ITU Seminar for Americas Region

PASSIVE SENSING

Jean PLA, Frequency Management
CNES, Toulouse, FRANCE
jean.pla@cnes.fr

- ✓ **Remote sensing**
- ✓ **What is Radiometry?**
- ✓ **Absorption and transparent bands**
- ✓ **Geophysical parameters**
- ✓ **Main passive bands**
- ✓ **Types of sensors**
- ✓ **An example of a passive sensing mission**
- ✓ **The problem of radio-frequency interference**

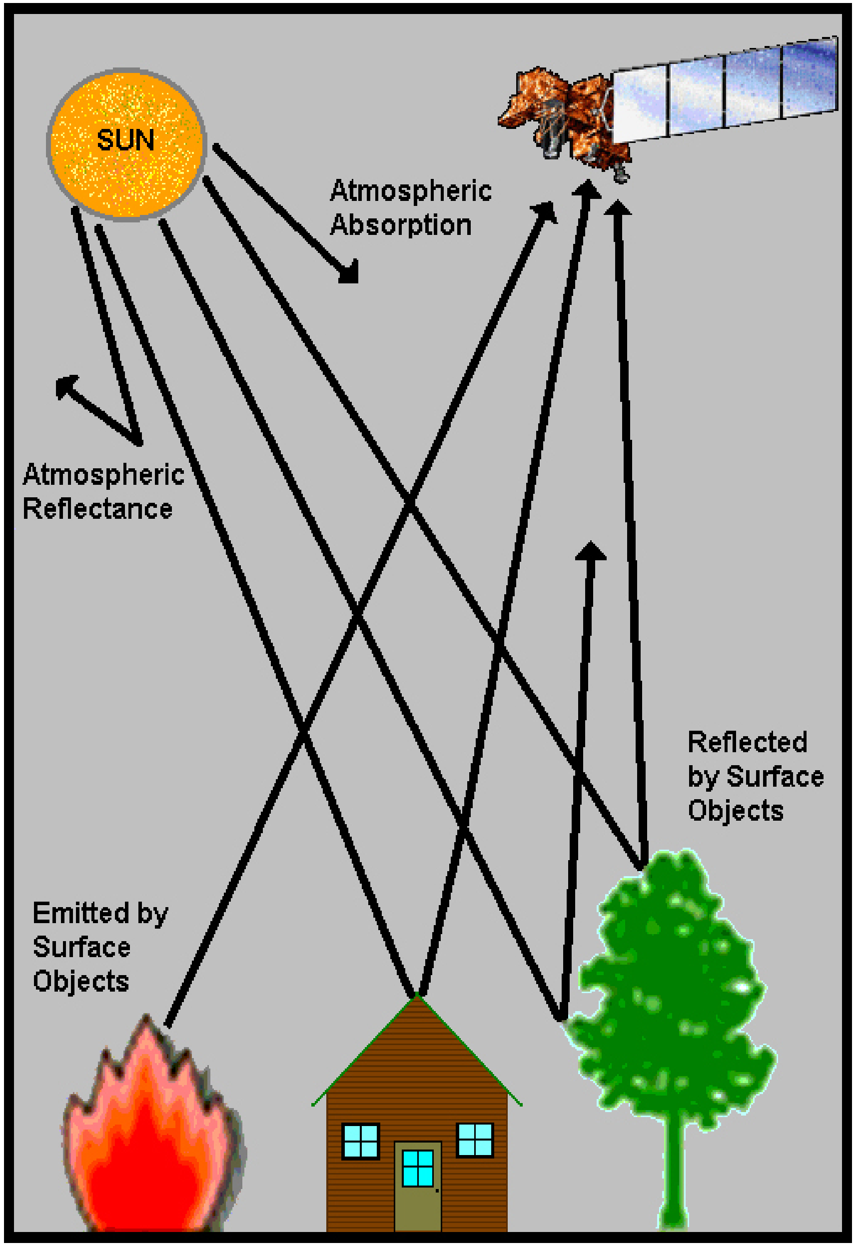
PASSIVE SENSOR

Remote sensing: art and science of **recording and measuring information about a phenomenon from a distance**.

Instruments capable of studying of large areas of the Earth's surface and of the atmosphere are known as remote sensors.

An **active sensor** transmits a signal that is reflected on a surface and received by the sensor. These **sensors are used for altimetry, cloud detection or imagery**.

A **passive sensor** needs an external energy source: Sun, Earth, atmosphere. These **sensors generally detect reflected and emitted energy wave lengths from a natural phenomenon**.



WHAT IS RADIOMETRY (1/2)?

Radiometer = instrument that measures a **brightness temperature**.

A **black body** absorbs all incident electromagnetic radiations and radiates the maximum possible energy. A black body is a perfect radiator.

The brightness temperature is then defined as the temperature a black body would be in order to produce the radiance perceived by the sensor.

Depending on the **nature of the source of radiation** and any **subsequent absorption**, the brightness temperature is dependent on the wavelength of the radiation.

In **selected microwave bands**, satellite-borne passive sensors capture the radiation emitted from the Earth, its atmosphere or objects on the Earth's surface such as vegetation, soil or water.

Advantage of microwaves = r*elative ability to penetrate clouds, haze, precipitation, and surface materials such as snow and ice*.

WHAT IS RADIOMETRY (2/2)?

Real objects are not perfect radiators, and can be referred to as **grey bodies:**
real objects radiate less energy than a black body

The **emissivity** ε *(between 0 and 1)* is the ratio between the energy radiated by an object and the energy of a black body at the same temperature.

The Emissivity depends on the dielectric constant of the object, surface roughness, temperature, wavelength, look angle, etc.

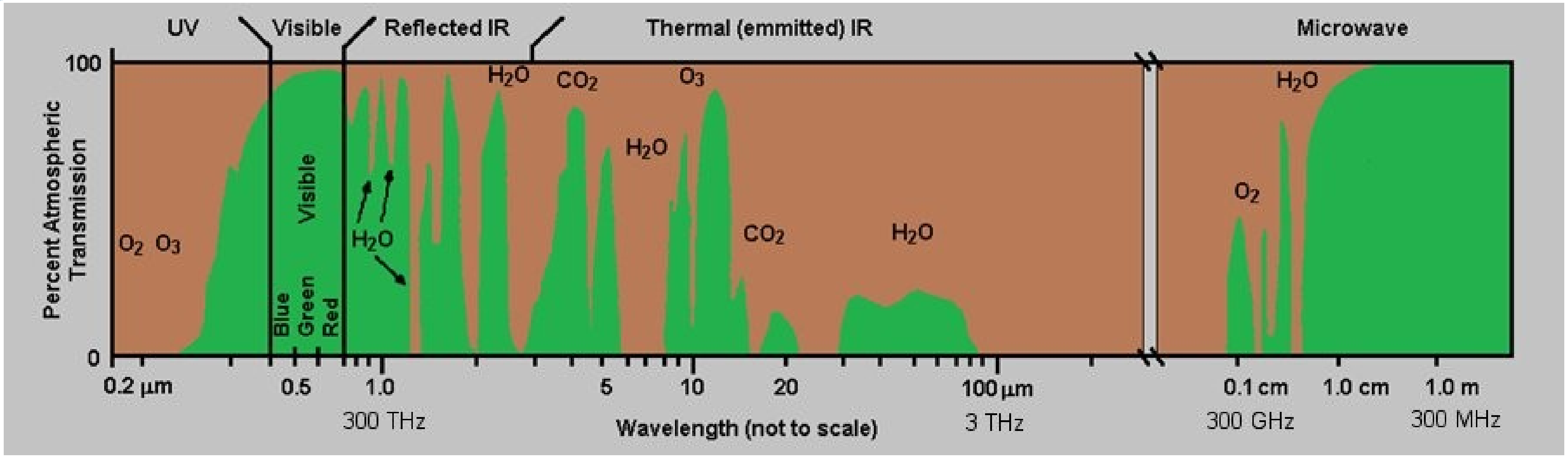
The relation between the temperature of a black body observed by the sensor (T_B) and the physical temperature of the observed object (T) is then : $T_B = \varepsilon T$.

Oceans and lakes have a low radiance . **Land areas** have a higher but more variable radiance because of the texture of objects.

Constituents of the atmosphere can modify the brightness temperature:

- energy from the Earth to the sensor can be reduced due to atmospheric absorption and scattering.
- energy received can be higher due to thermal emission from the atmospheric constituents.

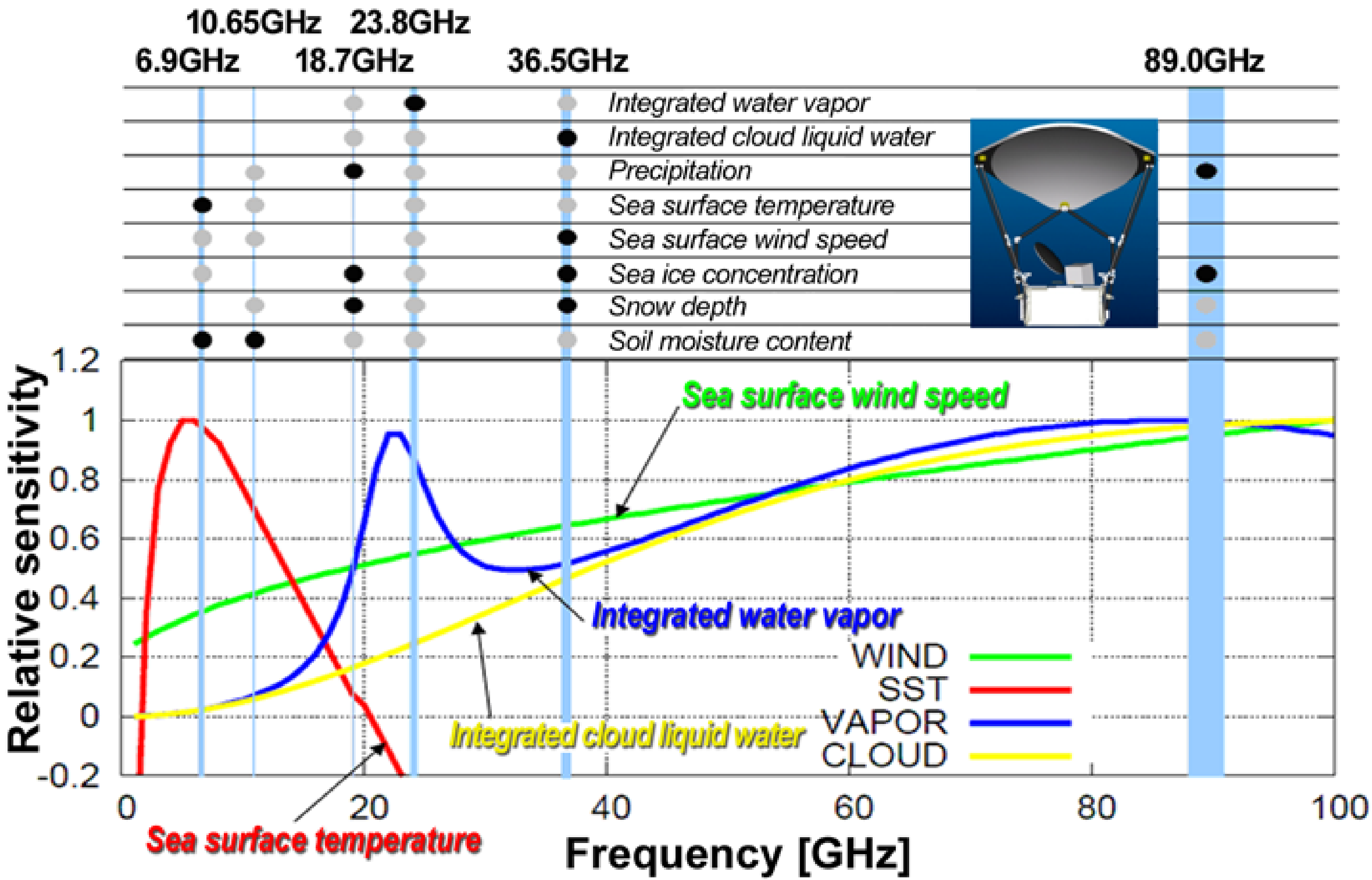
Absorption and transparent bands (window channels)



Absorption bands (shown in brown) are areas of the EM spectrum were radiations are absorbed by atmospheric gases such as water vapour, carbon dioxide, and ozone. These absorption bands are **useful for the knowledge of the atmosphere**.

Transparent bands (shown in green) are areas of the EM spectrum where the **atmosphere is transparent** (little or no absorption of energy) to specific wavelengths. These wavelength bands are known as **atmospheric "windows"**. It is in these windows that **sensors are used to gather information about Earth phenomena**.

Sensitivity of brightness temperature to geophysical parameters over ocean surface

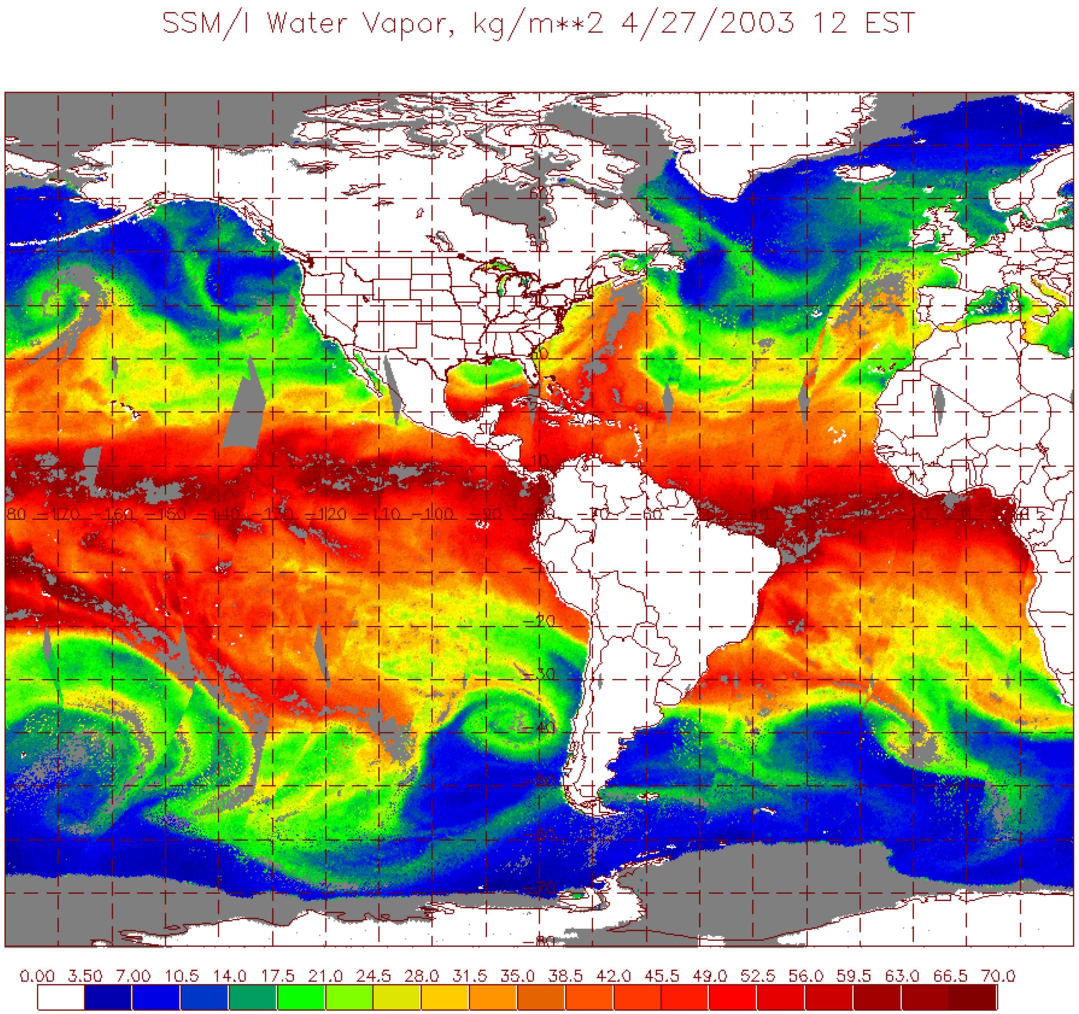


MAIN PASSIVE FREQUENCY BANDS below 100 GHz

1400-1427 MHz	**salinity** (ocean), *soil moisture* (ground)
10.6-10.7 GHz	rain, snow, ice, sea state, ocean wind
23.6-24 GHz	total content of **water vapour**
31.3-31.5 GHz	the lowest cumulated effects due to oxygen and water vapour in the vicinity of the 50 GHz band. **Optimum window channel to see the Earth's surface**: **reference for the other channels**.
36-37 GHz	**cloud liquid water**, vegetation structure, surface roughness
50.2-50.4 GHz	**temperature profile**
52.6-59.3 GHz	absorption band for the **oxygen**
86-92 GHz	**water vapour**

Example of EESS(passive) imaging: atmospheric Mapping

global water vapor:
86-92 GHz



Radiometric resolution

General definition: Spatial Resolution of the Sensors: refers to the **size of the smallest possible feature that can be detected**

For microwave passive sensors, this definition becomes: **smallest change in input *brightness temperature* or *radiance* that can be detected in the system output**.

$$\Delta Tb = \frac{\alpha Ts}{\sqrt{B\tau}}$$

where:

B: receiver bandwidth (Hz)

t : integration time (s), depends mainly on the orbit of the satellite

a :receiver system constant (depends on the configuration, on the radiometer type)

Ts: receiver system noise temperature (K).

Typical space instruments have sensitivities of 0.05 to 3 degrees K.

TWO TYPES OF PASSIVE SENSORS

❶Conical passive sensors

Conical scan passive sensors **turn around the nadir direction** **to maintain a constant ground incidence angle along the entire scan-lines**.
The footprints will remain constant in size.

Typical geometric characteristics are the following (for 850 km altitude):

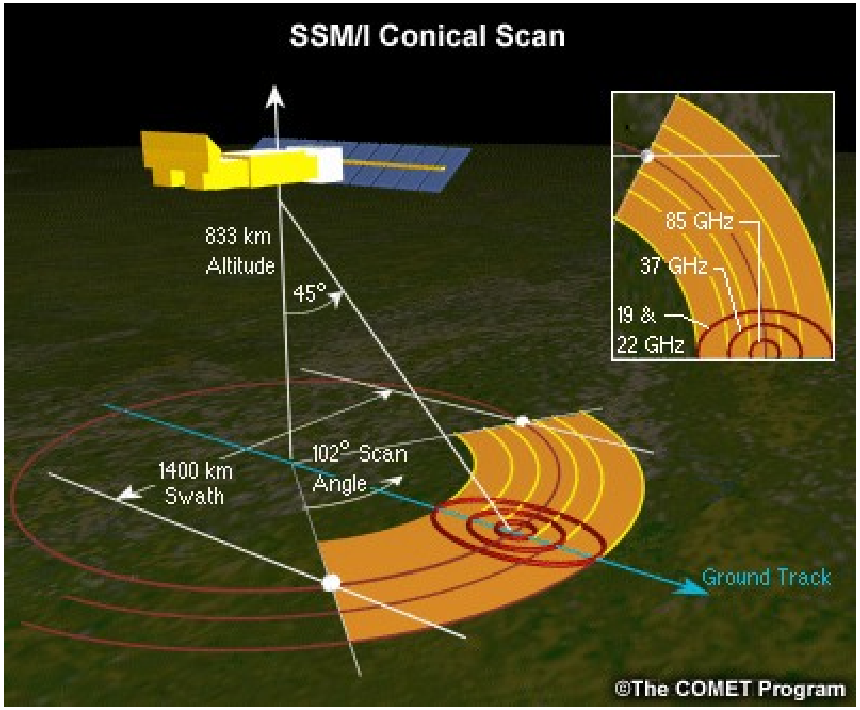
Ground incidence angle around 52° (for polarization reasons).
Half cone angle 44° re. the nadir direction
Useful swath: 1600 km
Pixel size varying with frequency and dish size, typically from 60 km at 6.8 GHz to 5 km at 89 GHz for a 1.5 m dish.

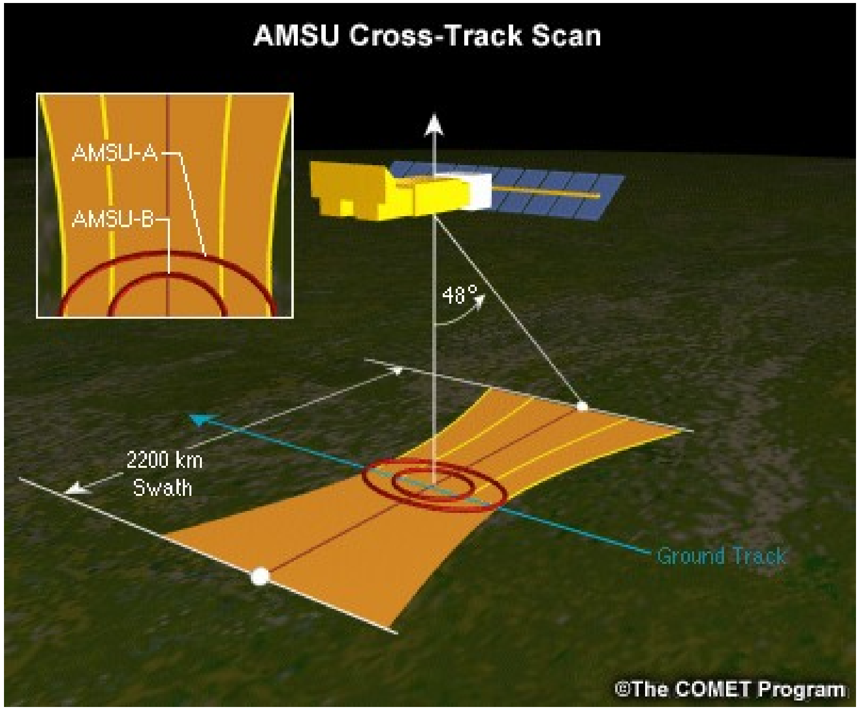
❷ Nadir passive sensors

Scan the Earth in a series of lines. The **lines are perpendicular to the direction of motion of the sensor platform** across the swath.

Each line is scanned from one side of the sensor to the other, using a **rotating antenna.** ***As the platform moves forward over the Earth, successive scans build up a two-dimensional image of the Earth's surface or the atmospheric layers***.

GEOMETRY OF A PASSIVE SENSOR





SMOS Soil Moisture and Ocean Salinity: an example of a passive sensing mission

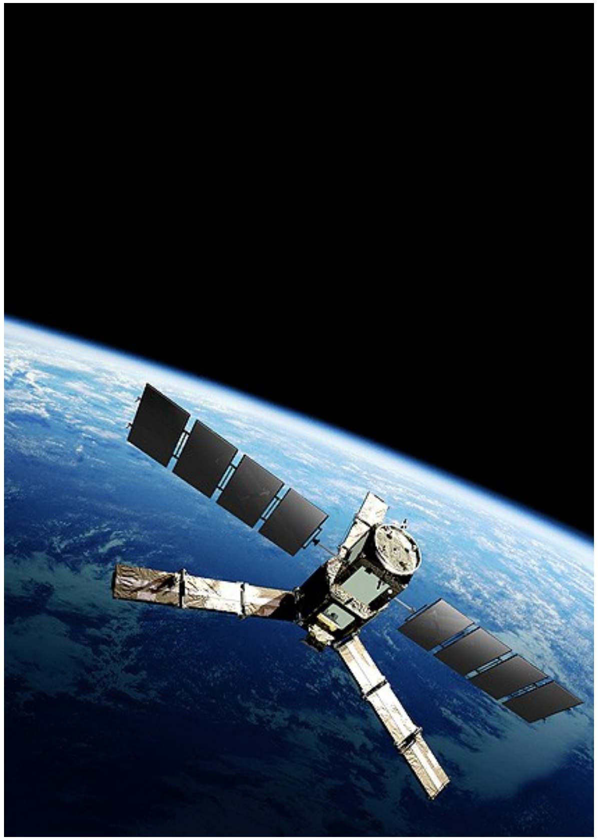
First global observation of **soil moisture** and **ocean salinity** (salinity is fundamental in determining ocean density and circulation).

The instrument is a microwave radiometer operating between **1400 and 1427 MHz** (L-band).

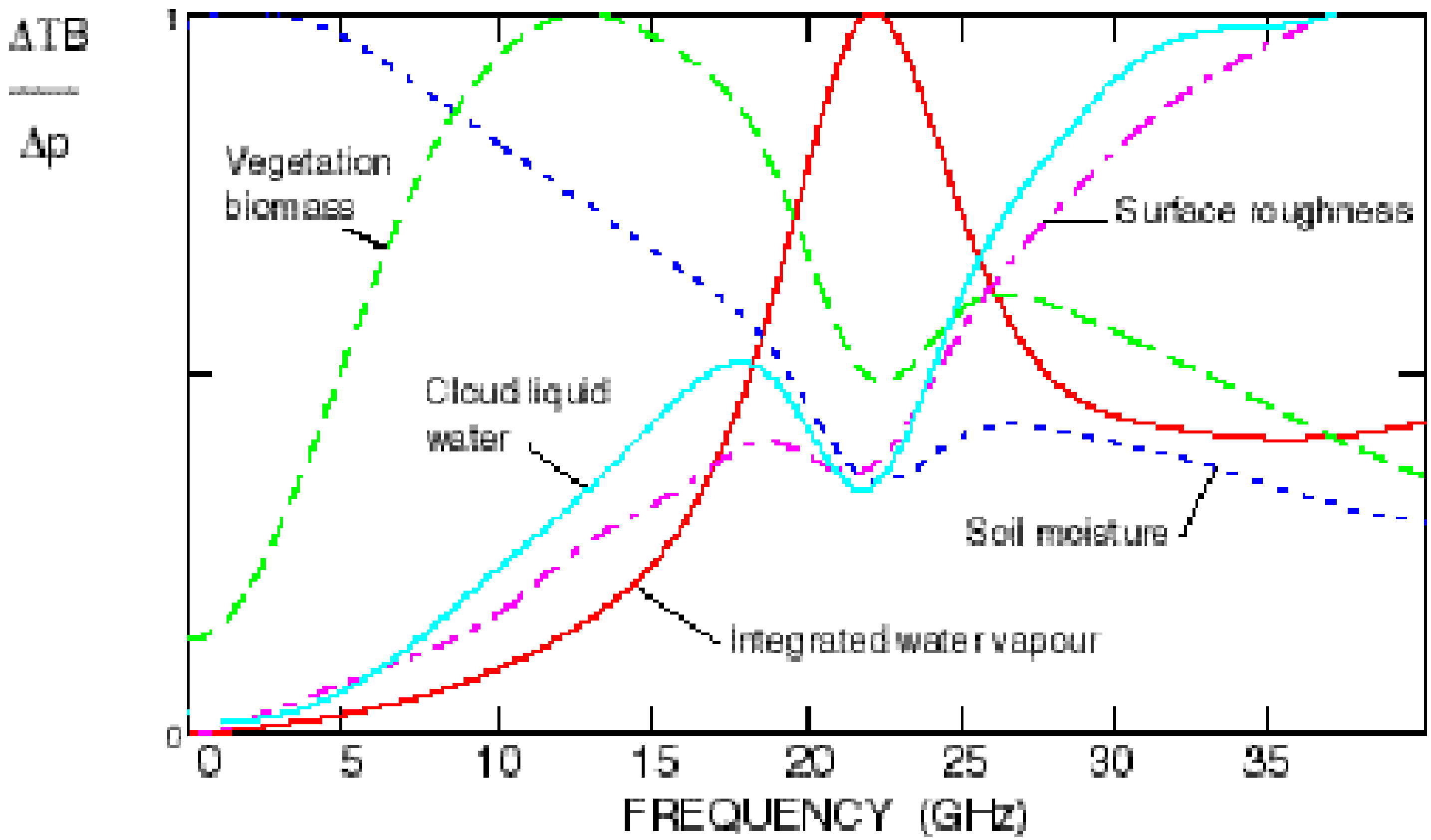
The satellite orbit, instrument design and data processing are designed to provide data every three days with a 35–50 km resolution.

The accuracy requirement of the ocean salinity observations has been set to **0.1 psu** every 10 days at 200 km spatial resolution.

practical salinity unit, 1 psu= 1 g of in 1 kg of seawater



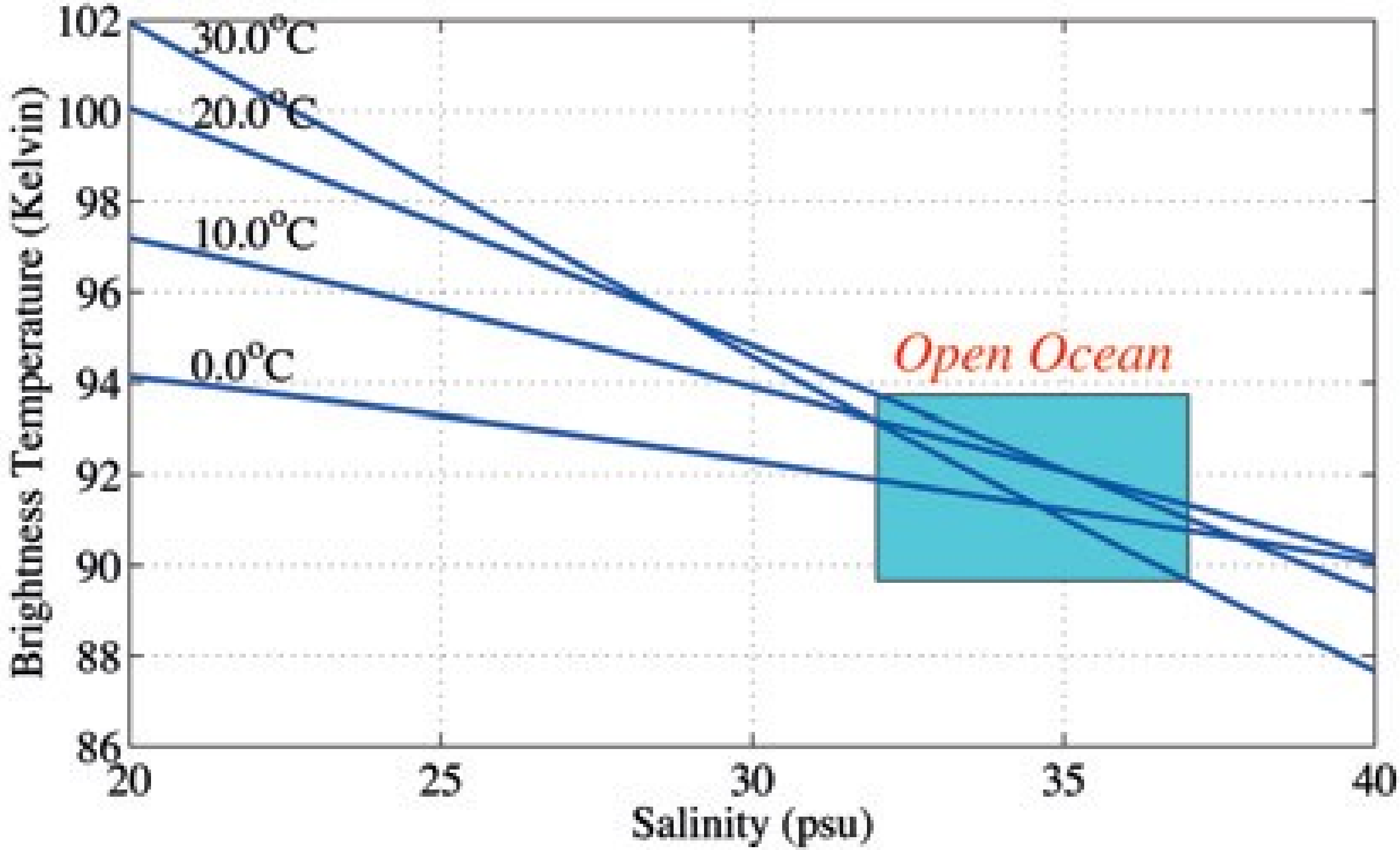
WHY 1400-1427 MHz for Soil Moisture?



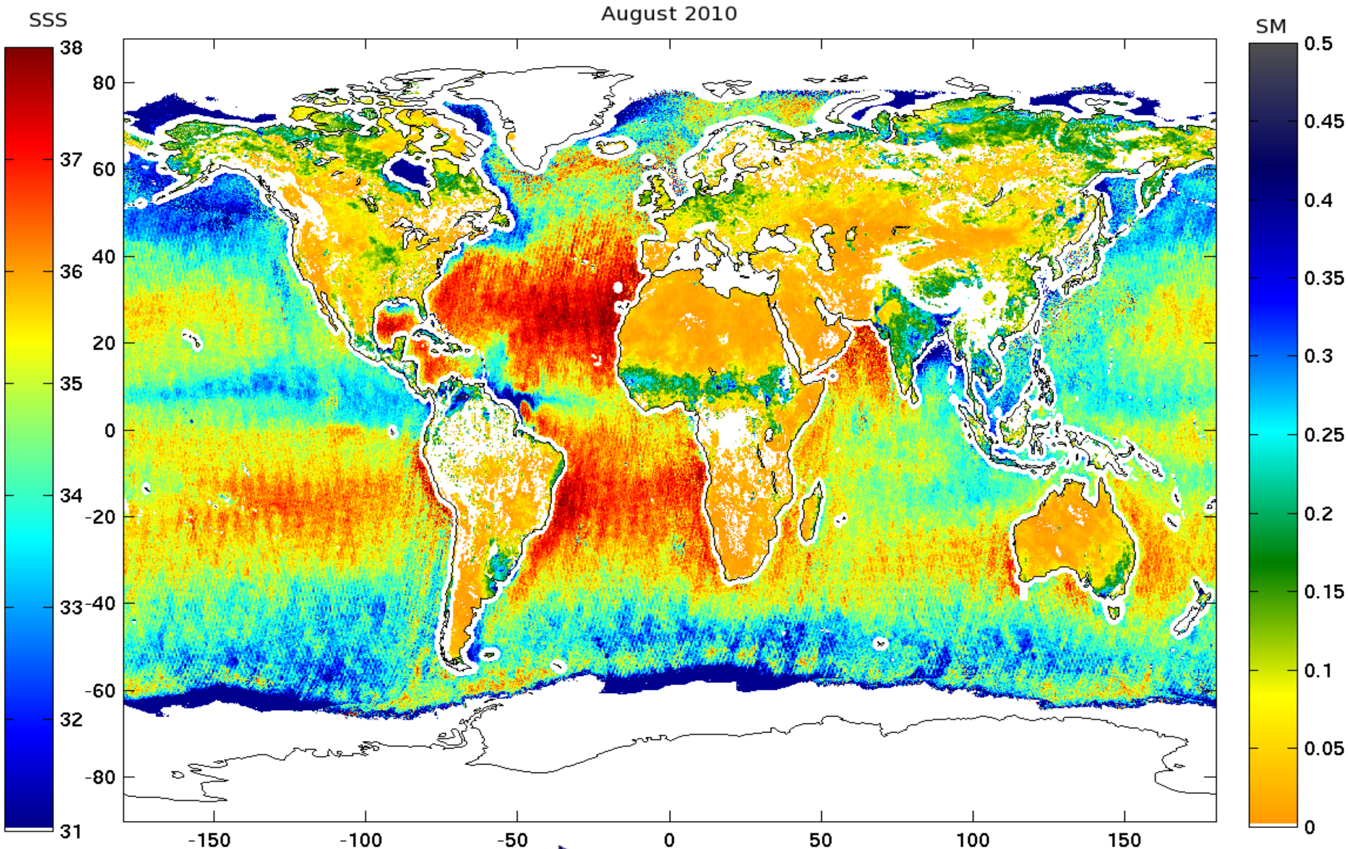
SEA SALINITY: BRIGHTNESS TEMPERATURE vs sea Temperature and salinity

Brightness temperature within the 1400-1427 MHz frequency band

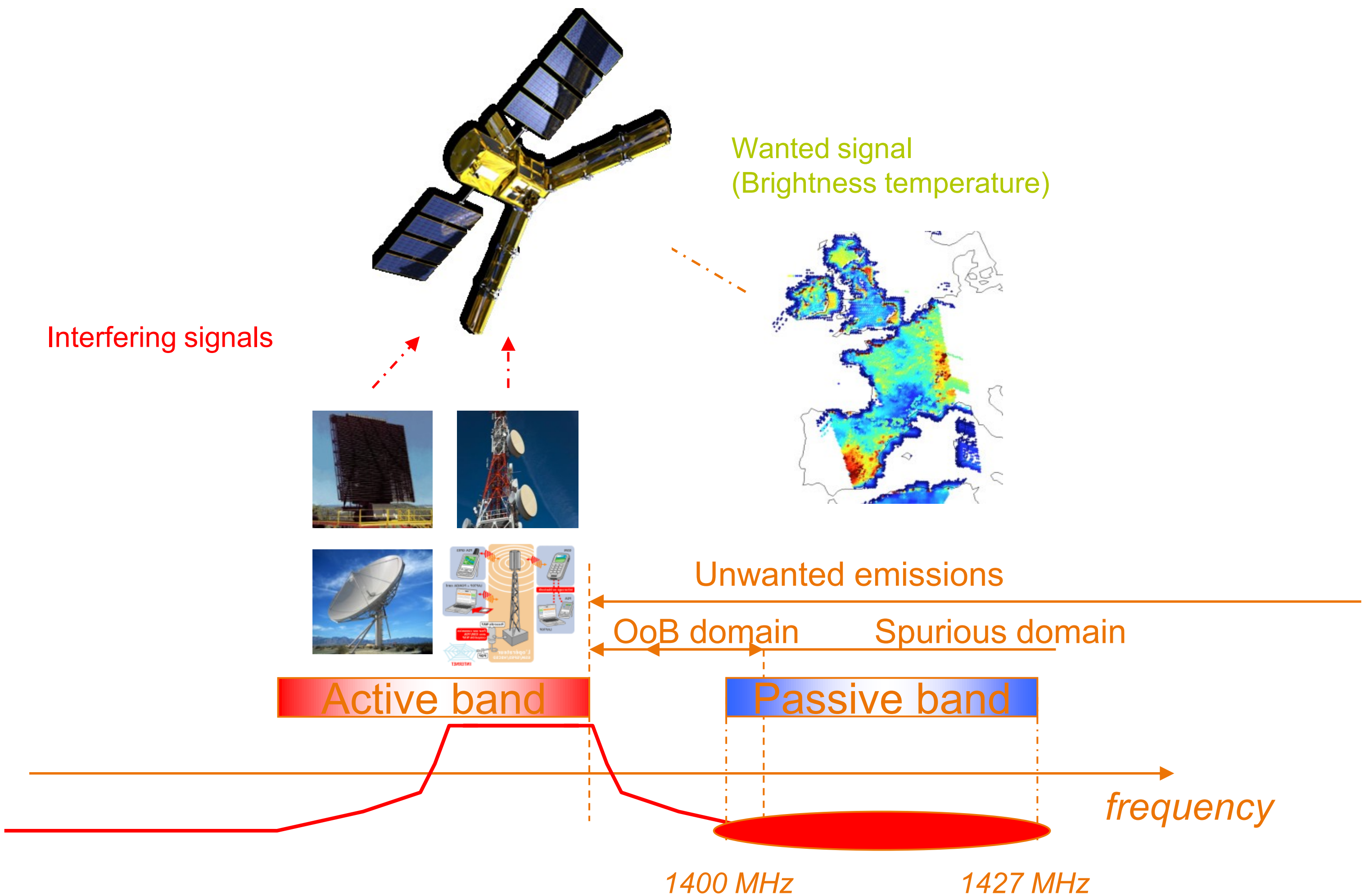
Typical salinity equals 35 psu



SMOS SOIL MOISTURE AND SEA SURFACE SALINITY

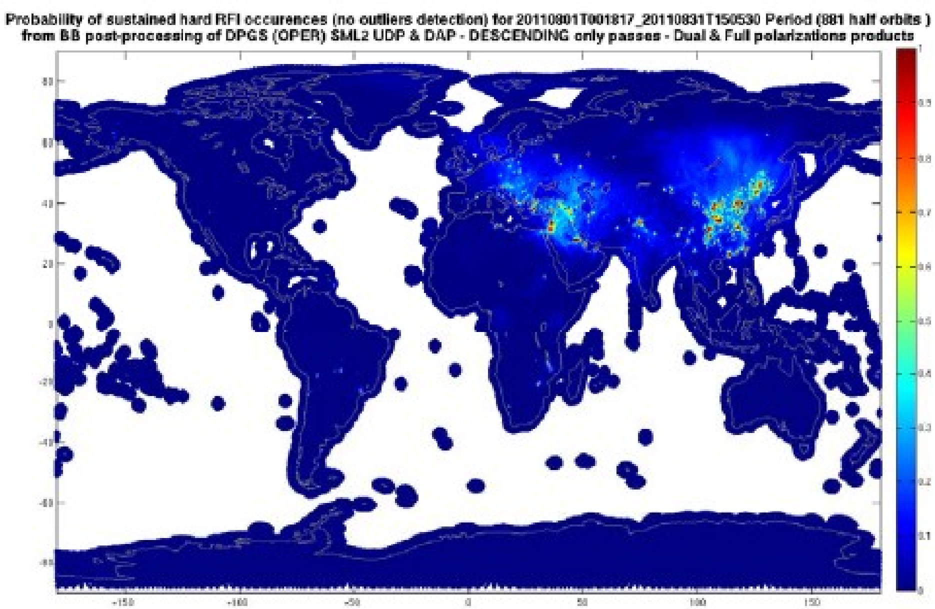


SMOS RFI: 1400-1427MHz band



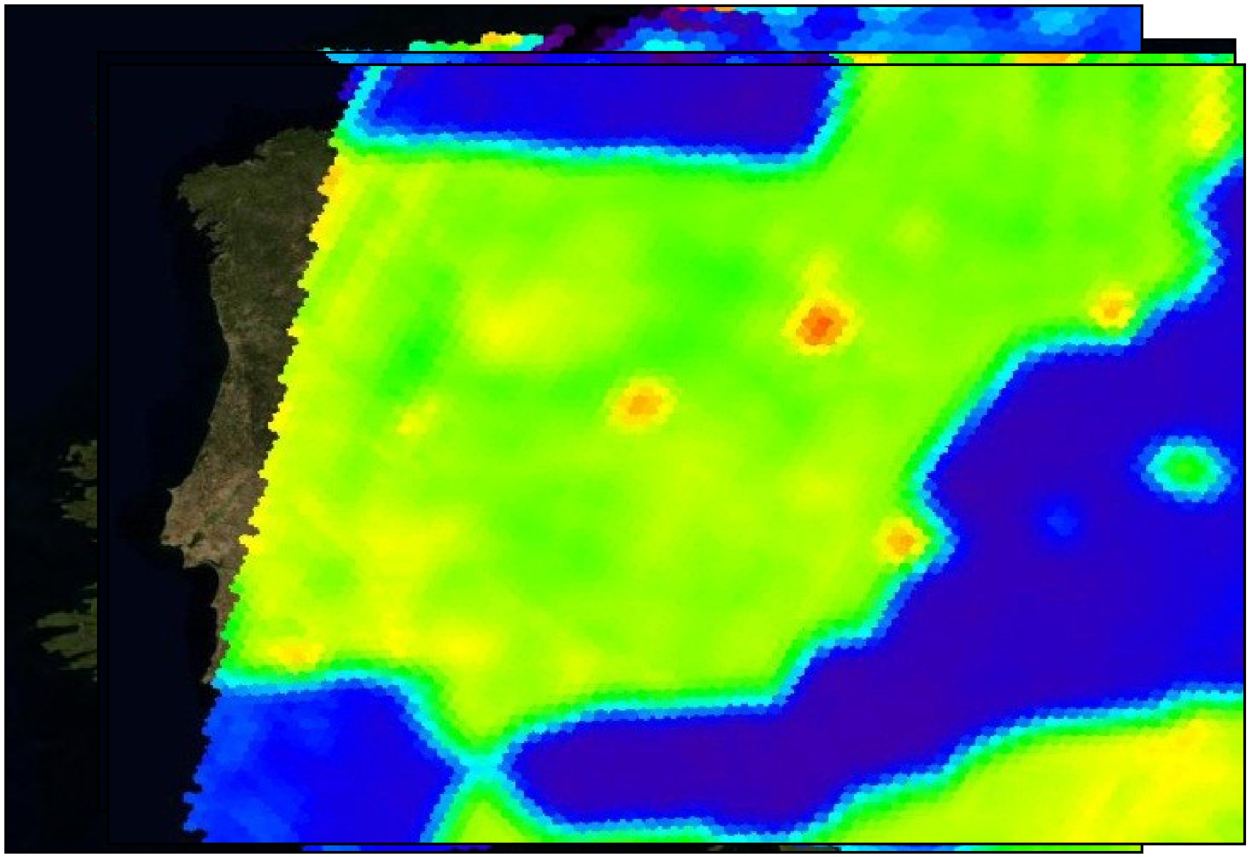
SMOS RFI contamination probability map

- Identification, geo-location and characterisation of the RFI sources (currently RFI emitters can be detected and located with accuracy as good as 5km)
- As a result of world-wide action, and thanks to the involvement and cooperation of the National Administrations involved, SMOS RFI scenario has improved considerably over the last two years
- However, there are still over 300 RFIs observed in the 1400-1427 MHz passive band worldwide



After Launch (early 2010)
August 2011

Some examples of RFI SMOS removal



What are RFI ?

The **RFI sources observed by SMOS** satellite can be grouped in two main categories :

- **illegal in-band emissions** inside the protected band
- **excessive unwanted emissions** from systems operating in the adjacent bands

Three categories of RFI received by a passive sensor :

- **High levels of RFI** that are **obviously inconsistent with natural radiation**. As such, these can be detected, but the corresponding measurements are lost.
- **Very low levels of RFI** **below protection criteria**: cannot be detected by on-board passive sensors, and hence do not have impact on the output products.
- **Low levels of RFI** that **cannot be discriminated from natural radiations**: represent very serious problem since degraded data would be seen as valid.

ITU-R REGULATIONS

RESOLUTION 750 (WRC 2007) Compatibility between the Earth exploration-satellite service (passive) and relevant active services ../..

5.340 « **All emissions are prohibited in the following bands:** 1400-14.7 MHz, 10.68-10.7 GHz, 23.6-24 GHz, 31.3-31.5 GHz, 50.2-50.4 GHz, 86-92 GHz …. …..»

Article 29bis and RESOLUTION 673 (Rev WRC-12): The importance of Earth observation radiocommunication applications

CONCLUSIONS

<u>1. Earth observation activities</u>: based on the increased and essential importance of passive microwave sensing. **Satellite operations in passive bands without degradation due to radio-frequency interference (RFI) is essential**. **The <u>passive frequency bands, which have been chosen on purpose</u>, are well defined in the Radio regulations (RR)**.

<u>2. Applications of the operational usage of passive sensors</u>: meteorology, climatology and climate change. Climate change has now become a reality and the data accumulated for years show that the climate is warming on a global scale. Climatology relies increasingly on space technology. **Earth observation delivers series of precise, global measurements matching the scale of planetary climate phenomena**.

<u>3. Removal of interference:</u> <u>one of the priorities of the ITU-R (constitution).</u>