lidar (only Aeolus in this period)

**Other** = All other observation types

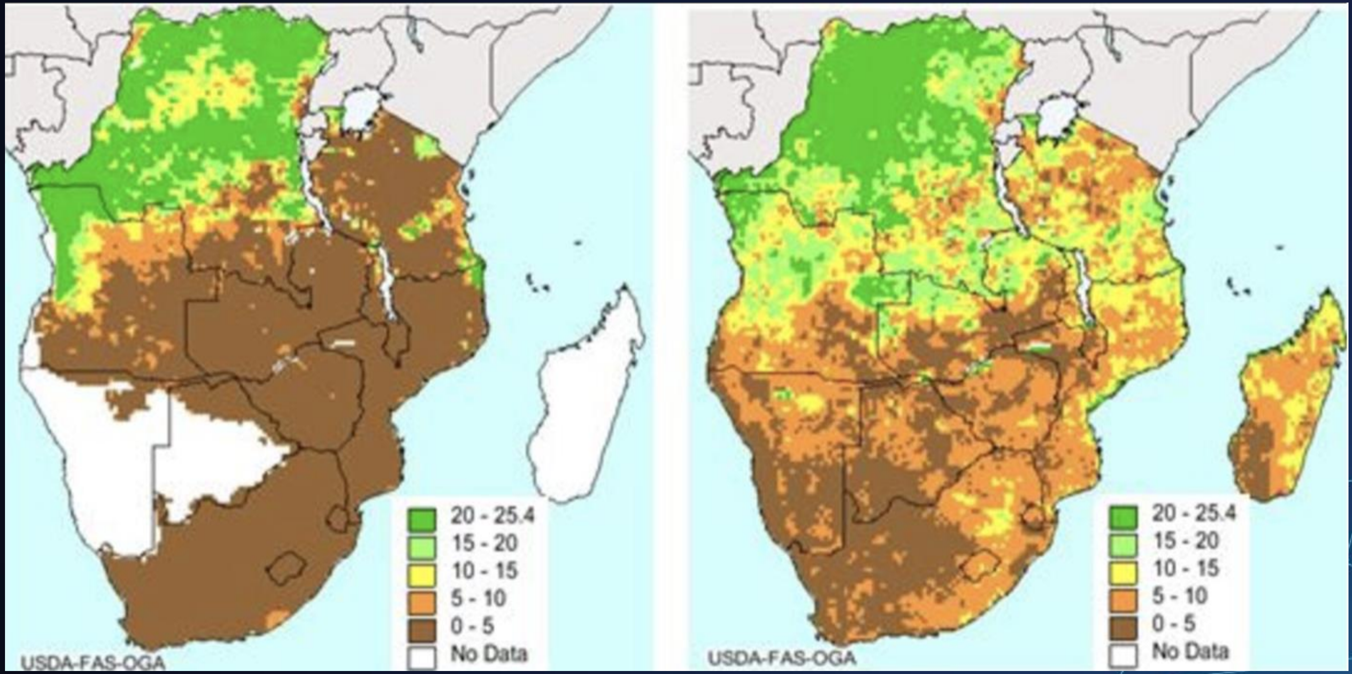
# Climate

## Sea ice seasonal and long-term monitoring



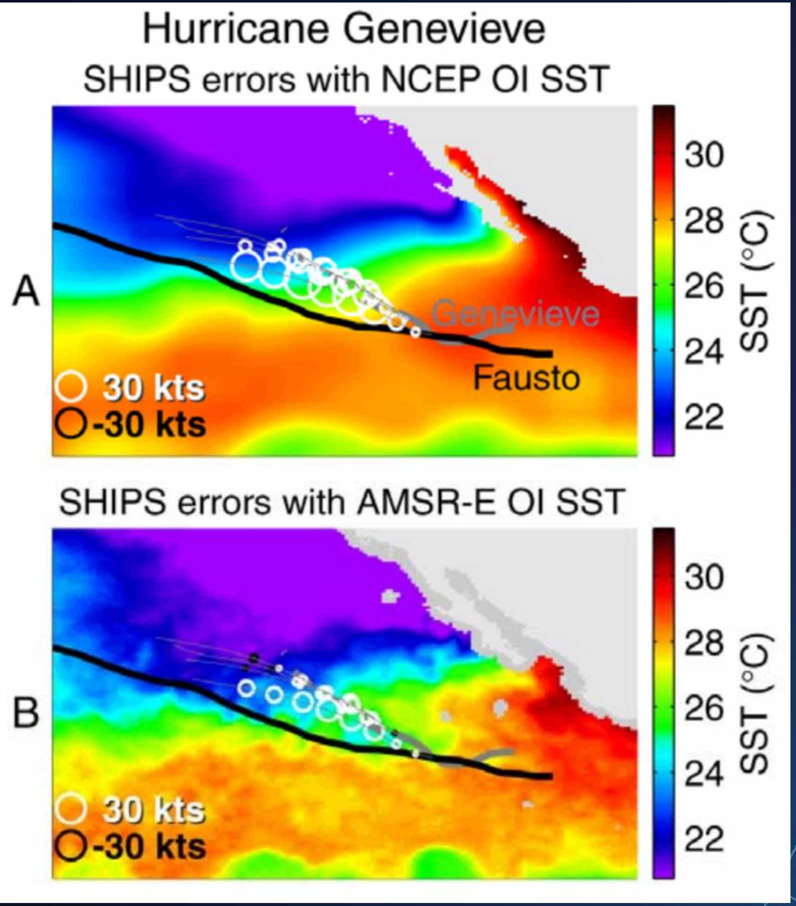
# Socio-economical benefits (example for land)

## Food security/Crop yield estimates



# Socio-economical benefits (example for ocean)

## Hurricane prediction



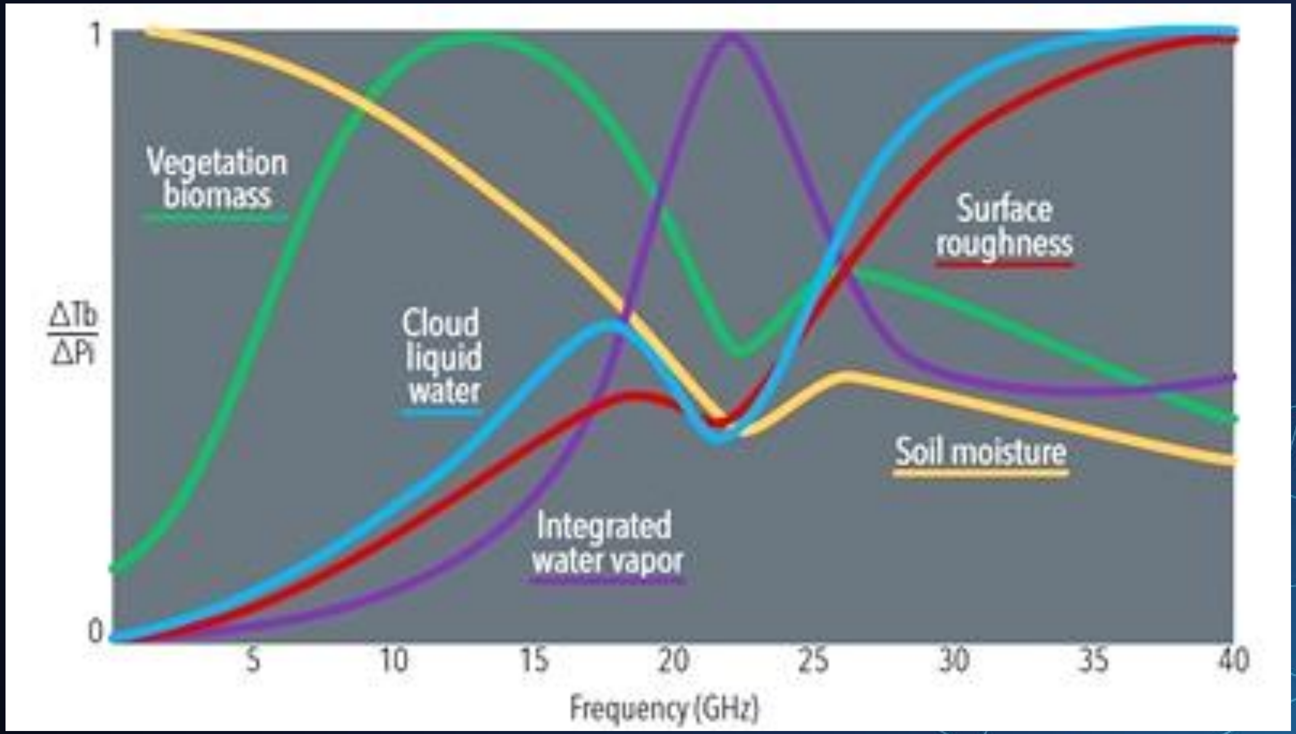

Gentemann et al., 2006

# Frequencies for passive sensing

# EO Spectrum needs

Passive sensing systems have no control over the frequency/intensity of the desired signal

At each specific frequency, the intensity of the natural signal depends on the geophysical characteristics of the surface/atmosphere

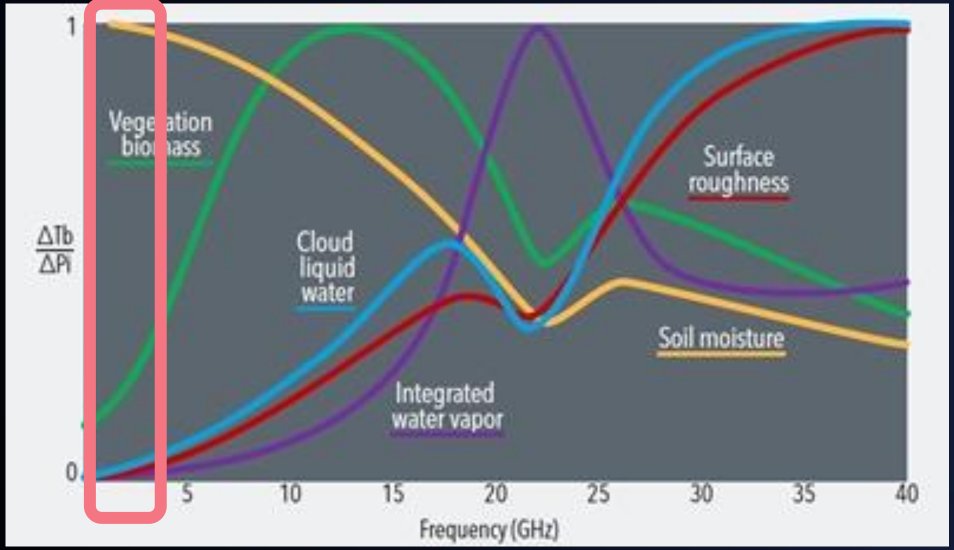



Sensitivity to Land parameters

# EO Spectrum needs

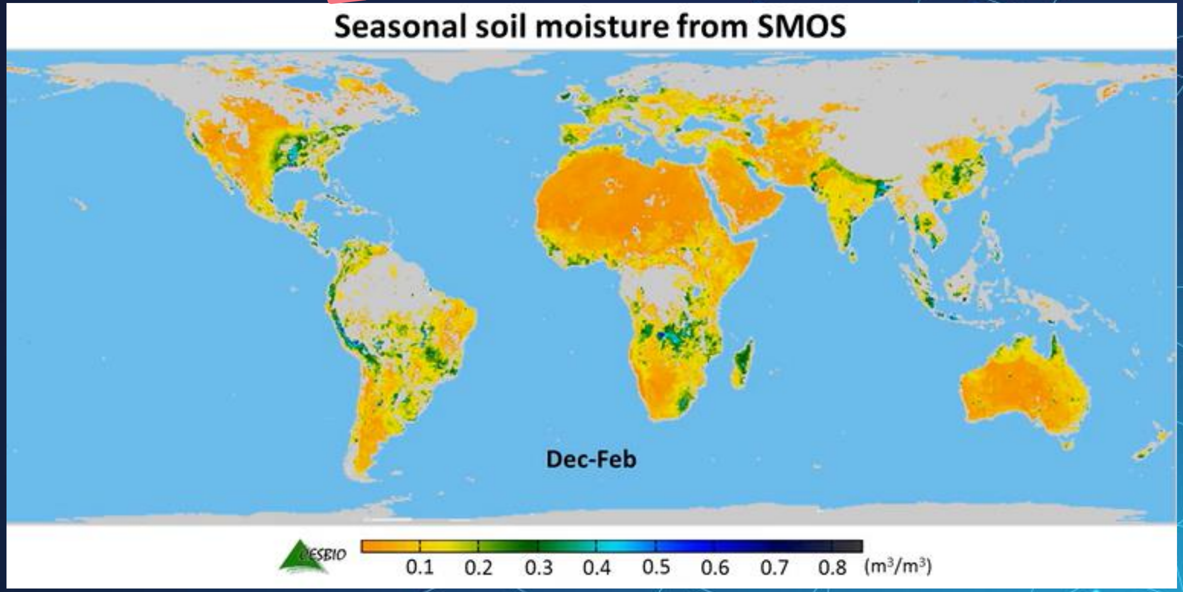
The frequencies that can be used by passive sensors are dictated by physical laws:

➢ **They can't be changed**




Sensitivity to Land parameters

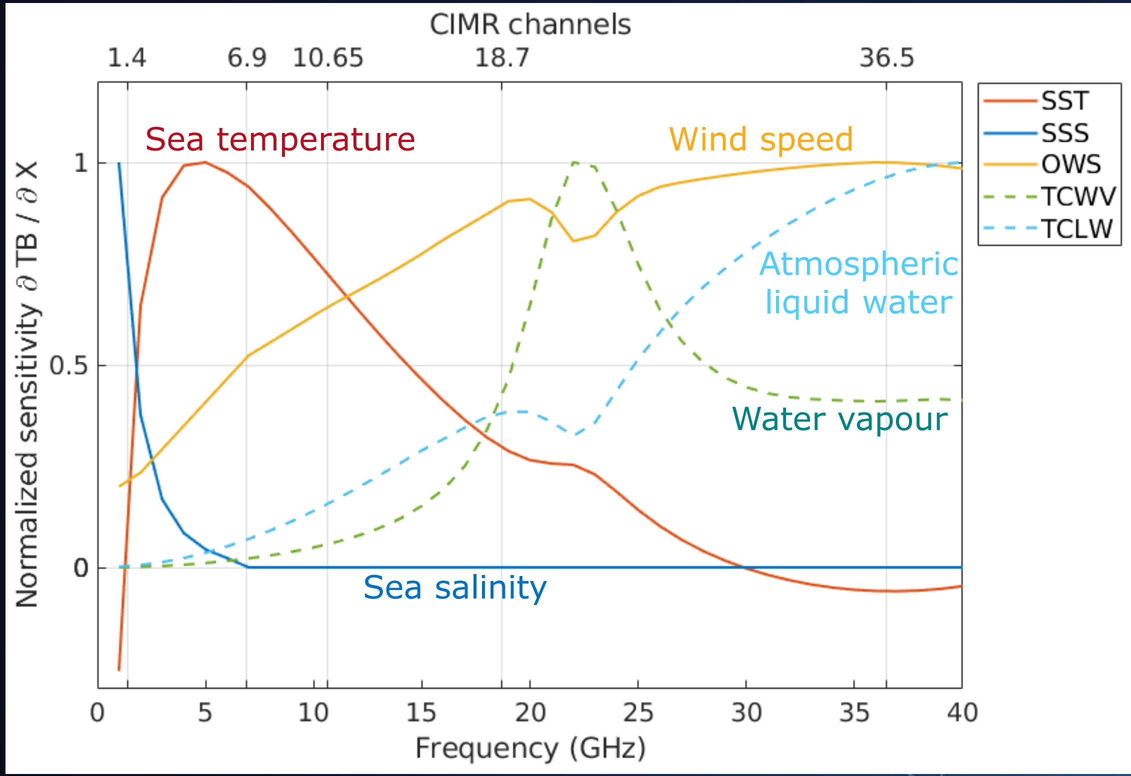
*Need this specific band to measure soil moisture*



# EO Spectrum needs

Sometimes sets of frequencies are needed at the same time.

In CIMR, using 5 channels will allow to measure the ocean surface & the atmosphere.



# Passive sensing instruments

# Passive sensors

Passive sensors measure the faint signal of the thermal noise emitted by the Earth.

They need extremely sensitive receivers.

An example: **CIMR**

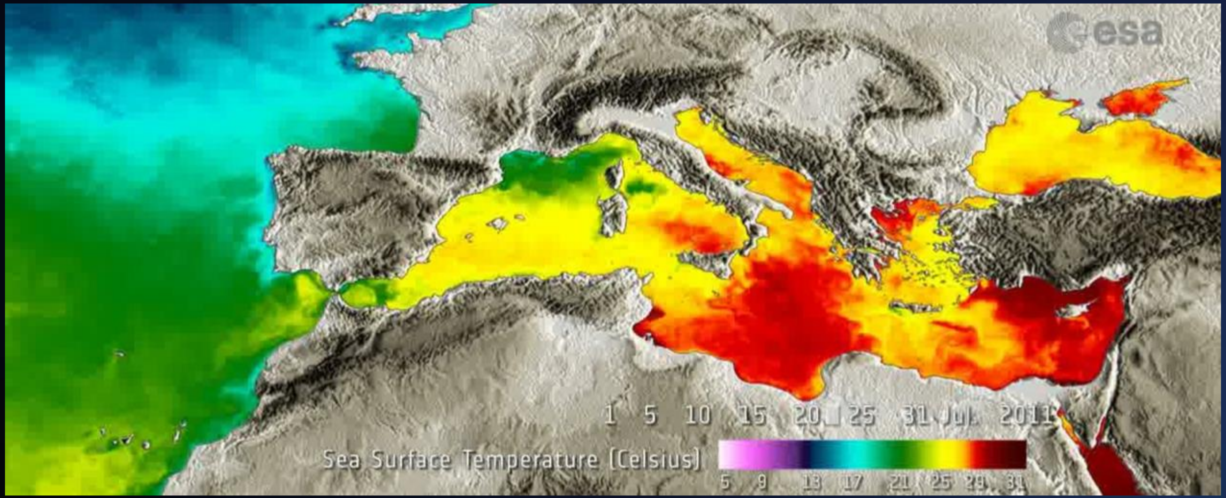
7.4 m reflector
8 rotations/minute
5 channels (1.4 to 36.5 GHz)
39.1 to 59.6 dBi peak antenna gain
1900 km swath width

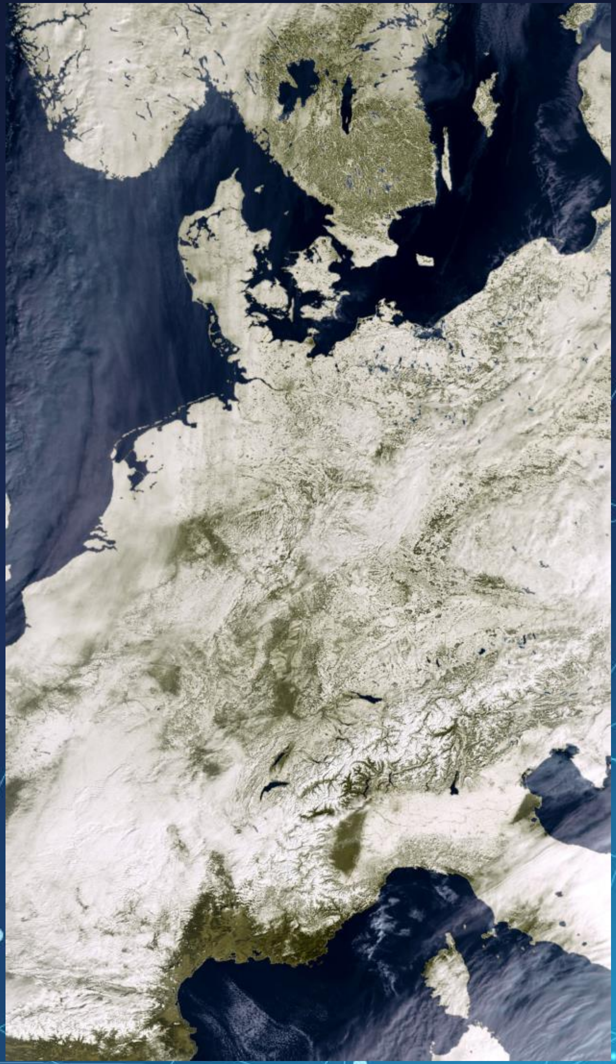
Sub-daily coverage of Polar regions

# Example of passive sensor objectives

To get a sense of the sensitivity of radiometers, the CIMR objectives are:

- Sea Surface Temperature: uncertainty < 0.3 K
- Snow Water Equivalent: uncertainty < 4 cm



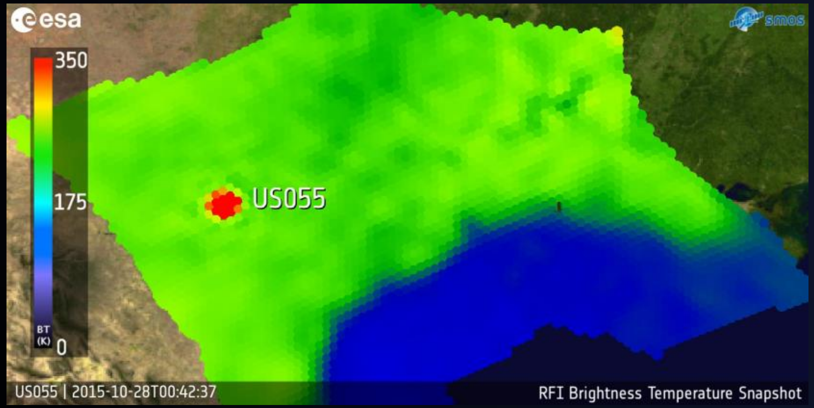



# Sensitivity of passive sensors to RFI

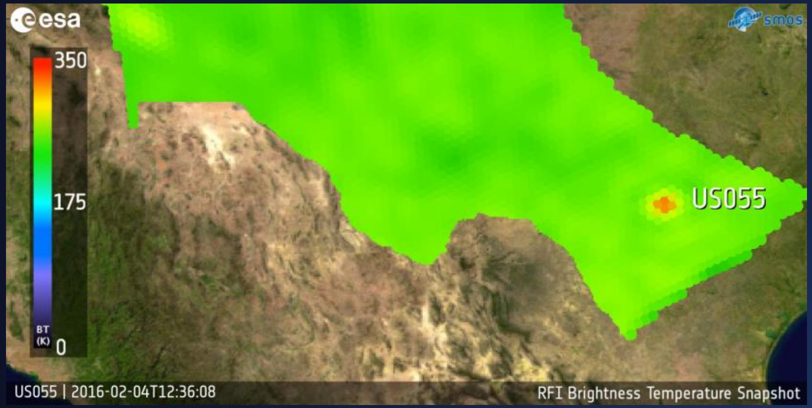
# Sensitivity to RFI (Example 1)

Because of their sensitivity, passive sensors are very easily affected by Radio-Frequency Interference (RFI).

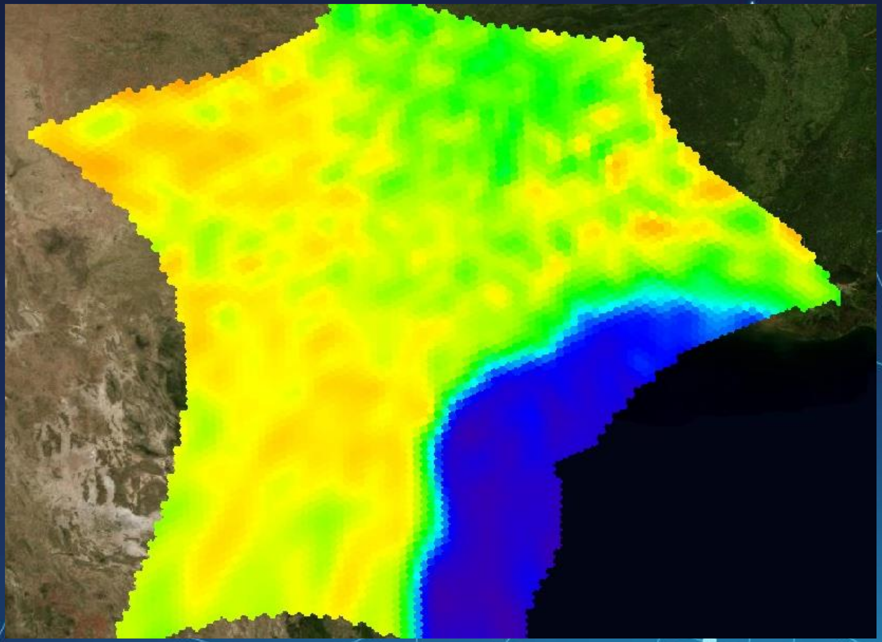
Visible RFI



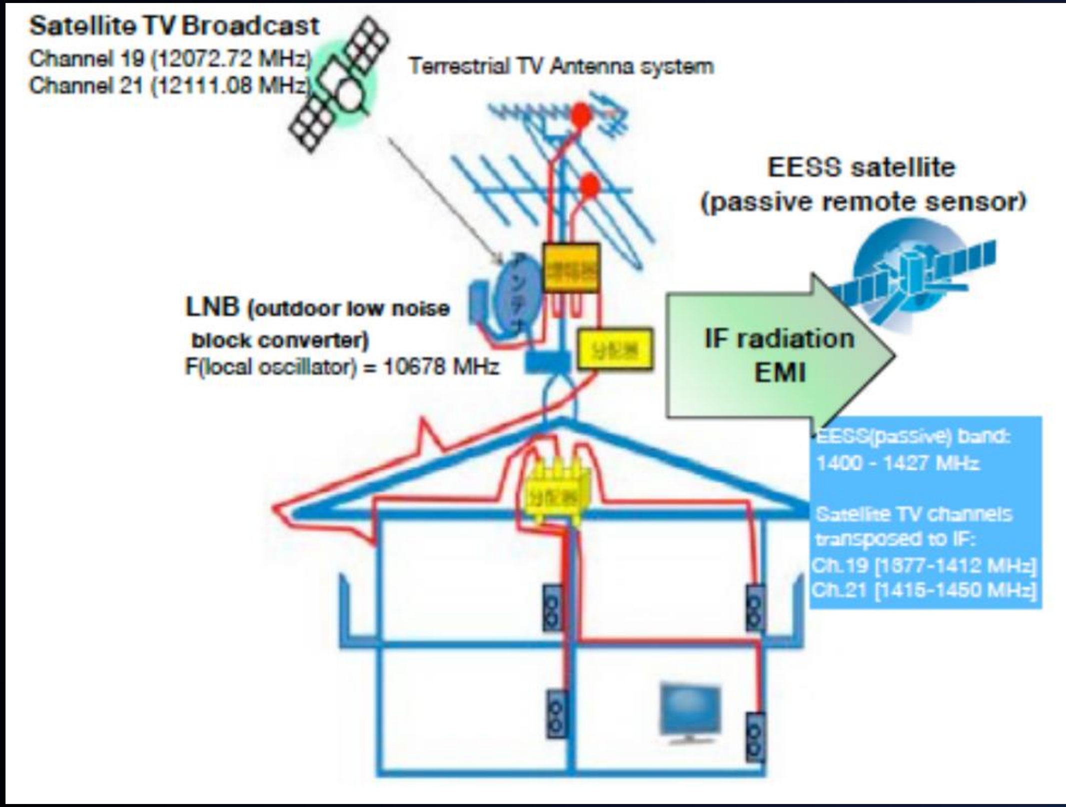

Signal amplifier OFF
(RFI still visible)

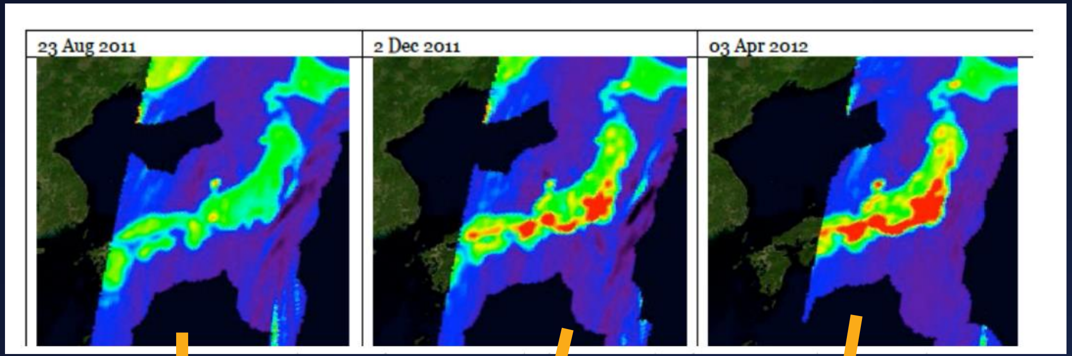


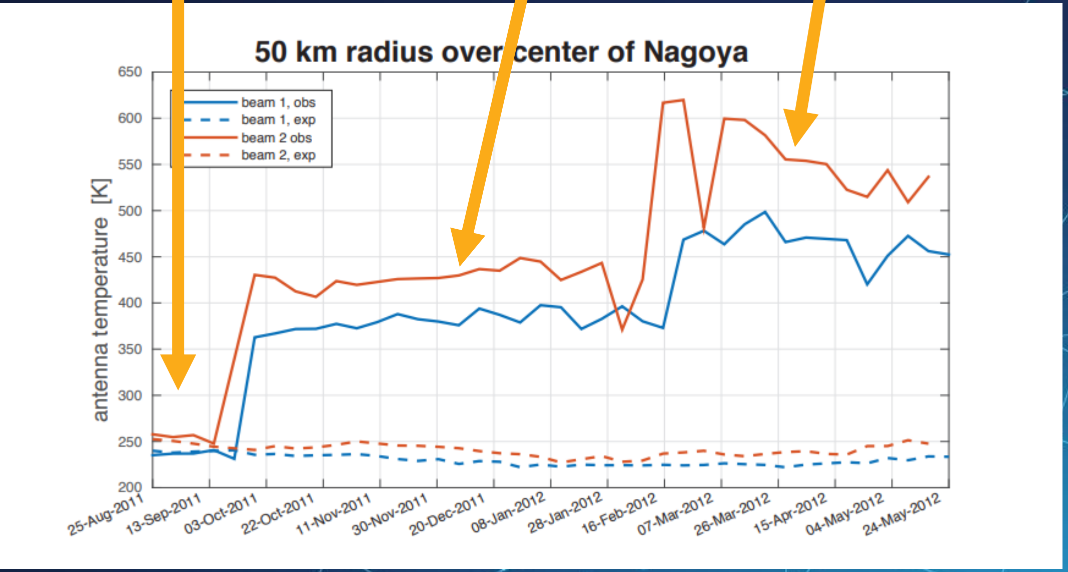

Signal amplifier &
wireless camera OFF



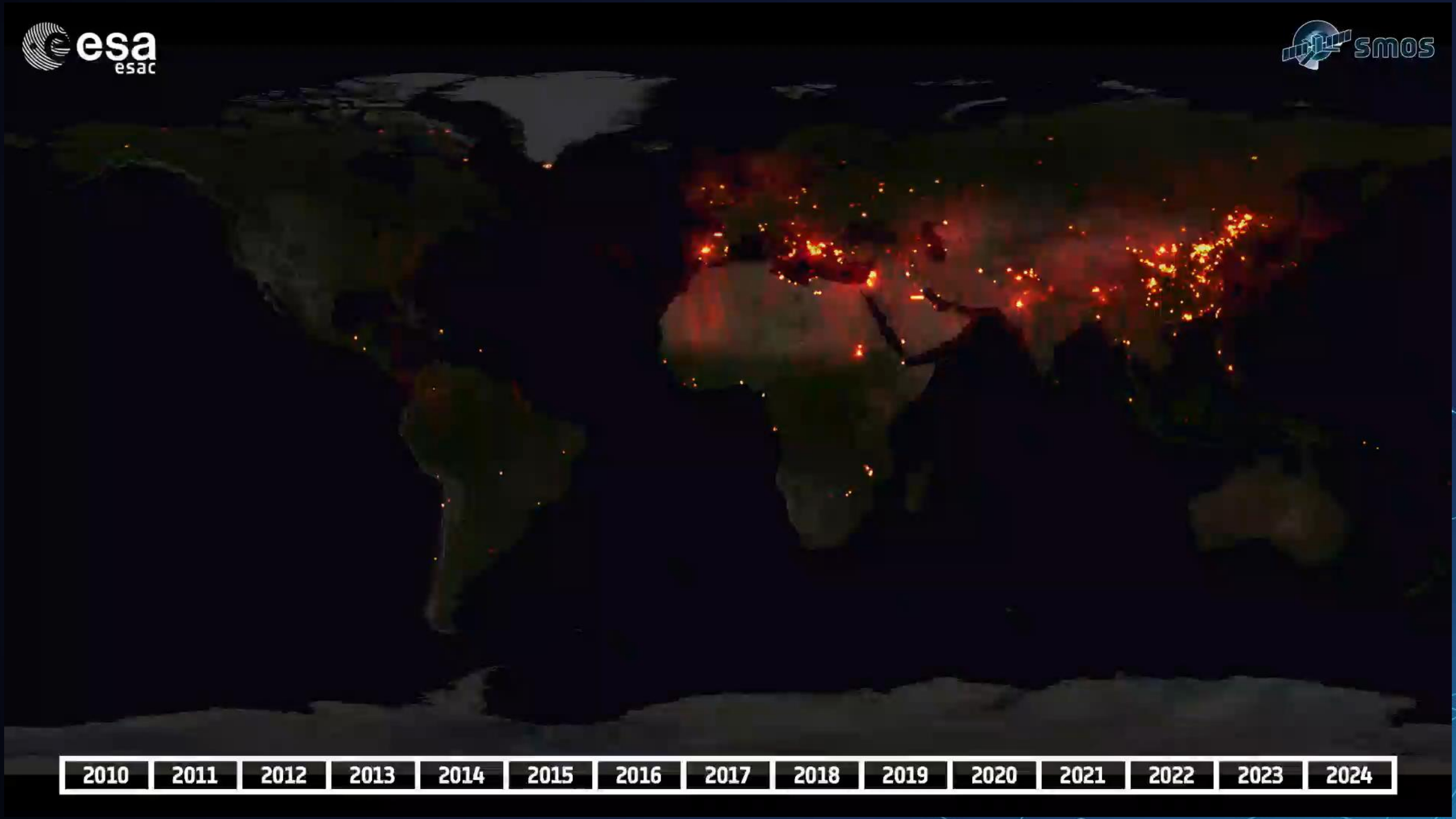
# Sensitivity to RFI (Example 2)



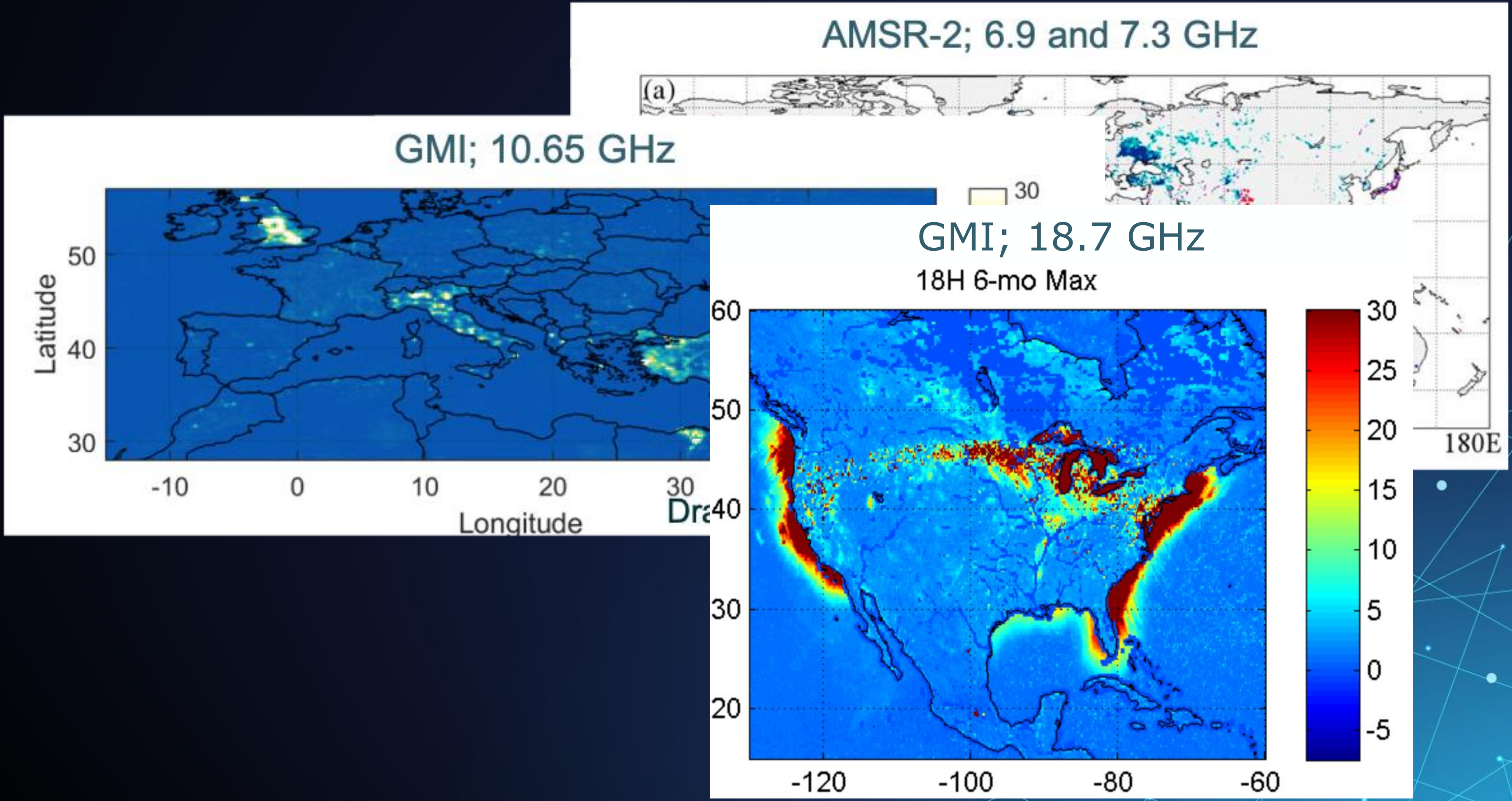



# RFI evolution over several years (SMOS mission)



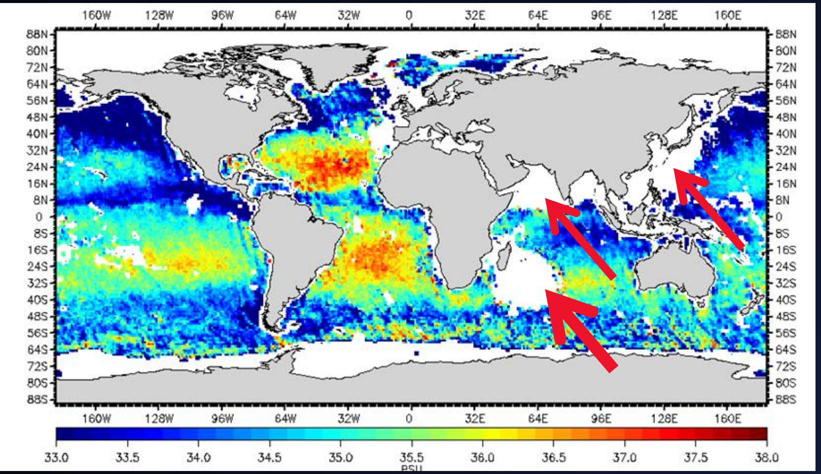
# Examples of RFI at other frequencies



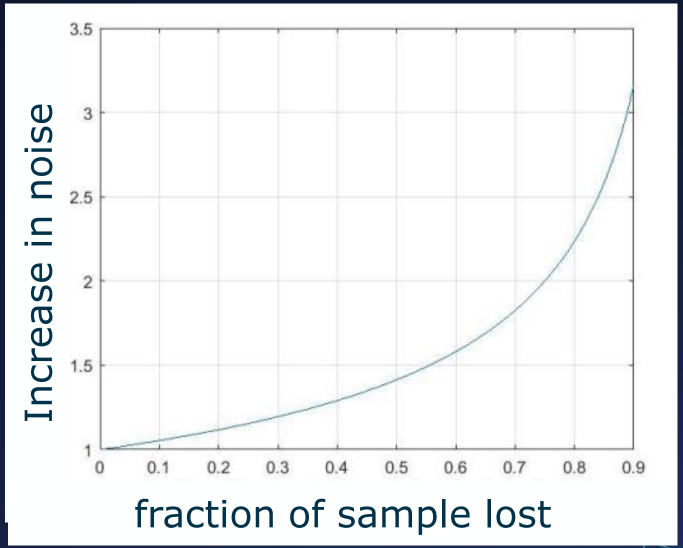
# Impact of RFI

# Impact on Science

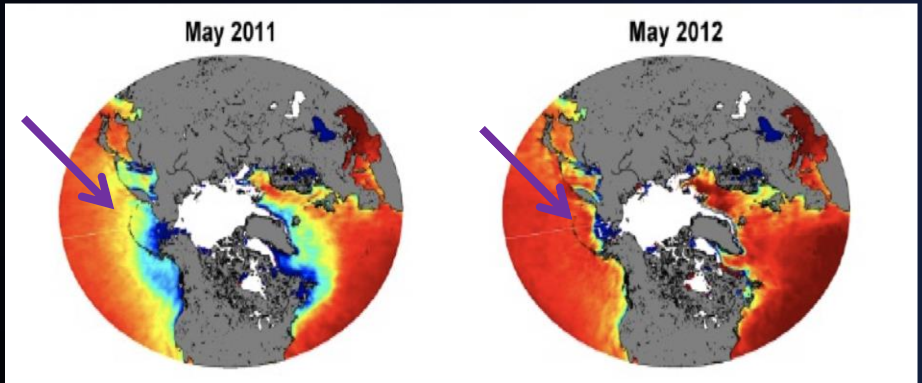
## Data loss



## Noise increase

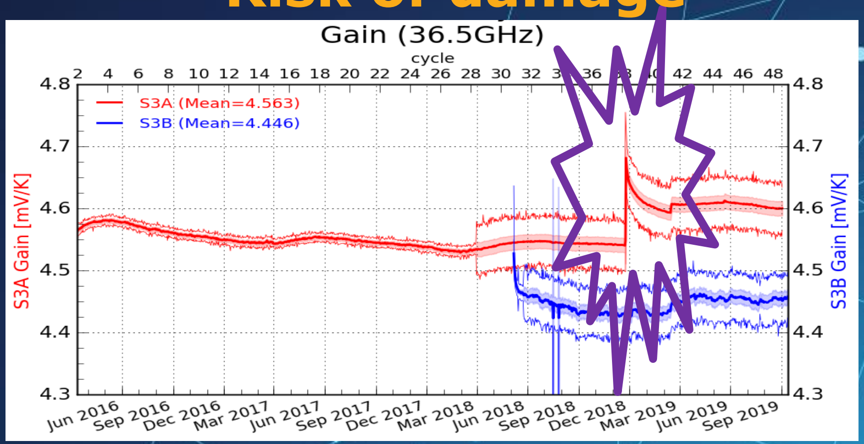



## Incorrect retrievals




Salinity (RFI-affected) Salinity (no RFI)

## Risk of damage



# Impact on Costs & ROI

- Less data
- Larger uncertainties
- Incorrect retrievals
- Risk of damage

Science

Cost

- More complex design
- More complex data exploitation
- Reporting of interference

This means:

- Lower **Return On Investment (ROI)**
- Lower **Socio-Economic and Scientific usefulness**

# ITU References & Takeaways

# Main ITU-R References

<u>Characteristics</u> of EESS (passive) sensors: Rec ITU-R RS.1861

<u>Interference and protection criteria</u> for EESS (passive) sensors: Rec ITU-R RS.2017

See also:

- Rec ITU-R RS.1859 “Use of remote sensing systems for data collection to be used in the event of natural disasters and similar emergencies”
- Rec ITU-R RS.1883 “Use of remote sensing systems in the study of climate change and the effects thereof”
- Rep ITU-R RS.2178 “The essential role and global importance of radio spectrum use for Earth observations and for related applications”

# Takeaways

- Passive sensors contribute to various applications & socio-economical benefits.
- Passive sensors have no control over the signal they want to receive.
  They can't change the frequency at which they operate.
- Because they measure "noise", they have extremely sensitive receivers. This makes them particularly vulnerable to RFI.
- RFI to passive sensors decreases the science value and increases their costs.
- Public data access for most passive sensors -> large user base
- **Need to protect passive sensors in regulatory terms.**