

Passive and active spaceborne remote sensing

Yan Soldo (ESA)

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→ THE EUROPEAN SPACE AGENCY

- Earth Exploration-Satellite Service (EESS)
- Importance and Applications
 - Role in disasters
- Types of active/passive sensors
- Frequencies needed
- Sensitivity to RFI
- Impact of RFI

ITU Services for Meteorology:

MetSat ✓

EESS

1.51 Earth exploration-satellite service: A radiocommunication service between earth stations and one or more space stations, which may include links between space stations, in which:

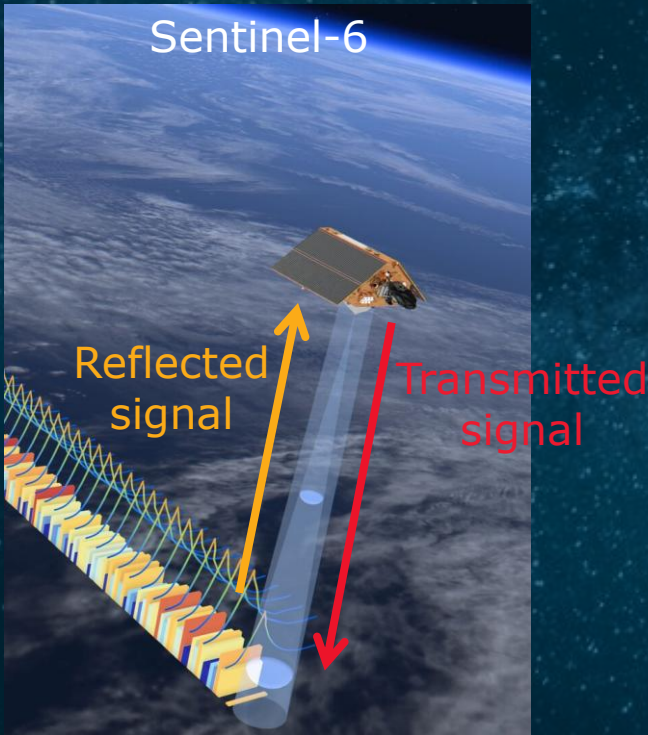
- information relating to the **characteristics of the Earth and its natural phenomena**, including data relating to the state of the environment, is obtained from active sensors or passive sensors on Earth satellites;
- similar information is collected from airborne or Earth-based platforms;
- such information may be distributed to earth stations within the system concerned;
- platform interrogation may be included.

This service may also include feeder links necessary for its operation.

EESS exploits the **unique vantage point of space** to measure Earth's system

- global coverage
- remote/uninhabited areas
- frequent revisits
- long time-series

Active sensing
(RR No. 1.182)



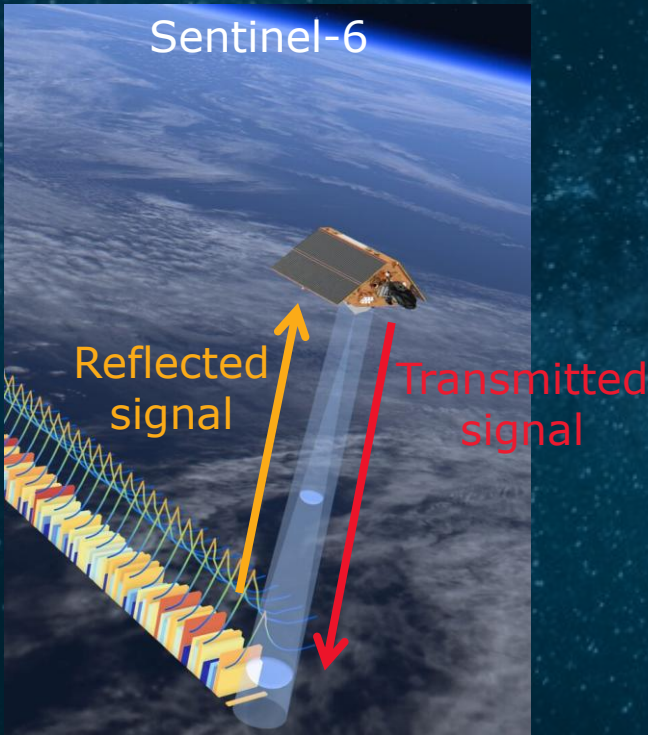
Passive sensing
(RR No. 1.183)



Communication links
(TT&C; Payload data downlink)



Active sensing
(RR No. 1.182)



Passive sensing
(RR No. 1.183)

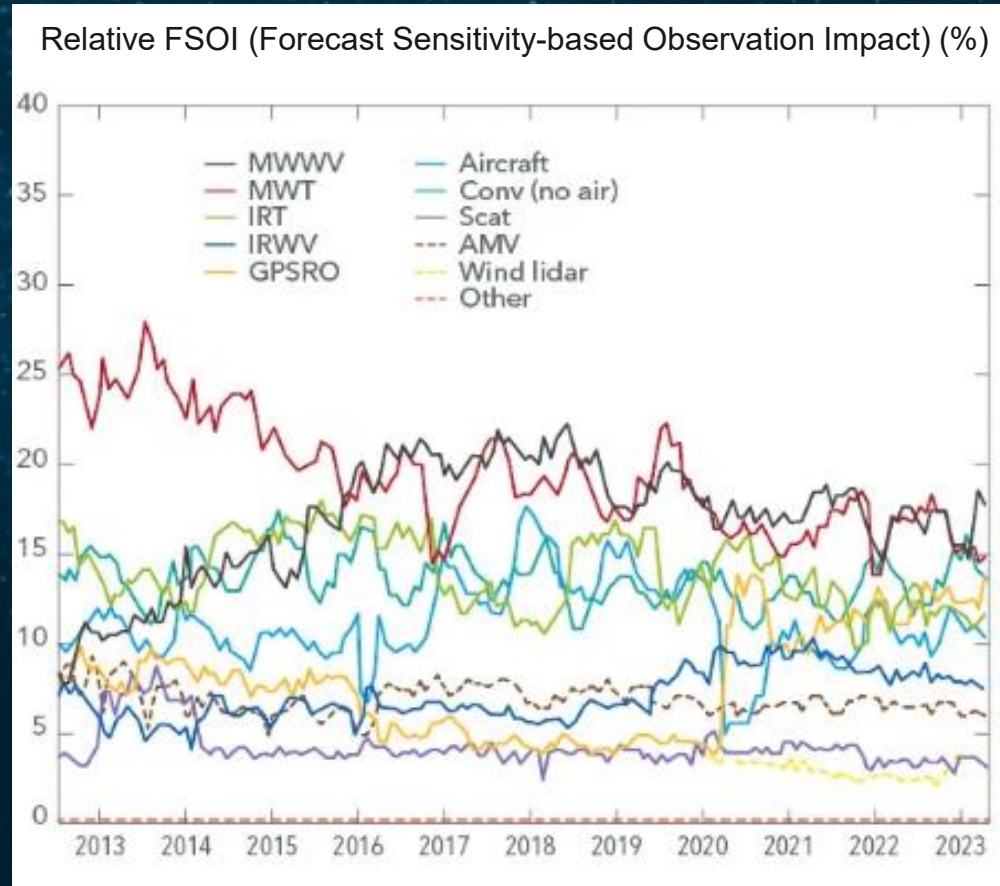


Communication links
(TT&C; Payload data downlink)



Applications & Importance of remote sensing

Main contributor to weather forecasting skill



MWV = 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

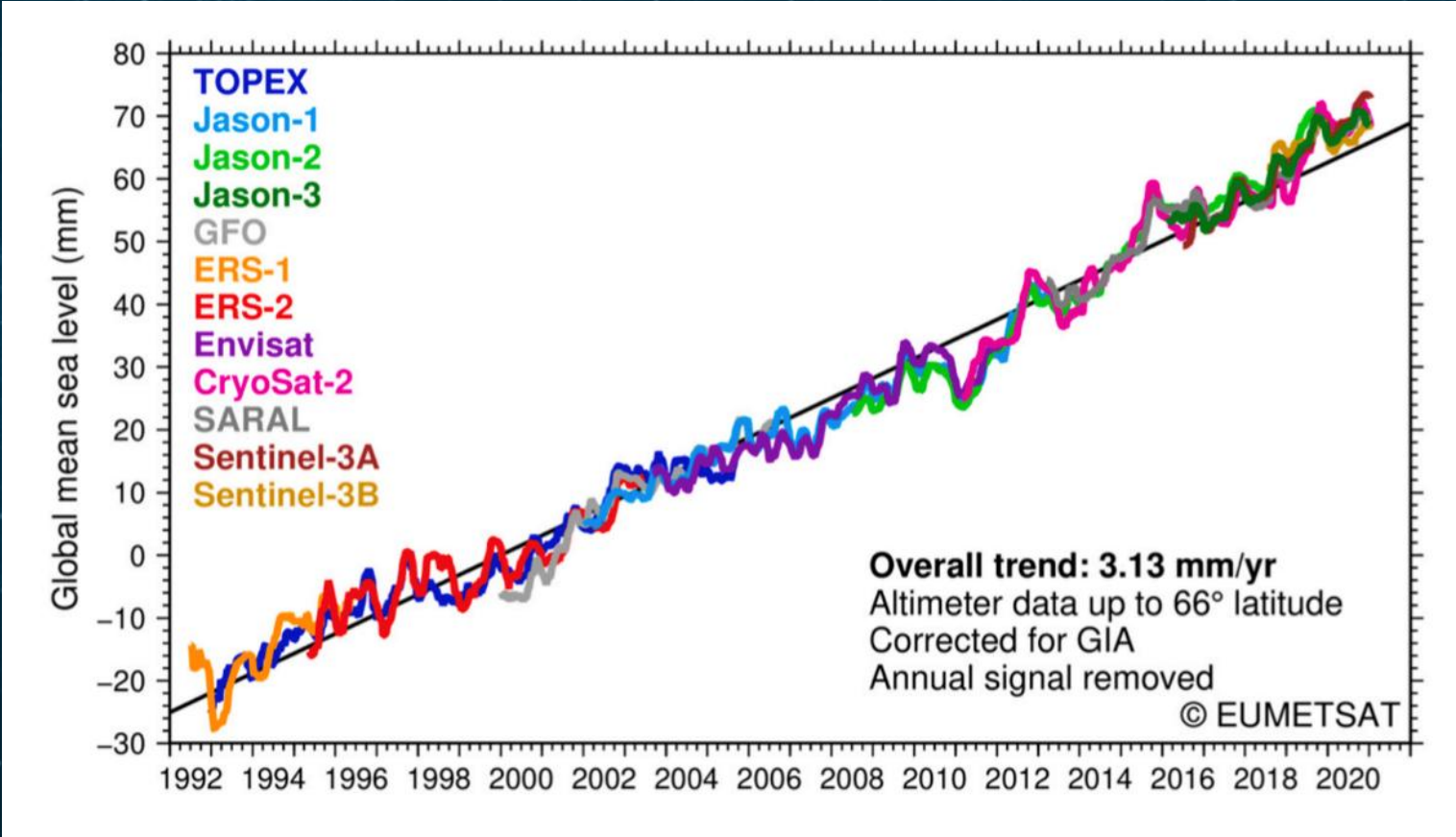
AMV = Atmospheric motion vectors

Wind lidar = UV doppler wind lidar

Other = All other observation types

English, 2023

Monitoring of climate indicators (Sea Level)



Donlon et al., 2021

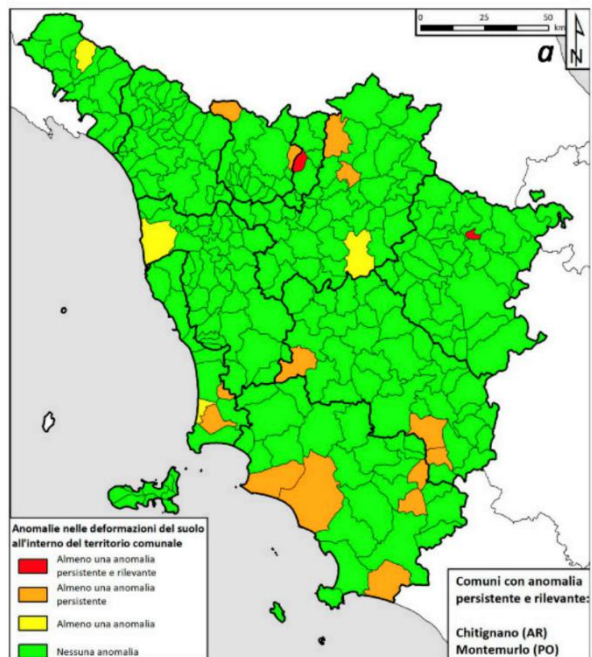
Land/building subsidence



UNIVERSITÀ
DEGLI STUDI
FIRENZE

DST
DIPARTIMENTO DI
SCIENZE DELLA TERRA
CENTRO DI COMPETENZA DEL
SERVIZIO NAZIONALE DELLA
PROTEZIONE CIVILE

BOLLETTINO DI MONITORAGGIO RADAR SATELLITARE DELLE DEFORMAZIONI DEL
TERRENO DELLA REGIONE TOSCANA



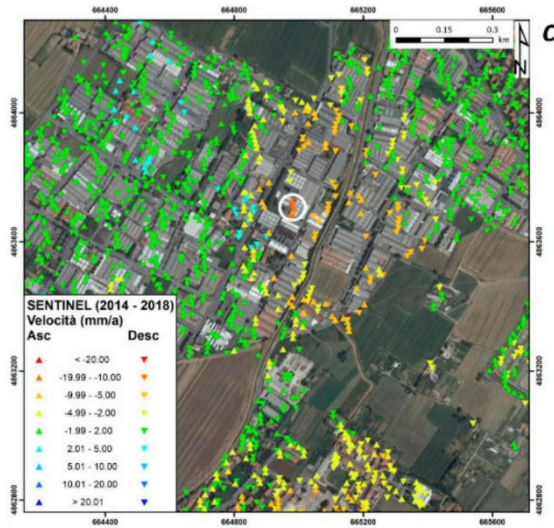
Monitoring bulletin

Del Soldato et al., 2019

Montemurlo (Prato)

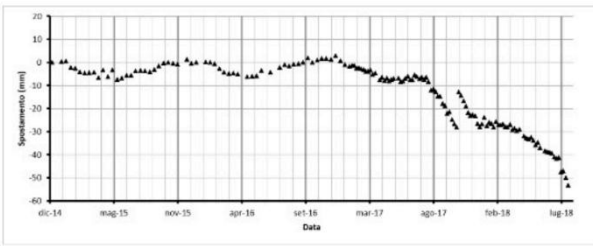
Provincia	Comune	Località	Coordinate (WGS 1984 UTM Zona 32N)	Elemento a rischio	Causa	Persistenza
Prato	Montemurlo	Bagnolo	664981 E 4863716 N	Centri abitati, nuclei abitati e case sparse	Subsidenza	17" e 18" aggiornamento

b



c

Deformation map

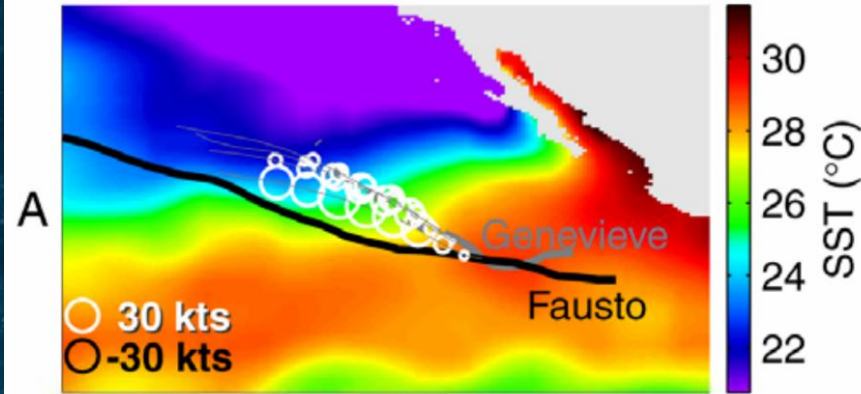


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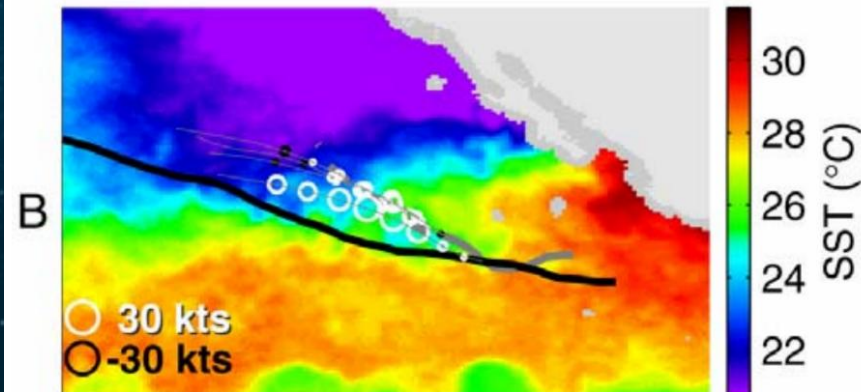
Time-series

Hurricane prediction

Hurricane Genevieve
SHIPS errors with NCEP OI SST



SHIPS errors with AMSR-E OI SST



Gentemann et al., 2006

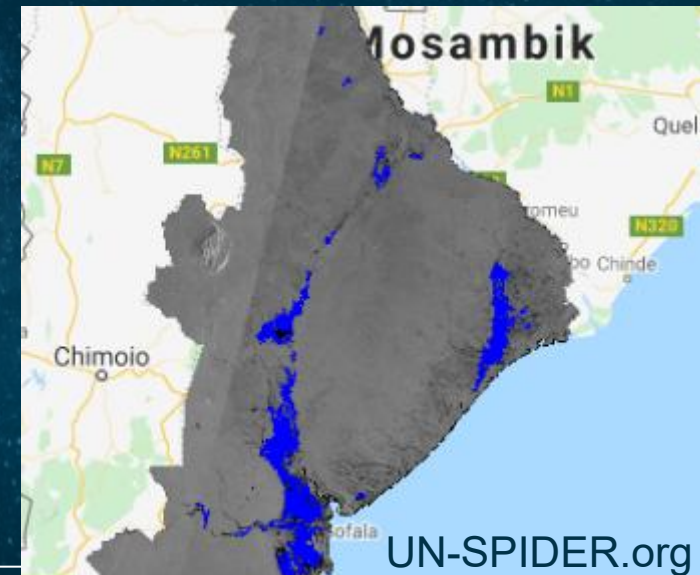
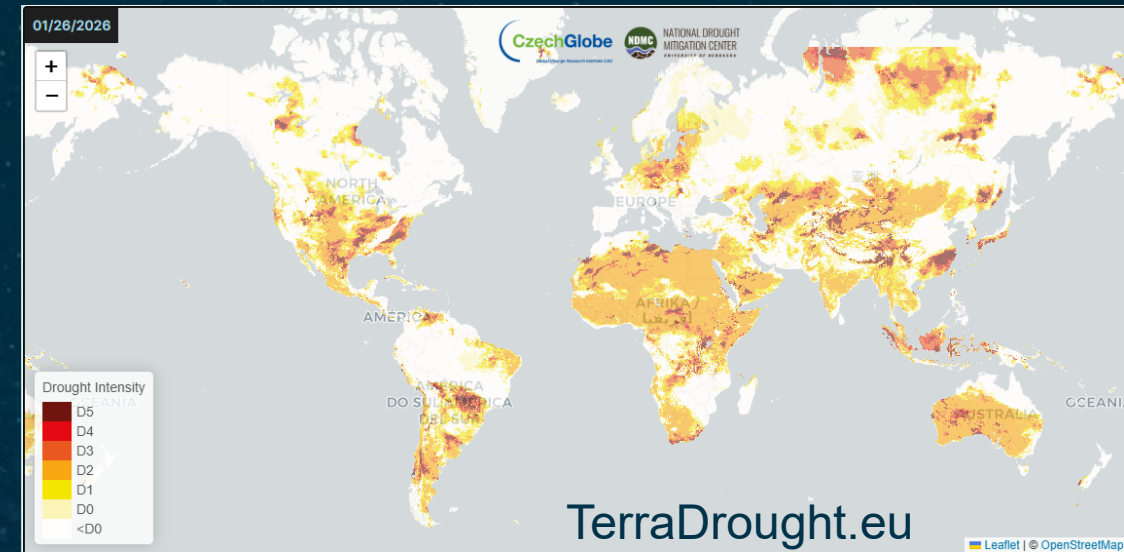
Support before & during disasters

Forecast / early warning of disasters, e.g.:

- Floods
- Landslides
- Tropical cyclones
- Volcanic eruptions

Monitoring / Response, e.g.:

- Droughts
- Wildfires
- Damage mapping (from earthquakes, tsunamis, ...)



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”

UN-SPIDER (<https://www.un-spider.org/>)

UNOSAT (<https://www.unosat.org/>)

COPERNICUS (<https://emergency.copernicus.eu/>)

SFCG disaster database (<https://sfcgonline.org/>)

Data access

Data from many Active/Passive sensors is **distributed for free**. Examples:

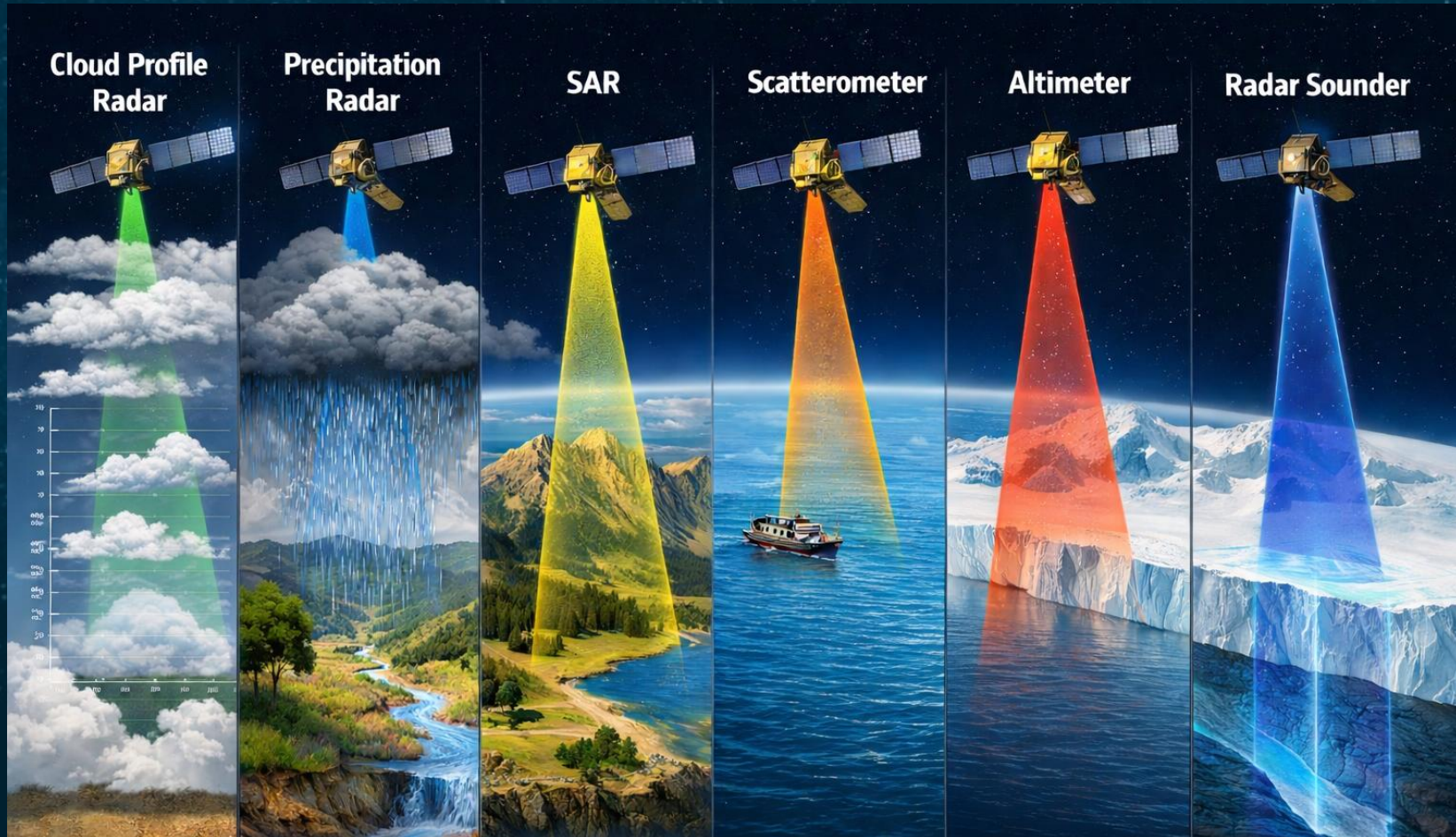
- **Copernicus** missions: <https://dataspace.copernicus.eu/>
- **ESA** missions, including supported 3rd party missions: <https://earth.esa.int>
- **EUMETSAT** missions: <https://data.eumetsat.int/>
- **JAXA** missions: <https://gportal.jaxa.jp/>
- **NASA** missions: <https://www.earthdata.nasa.gov/>

There are only **few EESS satellites/operators**, but **many users** (e.g. meteo services)

Types of active and passive instruments

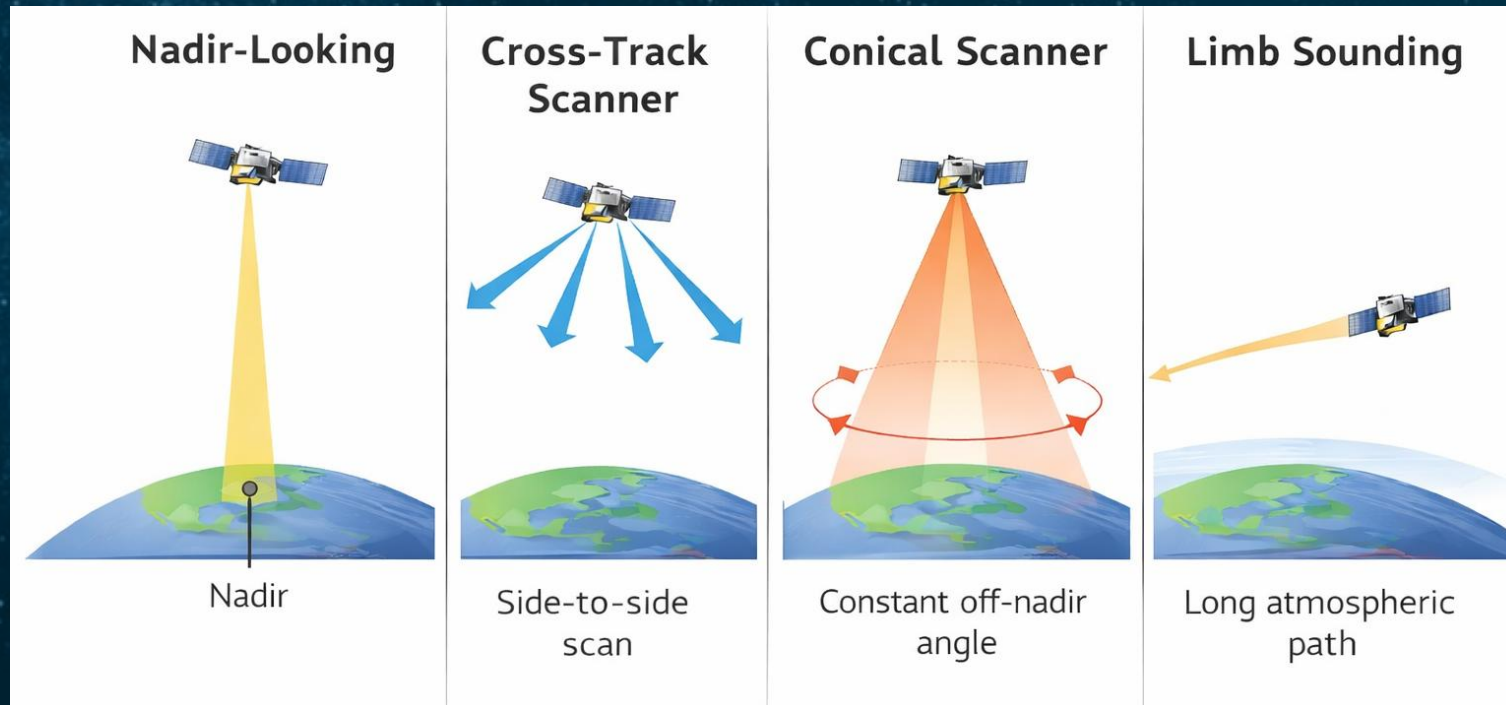
Types of Active instruments

Based on what physical quantities we want to observe from the satellite, different active instruments will be used.



Types of Passive instruments

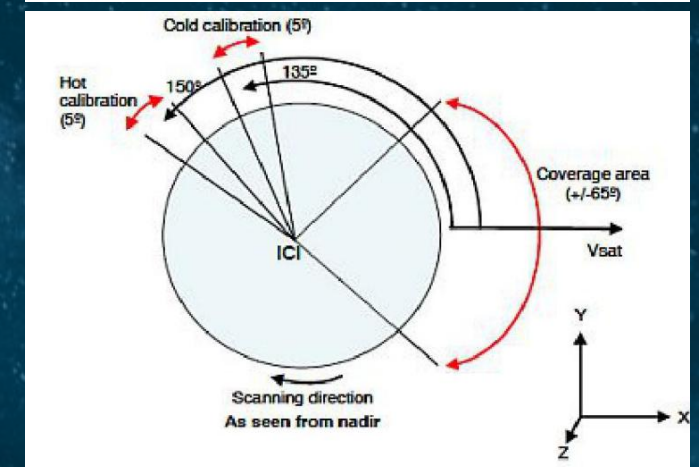
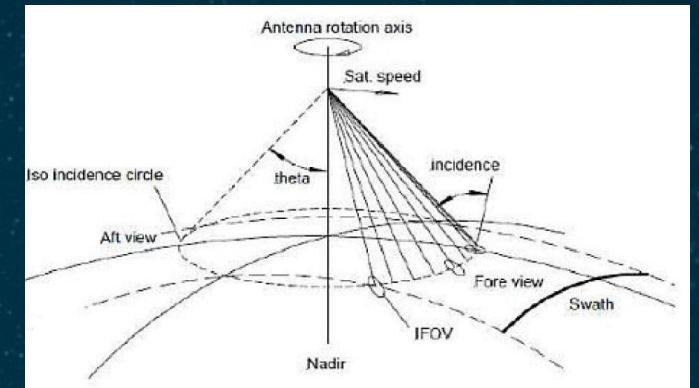
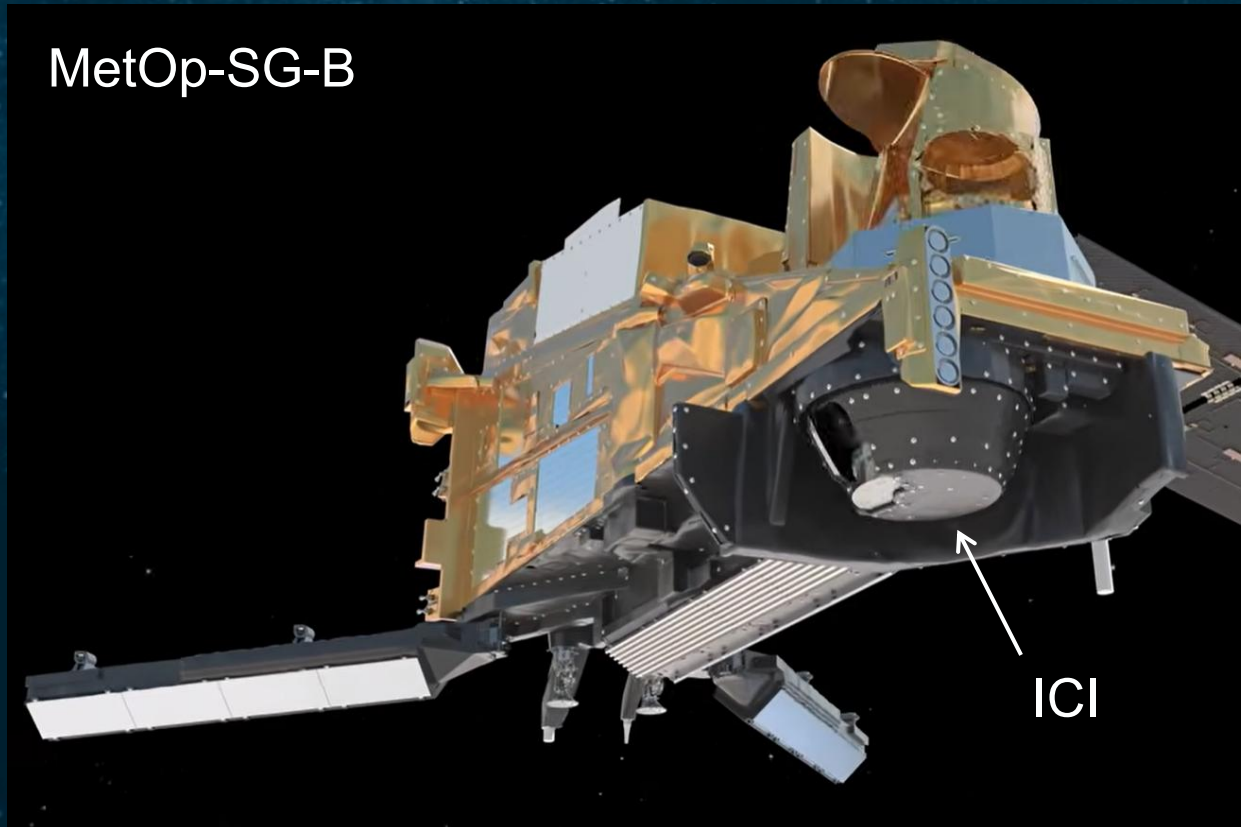
Passive instruments have different geometries, based on their purpose, e.g. measurements in the upper or lower layers of the atmosphere, or support to altimeters, or measurements of the surface.



Cold sky calibration

For calibration, the instruments need to make measurements of the “cold sky”, i.e. portions of space without nearby celestial bodies.

These measurements are done in different ways depending on the type of sensor.



Credit: Airbus DS-CASA Espacio

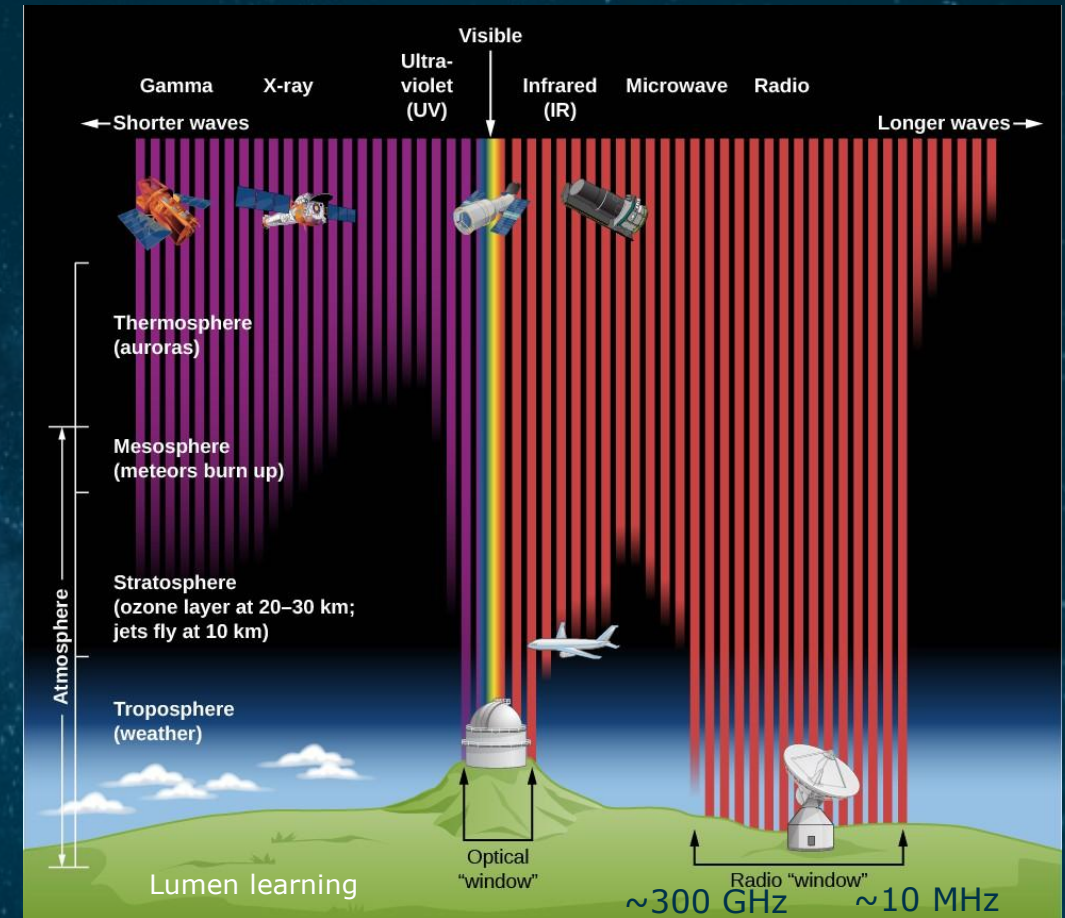
Frequencies for active and passive instruments

Which frequencies do sensors need?

The physics of the measurements depend on frequency, e.g.:

- Atmospheric opacity
- Sensitivity to geophysical parameters
- Wave penetration (soil; vegetation)
- Size of the particles in the atmosphere
- Coherence time for repeat-pass interferometry

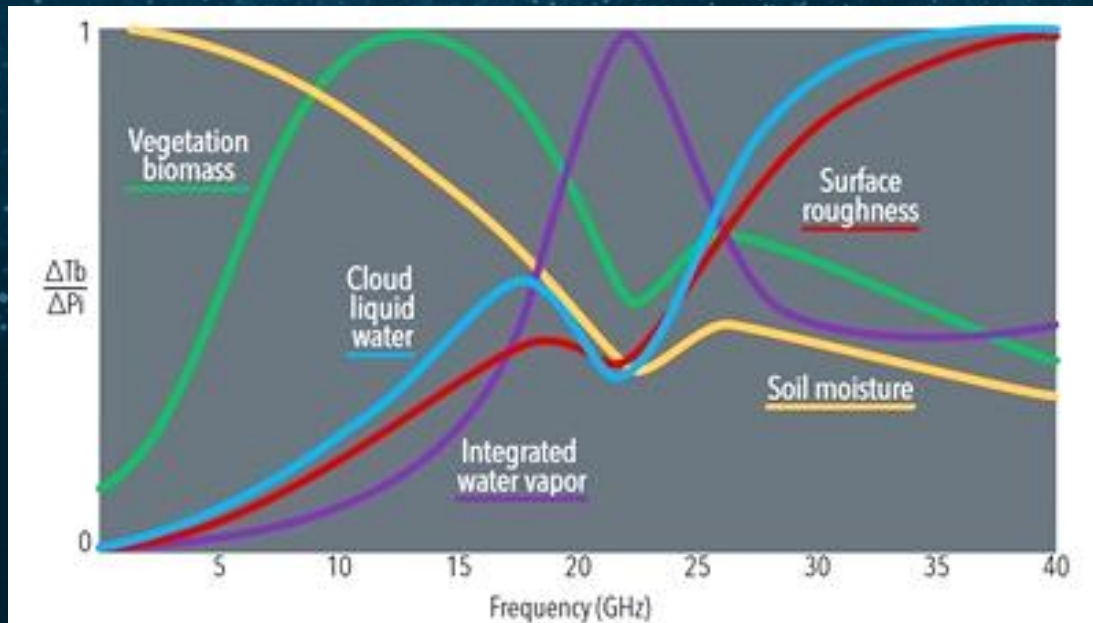
Active/Passive sensors cannot operate interchangeably in different bands!



Frequency needs – Passive imagers

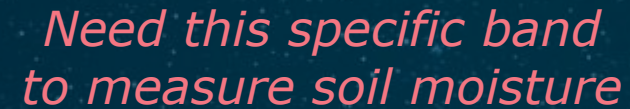
Passive sensors are even more constrained by the physics of the observation, since they have **no control over the signal they need to measure**.

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

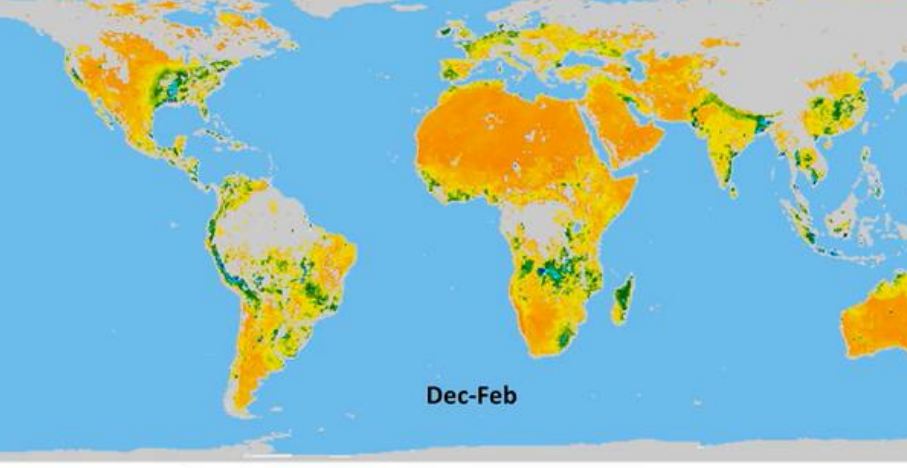


Sensitivity to Land parameters

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



Seasonal soil moisture from SMOS



Dec-Feb

0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 (m^3/m^3)

ESA/ESRIO

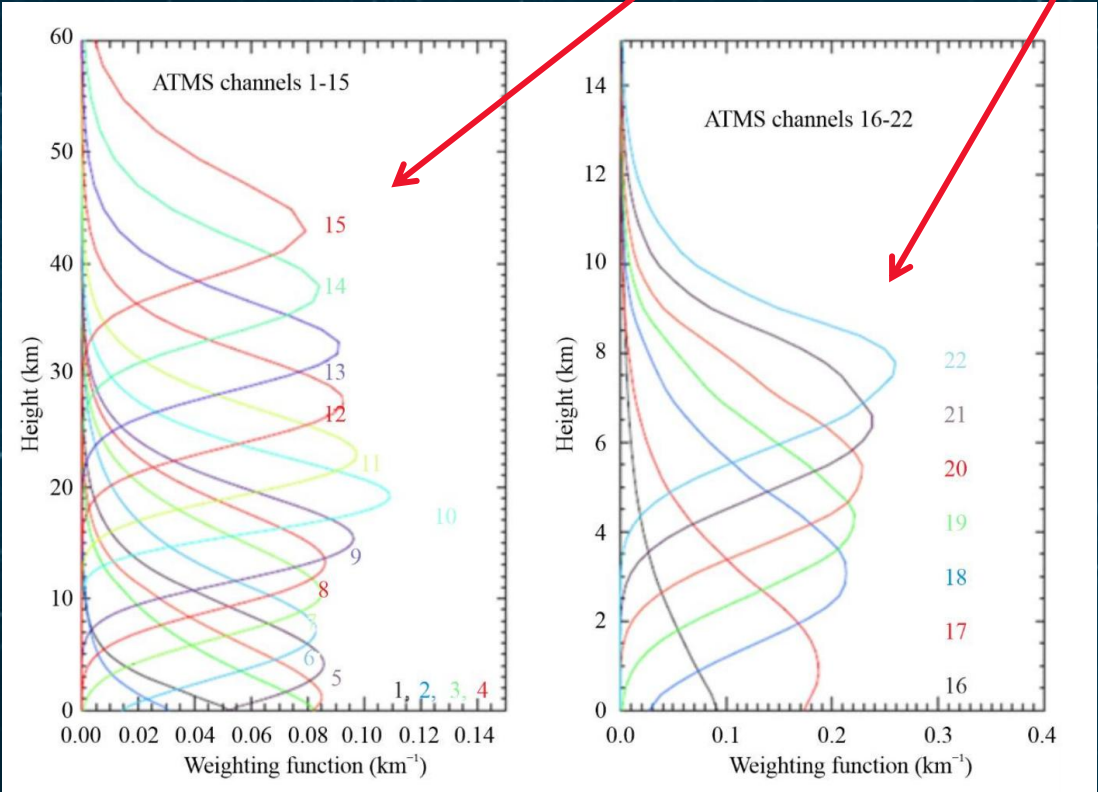
THE EUROPEAN SPACE AGENCY

Frequency needs - Passive sounders

Passive sensors are even more constrained by the physics of the observation, since they have **no control over the signal they need to measure**.

Specific frequencies corresponds to specific heights in the atmosphere

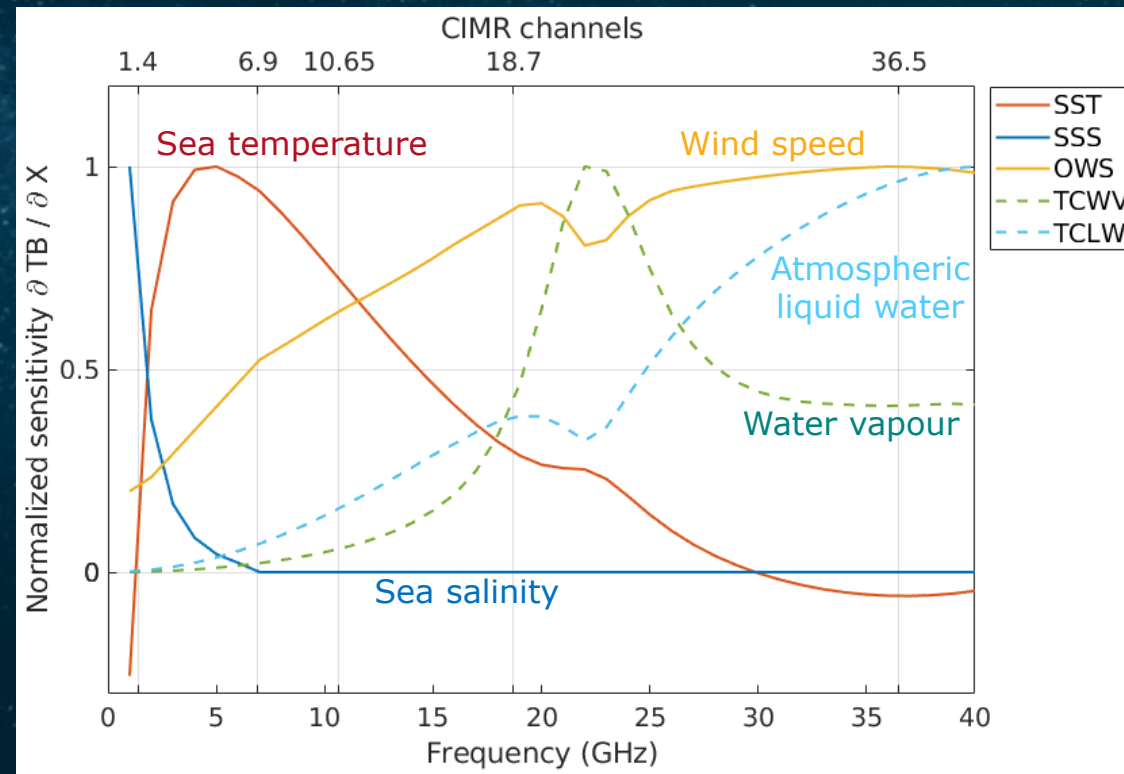
Channel Number	Central Frequency (MHz)
1	23,800
2	31,400
3	50,300
4	51,760
5	52,800
6	53,596 ± 115
7	54,400
8	54,940
9	55,500
10	f0 = 57,290.344
11	f0 ± 217
12	f0 ± 322.2 ± 48
13	f0 ± 322.2 ± 22
14	f0 ± 322.2 ± 10
15	f0 ± 322.2 ± 4.5
16	88,200
17	165,500
18	183,310 ± 7000
19	183,310 ± 4500
20	183,310 ± 3000
21	183,310 ± 1800
22	183,310 ± 1000



Needed complementarity between bands

Sometimes, **sets of frequencies** are needed at the same time. This allows to estimate multiple contributions that are influencing the same signal.

Example: in CIMR, using 5 channels will allow to measure the **ocean** surface & the **atmosphere**.



For remote sensing we have 3 types of frequency allocations:

For **active sensing** i.e., allocated to EESS (active)

1. Shared with other active services (typically terrestrial)
15 bands between 40 MHz and 238 GHz

For **passive sensing**, i.e., allocated to EESS (passive):

2. Shared with active services (typically terrestrial)
16 bands between 2.6 and 247 GHz
3. Shared only with passive services
22 bands between 1.4 and 252 GHz

For remote sensing we have 3 types of frequency allocations:

For **active sensing** i.e., allocated to EESS (active)

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16 bands between 2.6 and 247 GHz
3. **Shared only with passive services**
22 bands between 1.4 and 252 GHz

RR No. 5.340 "All emissions are prohibited"

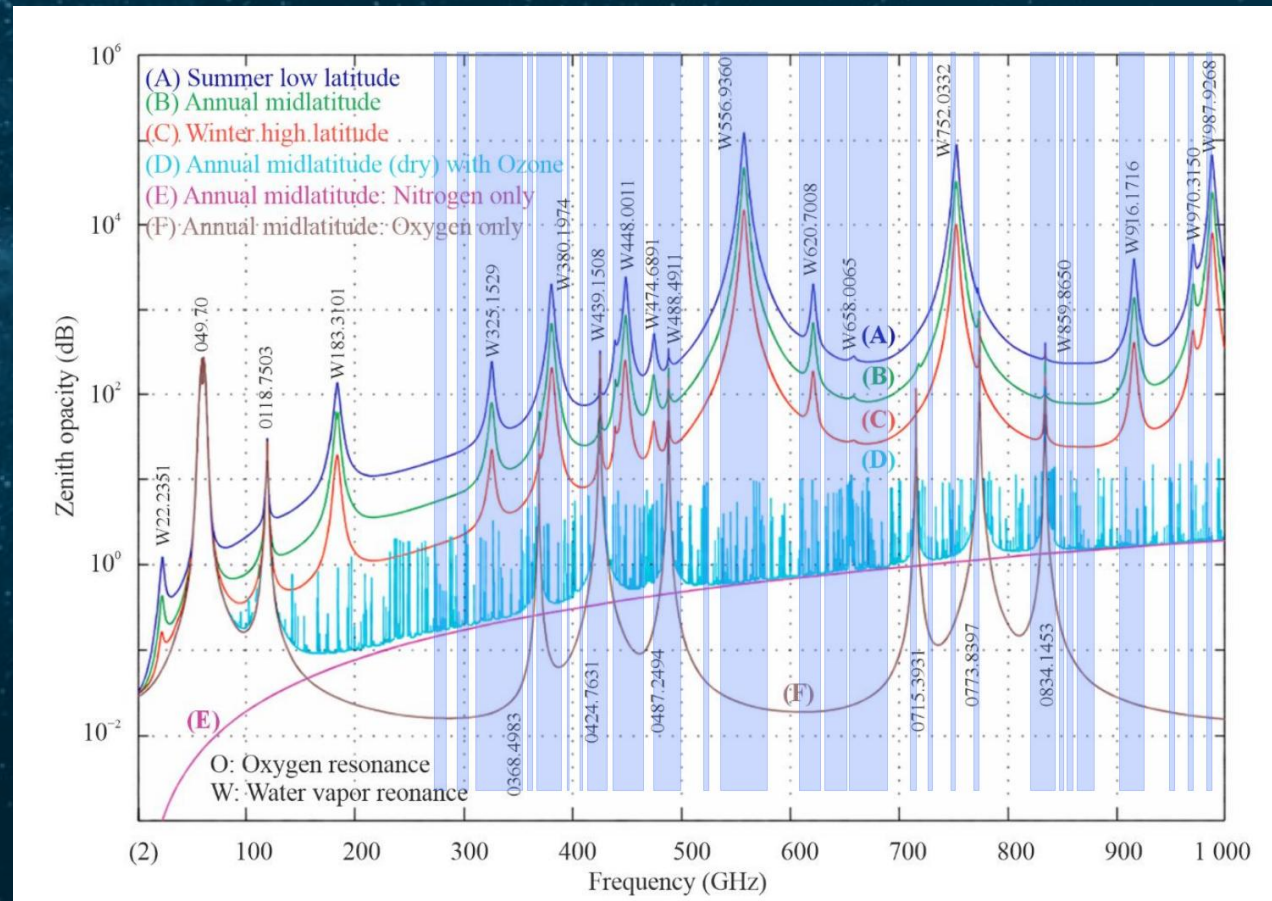
RESOLUTION 750 (REV.WRC-19)

Compatibility between the Earth exploration-satellite service (passive)
and relevant active services

Protection from services in adjacent bands

Frequency identifications

Above 275 GHz there are no allocations, however, RR No. 5.565 identifies 27 frequency ranges for uses by EESS (passive)



Sensitivity to RFI

The Washington Post
Democracy Dies in Darkness

CAPITAL WEATHER GANG

Head of NOAA says 5G deployment could set weather forecasts back 40 years. The wireless industry denies it.

Government agencies are at an impasse on how to proceed.

 By [Jason Samenow](#)

May 23, 2019 at 10:16 a.m. EDT

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Satellite constellations could interfere with meteorological spectrum

by Debra Werner January 23, 2023



Active system

Signal from
transmitter



Receiver

Noise is a nuisance

Passive system



Natural energy
emitted from Earth



Receiver

Noise is the
target signal

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

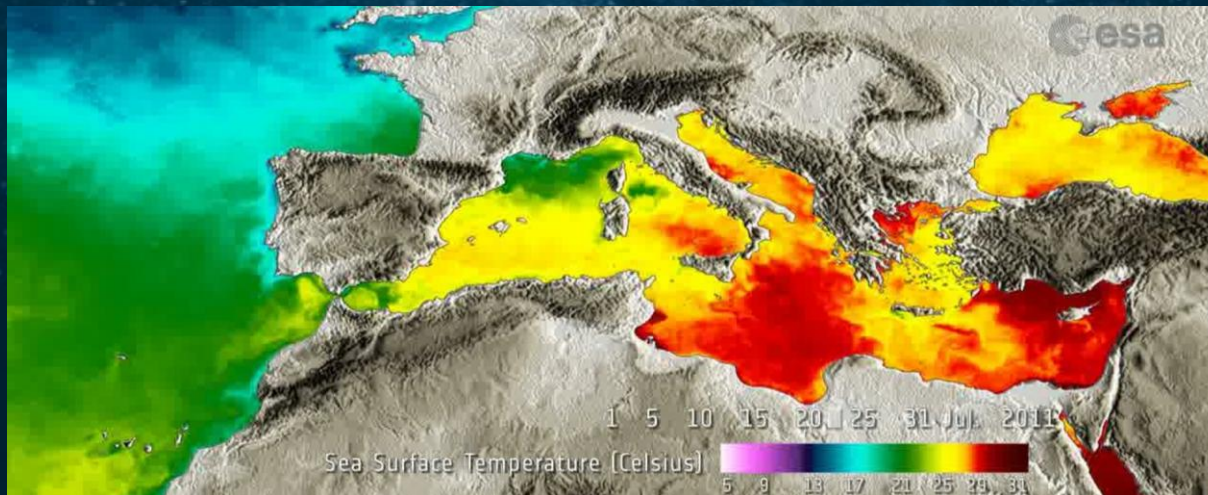
Sub-daily coverage of Polar regions

Example of passive sensor objectives

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

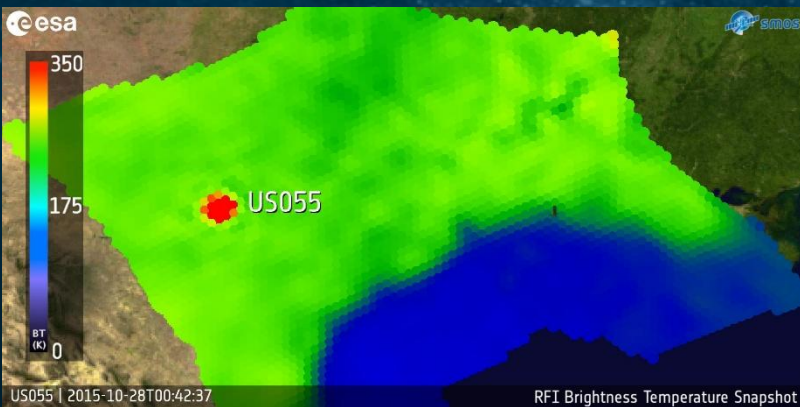
Snow Water Equivalent: **uncertainty < 4 cm**

Sea Surface Temperature: **uncertainty < 0.3 K**

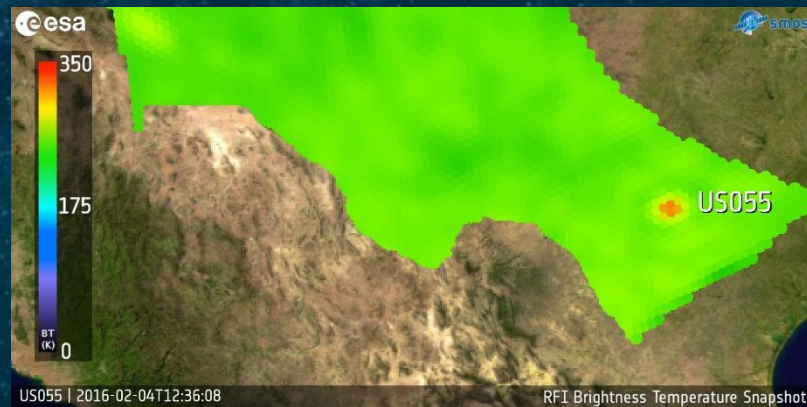


Because of their sensitivity, passive sensors are very easily affected by Radio-Frequency Interference (RFI).

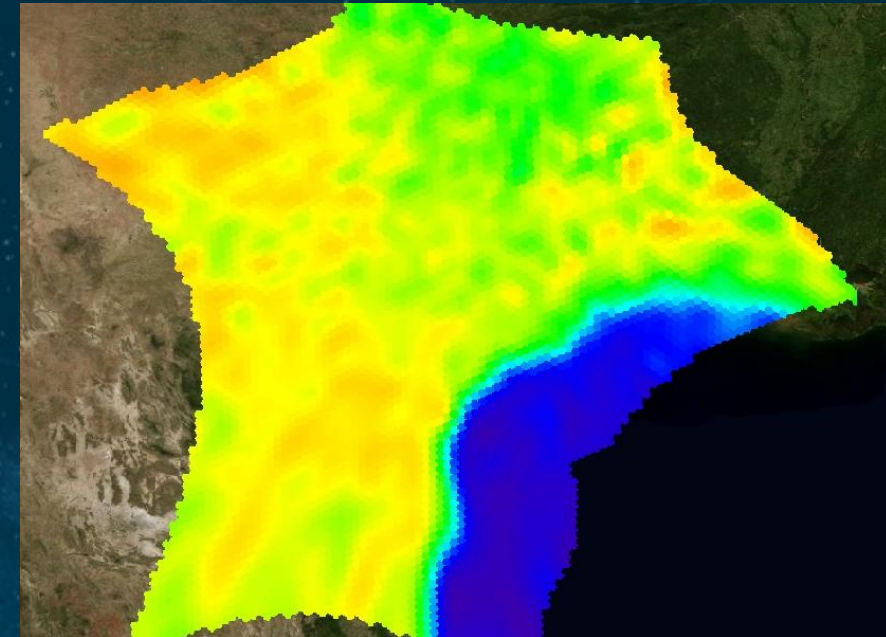
Visible RFI



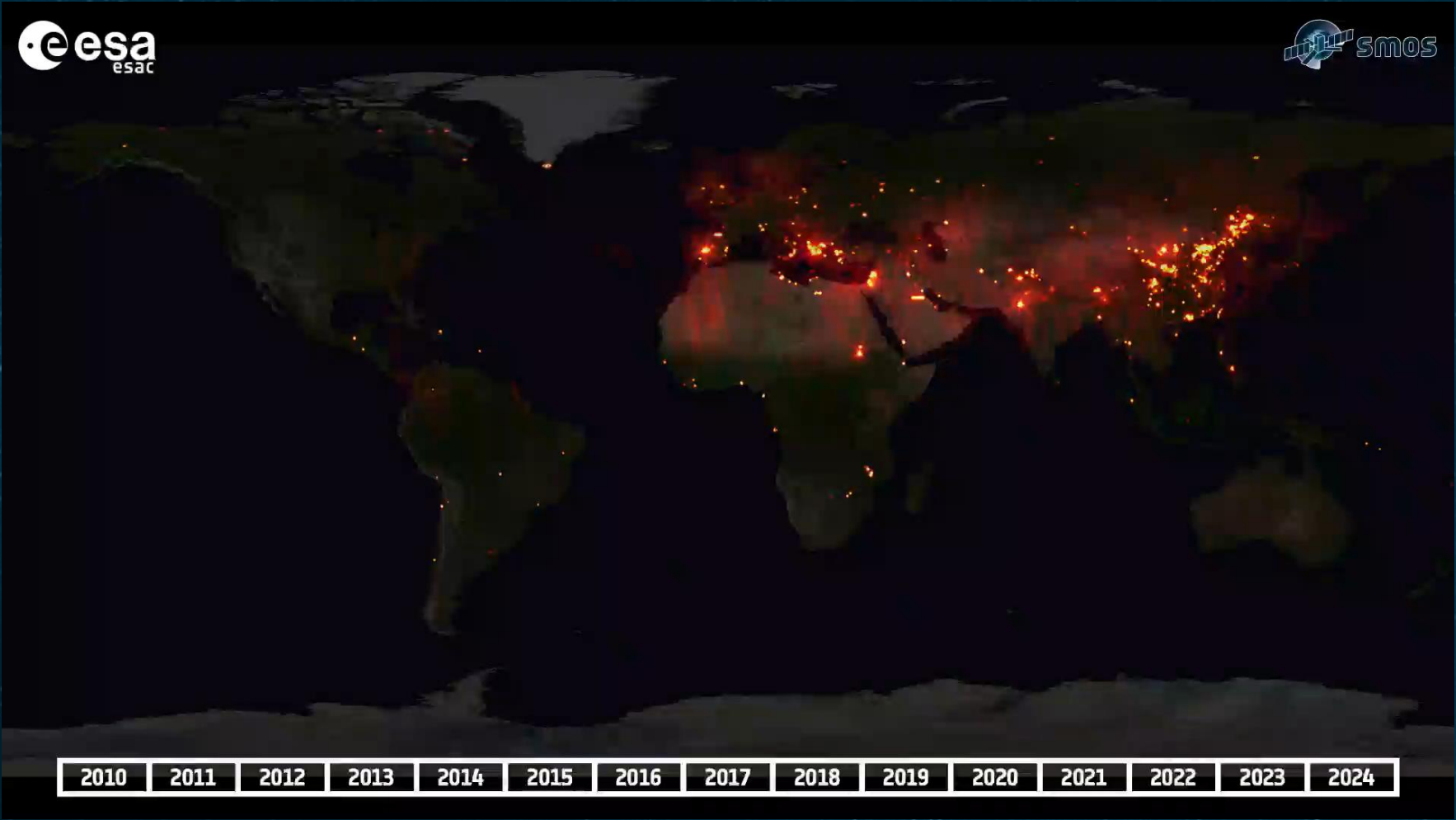
Signal amplifier OFF
(RFI still visible)



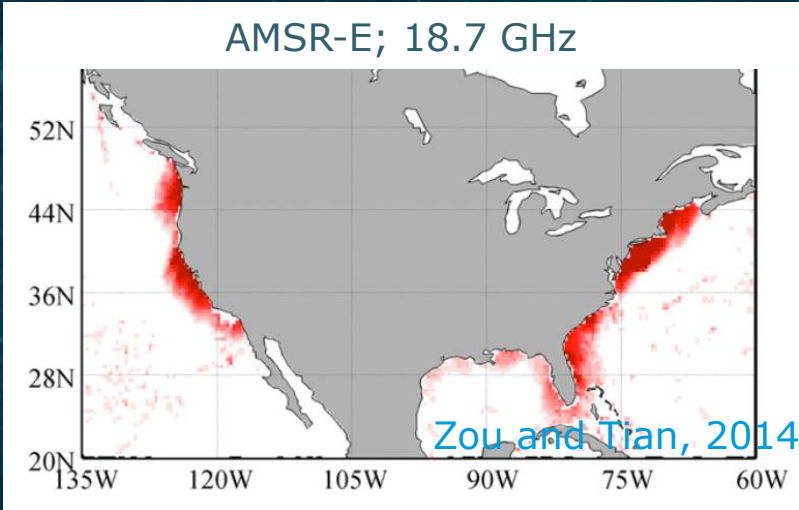
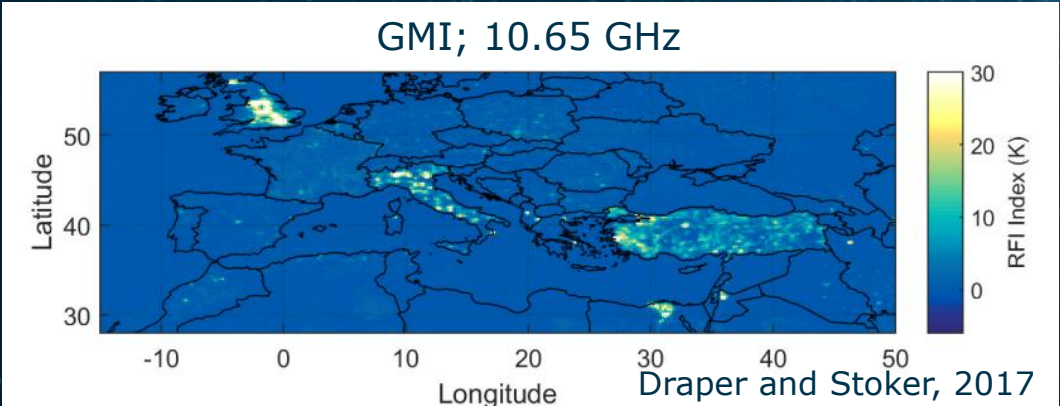
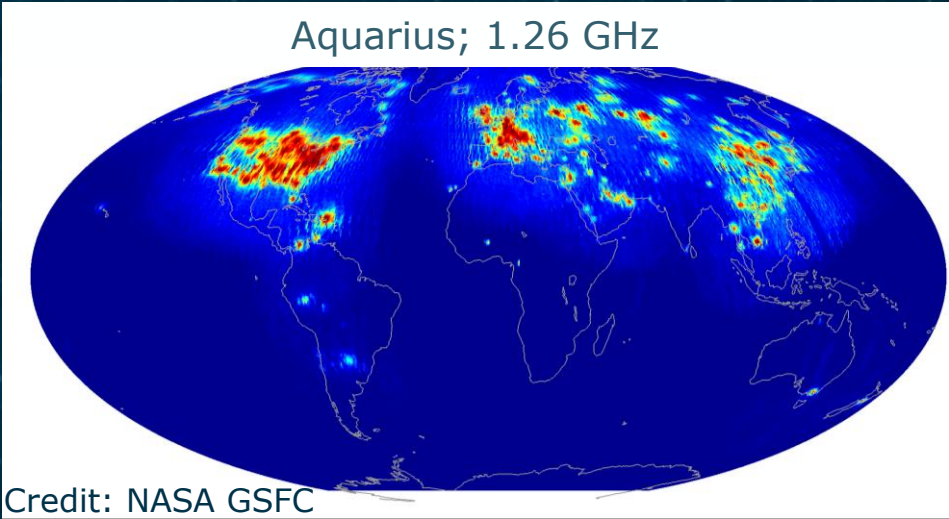
Signal amplifier &
wireless camera OFF



RFI evolution over several years (SMOS mission)

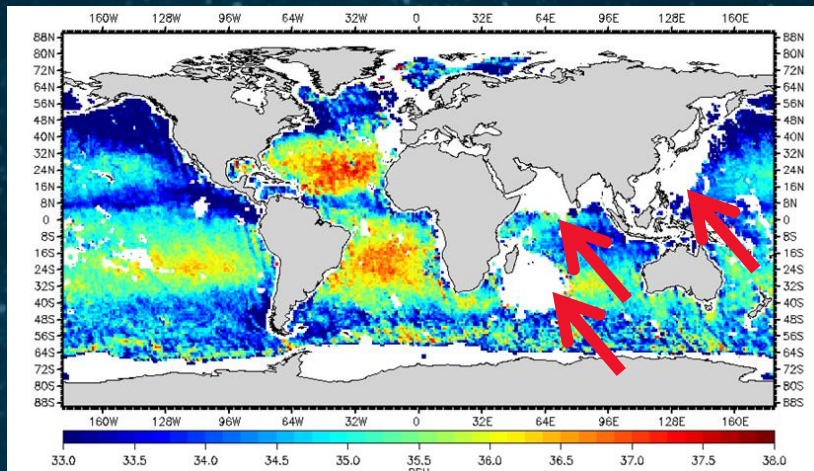


RFI in various bands/instruments

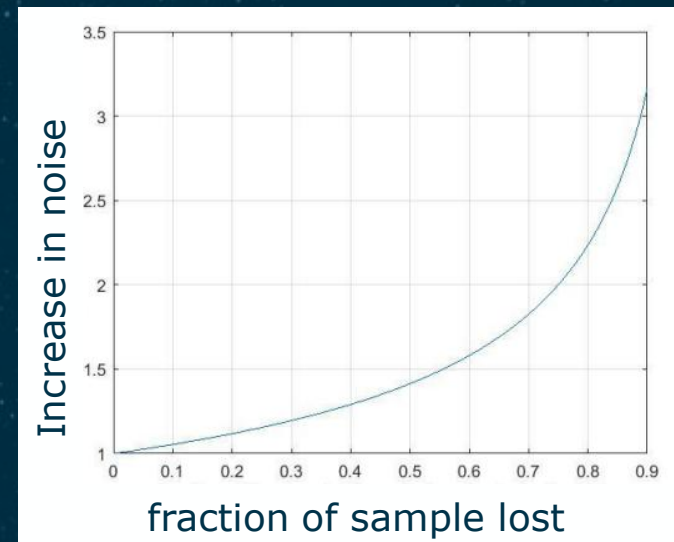


Impact of RFI

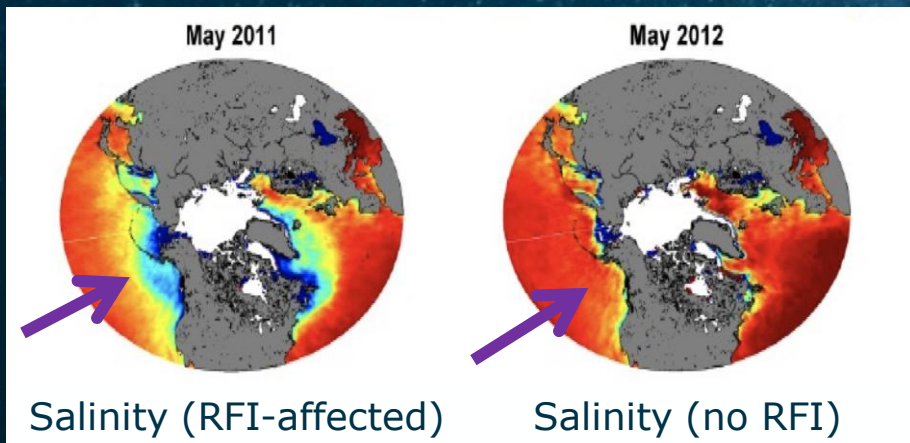
Data loss



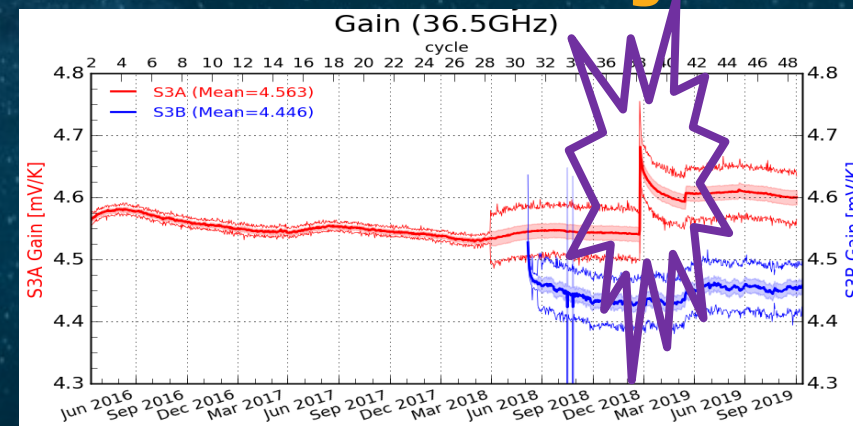
Noise increase



Incorrect retrievals



Risk of damage



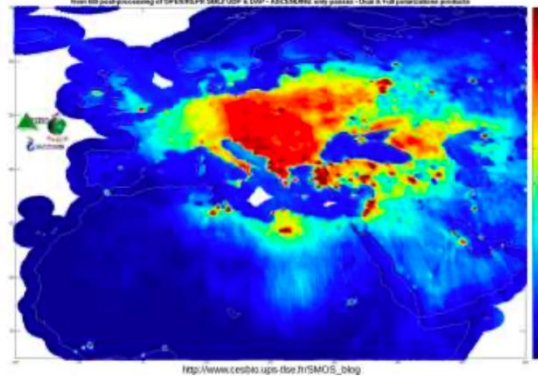


This means:

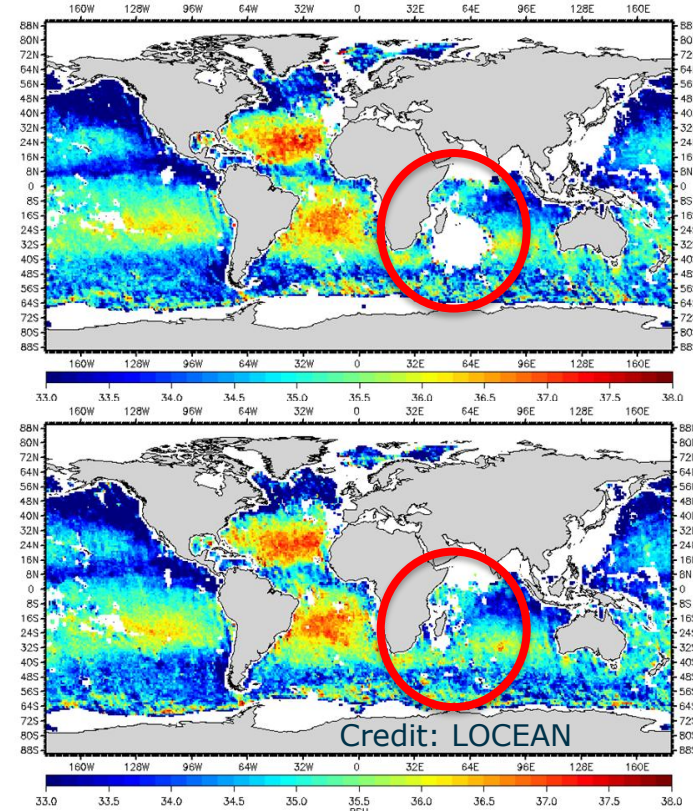
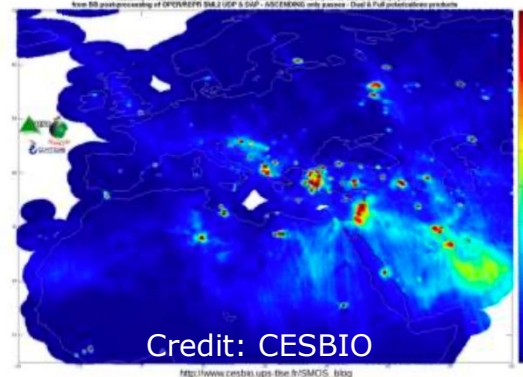
- Lower **Return On Investment (ROI)**
- Lower **Socio-Economic and Scientific usefulness**

Reporting of RFI

Before



After



Procedure for reporting RFI described in the RR (No 15, Appendix 10, No 13.2).

For **Space Services**: RFI can be reported via the [ITU SIRRS platform](#)

For **EESS (passive)** sensors, see also Rec. ITU-R RS.2106.

ITU References & Conclusions

Characteristics of EESS sensors: Rec ITU-R RS.1861 (passive) and RS.2105 (active)
Interference and protection criteria: Rec ITU-R RS.2017 (passive) and RS.1166 (active)

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"
- **ITU-WMO Handbook** "Use of radio spectrum for meteorology: weather, climate, water and related environmental applications"

- Active/passive sensors contribute to **various applications & socio-economic benefits**
- **Public data access** for most sensors --> **large user base**
- Sensors operate at **frequencies determined by the physics** of the measurement
- Passive sensors have **no control** over the signal they want to receive. Therefore, they have very sensitive receivers, which makes them particularly **vulnerable to RFI**
- **RFI to sensors decreases the science value and increases their costs**
- **Need to protect active/passive sensors in regulatory activities**

Questions?

yan.soldo@esa.int