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SPACEBORNE PASSIVE REMOTE SENSING MISSIONS:

• SOIL MOISTURE AND OCEAN SALINITY (SMOS)

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Summary

SMOS: SEA SALINITY AND SOIL MOISTURE, MEASUREMENT TECHNIQUES

MEGHA TROPIQUE: DETECTION OF CYCLONES

CLIMATE CHANGE AND PASSIVE REMOTE SENSING

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SMOS: INTRODUCTION

- Soil Moisture and Ocean Salinity (SMOS) mission is to globally observe soil moisture and ocean salinity, two crucial variables for modelling our weather and climate.
- Salinity is fundamental in determining ocean density and hence thermohaline circulation. Furthermore, ocean salinity plays a part in establishing the chemical equilibrium, which in turn regulates the CO2 uptake and release.
- Unlike sea surface temperature (SST) and sea level anomalies (SLA), it has not yet been possible to measure salinity from space.
- The SMOS instrument will be launched 2 November 2009, and is designed to provide temperature brightness (TB) data for 3–5 years. The instrument is microwave radiometer using the frequencies in the L-band, corresponding to 1.4 GHz.
- The satelite orbit, instrument design and dataprocessing prosedures is designed to provide data every third day with a 35–50 km resolution.
- The accuracy requirment of the ocean salinity observations has been set to 0.1 practical salinity units (1 psu= 1g salt in 1kg of seawater), every 10 days at 200 km spatial resolution.

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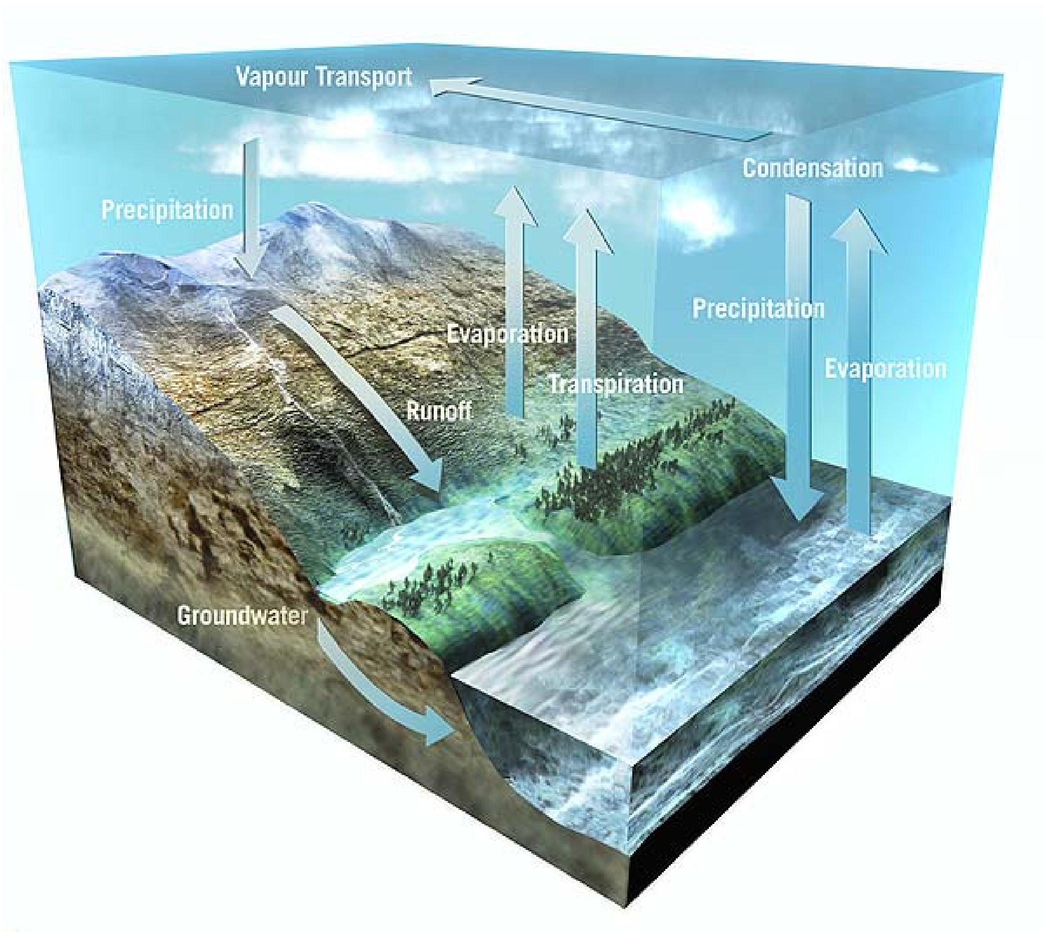
WATER CYCLE ON THE PLANET (1/2)



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WATER CYCLE ON THE PLANET (2/2)

- The SMOS mission: direct response to the current lack of global observations of soil moisture and ocean salinity which are needed to further our knowledge of the water cycle, and to contribute to better weather and extreme-event forecasting and seasonal-climate forecasting.
- Moisture: quantity of water that can be found within the first centimeters within the soil.
- Variability in soil moisture: driven by different rates of evaporation and precipitation. Severe drought or floods have various consequences on the landslides.
- SMOS: to provide the soil moisture at the soil surface: very useful for meteorological models. Current models are not able accurate estimates of soil moisture at the surface.
- The need for a such a data driven by climate change issues, water supply in some areas, extreme climatological events, meteorological forecast, …

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SEA SALINITY (1/2)

- Surface waters of the oceans: temperature and salinity control the density of seawater. **<u>The colder and saltier the water, the denser it is</u>**. Water evaporates from the ocean: salinity increases and the surface layer becomes denser.
- Additional fresh water is coming ⇒ this salty water has a tendency to go down to higher ocean depths. Precipitation: reduced density, and stratification of the ocean.
- **The heavy water salty and cold is rather located within deeper areas of the ocean, while hot water having a less salt density is located close to the surface.**
- Processes of seawater freezing and melting responsible for increasing and decreasing the salinity of the polar oceans. Sea-ice forms during winter ⇒ the freezing process extracts fresh water in the form of ice, leaving behind dense, cold, salty surface water.
- Density of the surface layer of seawater is increased sufficiently ⇒ water column becomes gravitationally unstable and the denser water sinks. Key process to the temperature and salinity-driven global ocean circulation. This conveyor-belt-like circulation is an important component of the Earth's heat engine, and crucial in regulating the weather and climate.

⇒ **Currently there are no global measurements of soil moisture/sea salinity available**. This is why the SMOS mission is so important for a better understanding and monitoring of our planet.

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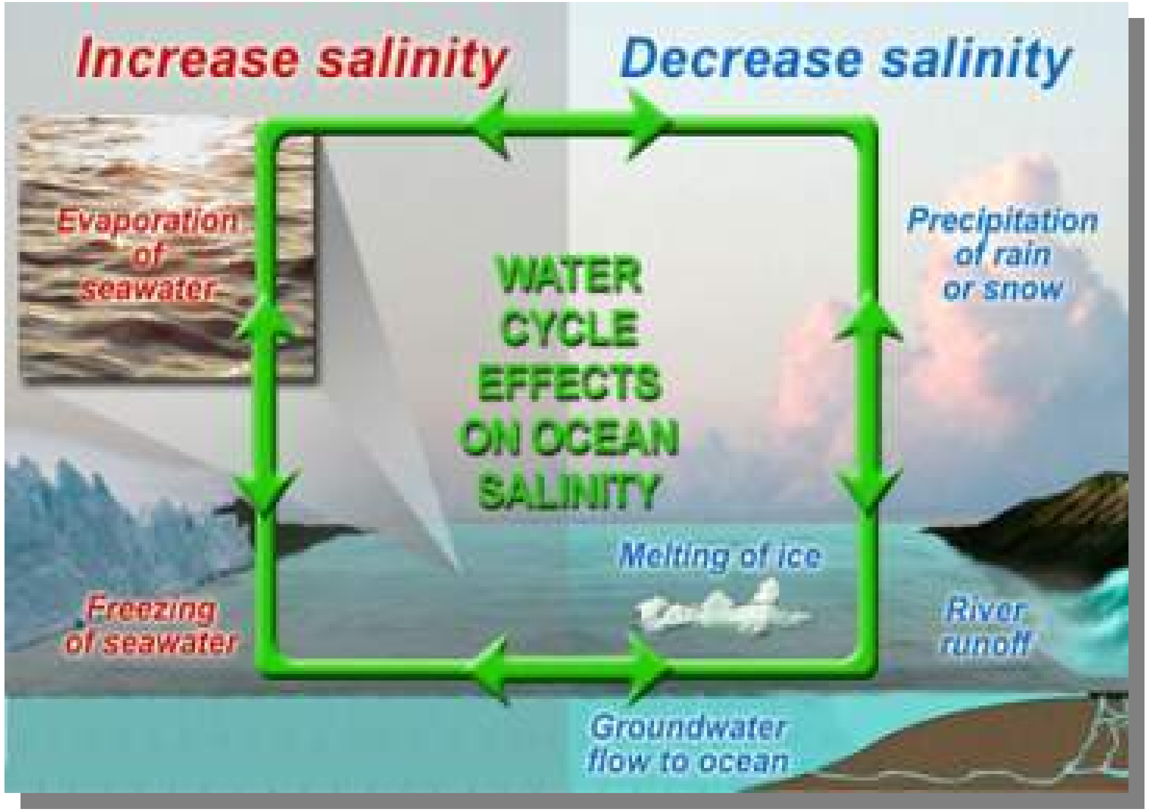
OCEAN SALINITY AND CLIMATE: link between the water cycle and the ocean circulation



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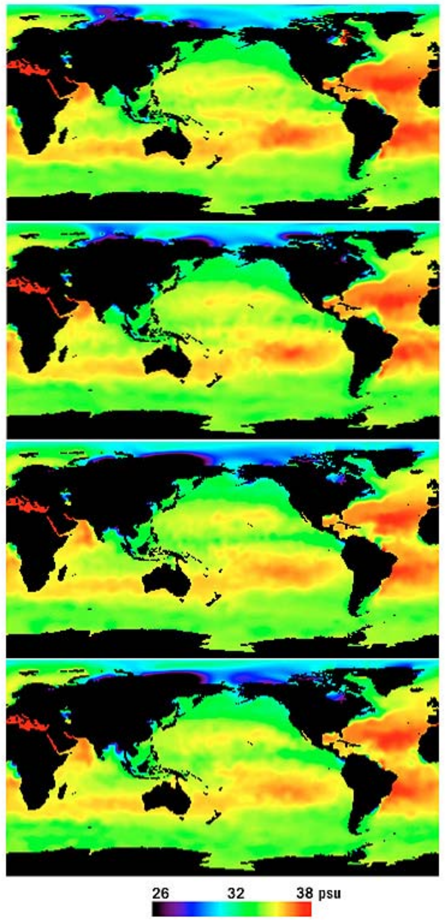
SEA SALINITY (2/2)

- Simulation, during the four seasons of the average salt concentration within the ocean. This salinity equals typically de 35 «units de practical salinity» (psu), which means that 35 gr. of salt are within 1 kg of water, about 1 l.

- This value is modified through evaporation and precipitations and is between 32 and 38 psu.

- The salinity is maximum at subtropical latitudes, where the evaporation is not enough compensated by rain.

- The salinity is minimum around the equator, where the rain is frequent, and also within polar regions, mainly because of the icecap melting.



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Thermohaline circulation (1/3)

- Once SMOS is launched, it is expected that SMOS will investigate the coupling between SSS (Sea Surface Temperature), the the North Atlantic Oscillation/Arctic Oscillation and The Atlantic Thermohaline Circulation.
- The Atlantic Thermohaline Circulation (ATHC) is a dynamically active component of the climate system, in particular on multi-annual to decadal time scales. The heat and salt carried northward across the Greenland-Iceland-Scotland (GIS) ridge are substantial, and both quantities are of importance for the water mass and ice distribution of the Nordic Seas and Arctic Ocean, and possibly also the deep mixing and water mass transformations taking place in the region.

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Thermohaline circulation (2/3)

The quantity of salt within the ocean has an essential impact on the behaviour of the overall thermolaline (from thermos, « temperature », and halin, « salinity ») circulation. Within some deep areas of the oceans, there is hot water, with salt. For instance, over the west part of the Pacific ocean, the précipitation rate is quite high and the water at the surface has a moderate amount of salt. But, below 30 and 60 meters, there are areas having warmer waters (+1 °C). The salinity is therefore an essential factor on the climate variability.

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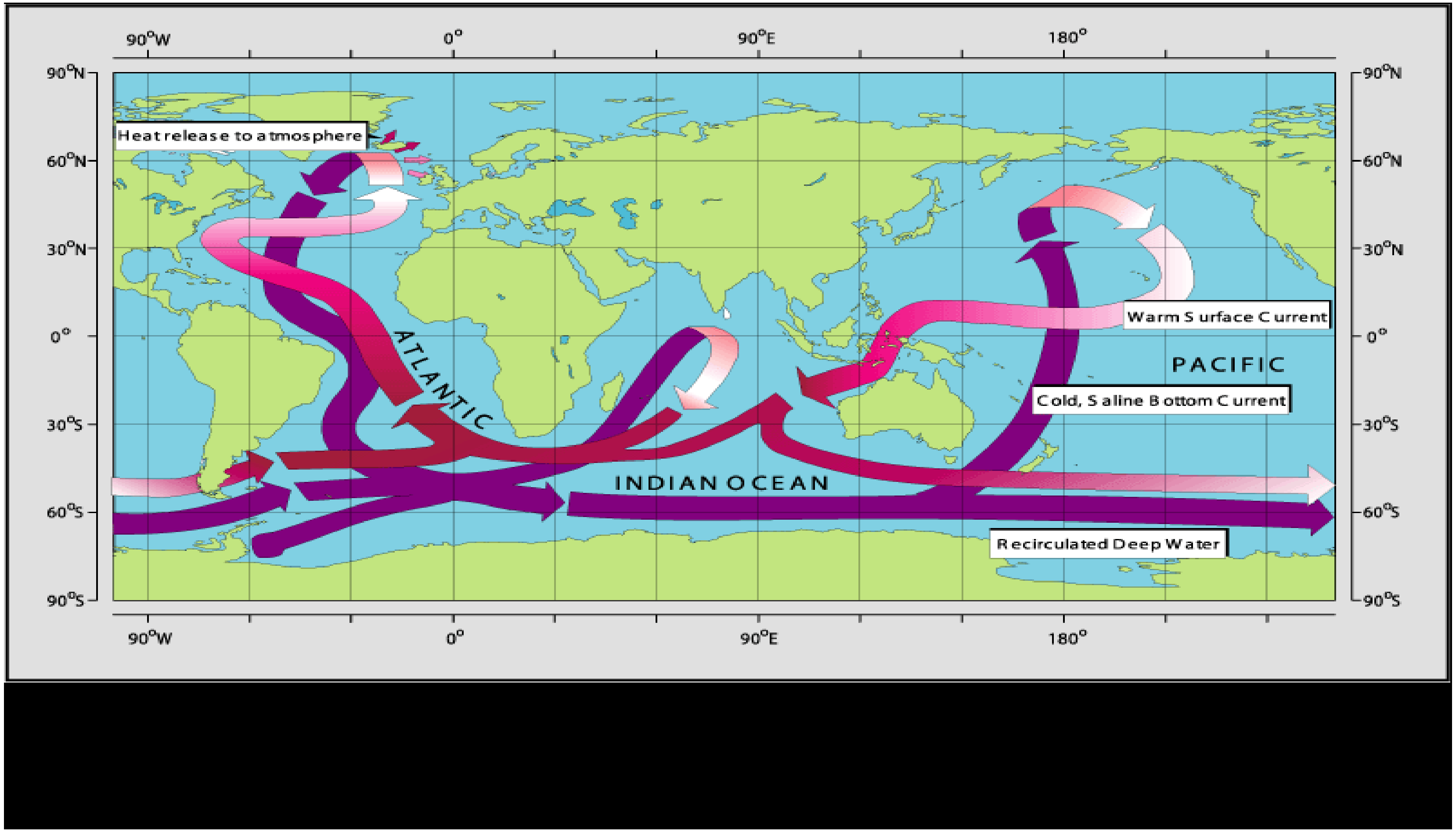
Thermohaline circulation (3/3)



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SMOS satellite

SMOS satellite: Mean altitude of 758 km and inclination of 98.44°; low-Earth, polar, Sun-synchronous, quasi-circular, 23-day repeat cycle

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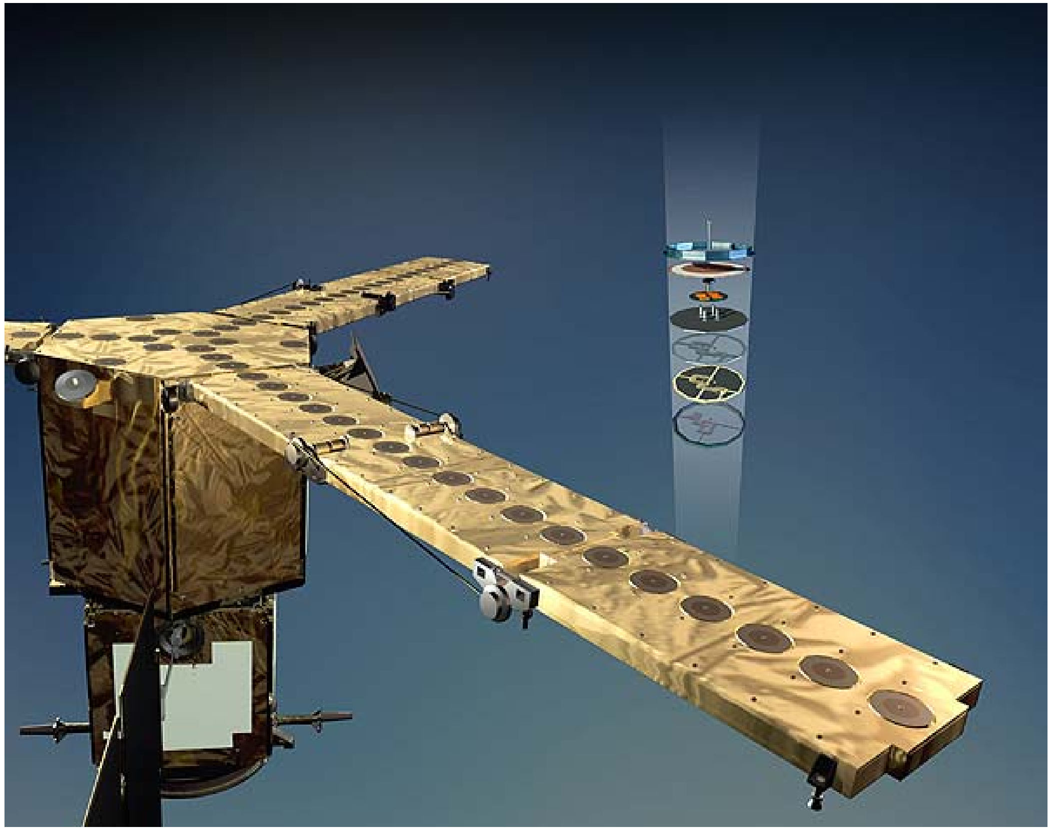
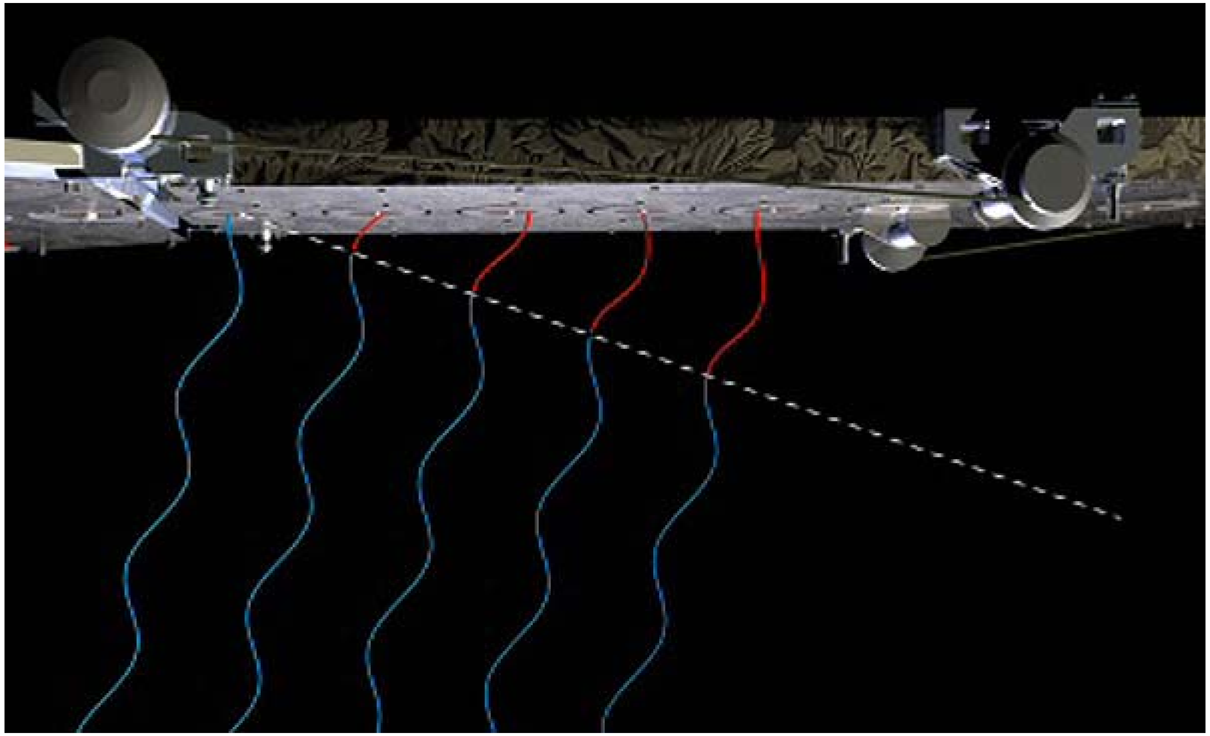
SMOS satellite: technology (1/2)



Radiometer MIRAS (Microwave Imaging Radiometer using Aperture Synthesis): **interferometer. 69 petites antennas are arranged on the 3 branches of an Y**, and simultaneously record the electromagnetic radiation from the Earth within the 1400 à 1427 MHz band. The collected data are then gathered. **The final image would correspond using a single antenna of 20 meters of diameter, while the deployed arms of the satellite represent only a diameter of 8 meters.**

⇒ ***Other space agencies may use other techniques***

SMOS technology (2/2), analysis of the phase differences



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SMOS data processing overview: to be incorporororated within meteorological forecasts

- **Raw data**
  SMOS instrument observation data
- **Level-0 data products**
  Unit conversion and calibration
- **Level-1a data products**
  SMOS reformatted and calibrated Observation and Housekeeping data in engineering units. Level-1a products are physically consolidated in pole-to-pole time-based segments.
- **Level-1b data products**
  The SMOS level-1b products are the output of the image reconstruction of the SMOS observation measurements and consist of Fourier Components of Brightness Temperatures in the antenna polarisation reference frame.
- **Level-1c data products**
  SMOS level-1c products constitute reprocessed level-1b, which are geographically sorted, that is swath-based maps of Brightness Temperature.
- **Level-2 data products**
  Level-2 products are of two separate types:
  - Soil Moisture swath-based maps
  - Ocean Salinity swath-based maps
- **Level-3 data products**
  Global maps will be produced in the next processing step (level-3 data).

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Monitoring of cyclones and tropical rainfall

The MEGHA-TROPIQUES satellite to be launched 2009/2010, is part of the Global precipitation mission (GPM). It is a french-indian MEGHA-TROPIQUES satellite devoted to the atmospheric research. The data collected by the satellite will allow to improve our knowledge on the water cycle contribution to the climate dynamic in the tropical atmosphere and our understanding of the processes linked to the tropical convection.

- provide simultaneous measurements of several elements of the atmospheric water cycle: water vapour, clouds, condensed water in clouds, precipitation and evaporation,
- measure the corresponding radiative budget at the top of the atmosphere, ensure high temporal sampling in order to characterise the life cycle of the convective system and to obtain significant statistics.

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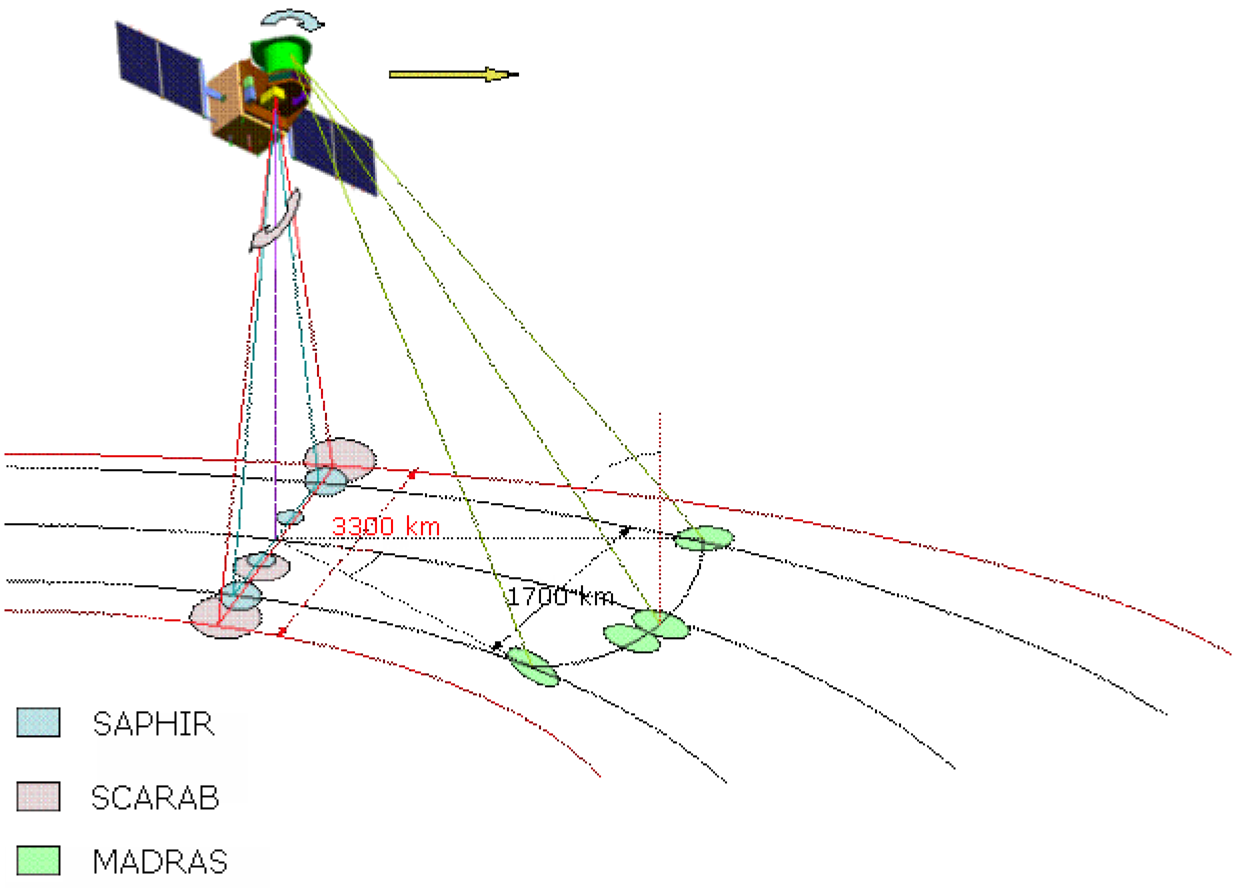
MEGHA-TROPIQUES

- MEGHA-TROPIQUES: to study the water and energy cycle in the tropics associated to convection and will perform the retrieval of rain, radiative budget and water vapour. The main applications are as follows.
  - Model data assimilation to improve weather forecast
  - General circulation models validation/improvement
  - Climate model validation/improvement
  - Risk assessment/management (floods, hurricanes)
- MADRAS passive microwave for rain/cloud estimates operating between 19 to 157 GHz

MEGHA-TROPIQUES SATELLITE



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Megha-Tropiques mission

To provide the following geophysical parameters:

- Cloud condensed water content
- Cloud ice content
- Convective-stratiform cloud discrimination
- Rain rate
- Latent heat release
- Integrated water vapour content
- Radiative fluxes at the top of the atmosphere
- Sea surface wind

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MADRAS instrument (range: 18.7 GHz-157 GHz)

- Rain retrieval over Ocean is easier because all channels are useful.
- Rain retrieval over Land is difficult because only higher frequencies are useful, especially 89 GHz.
- Tropical rain is VERY constrained by ice microphysics hence higher channels.
- 157 GHz is innovative and VERY promising for rain over land.

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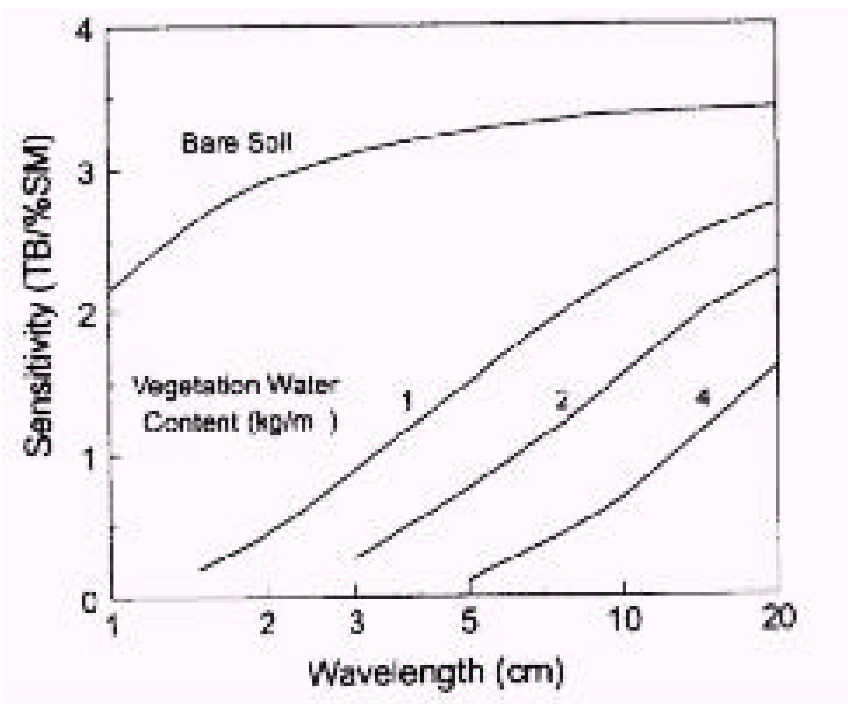
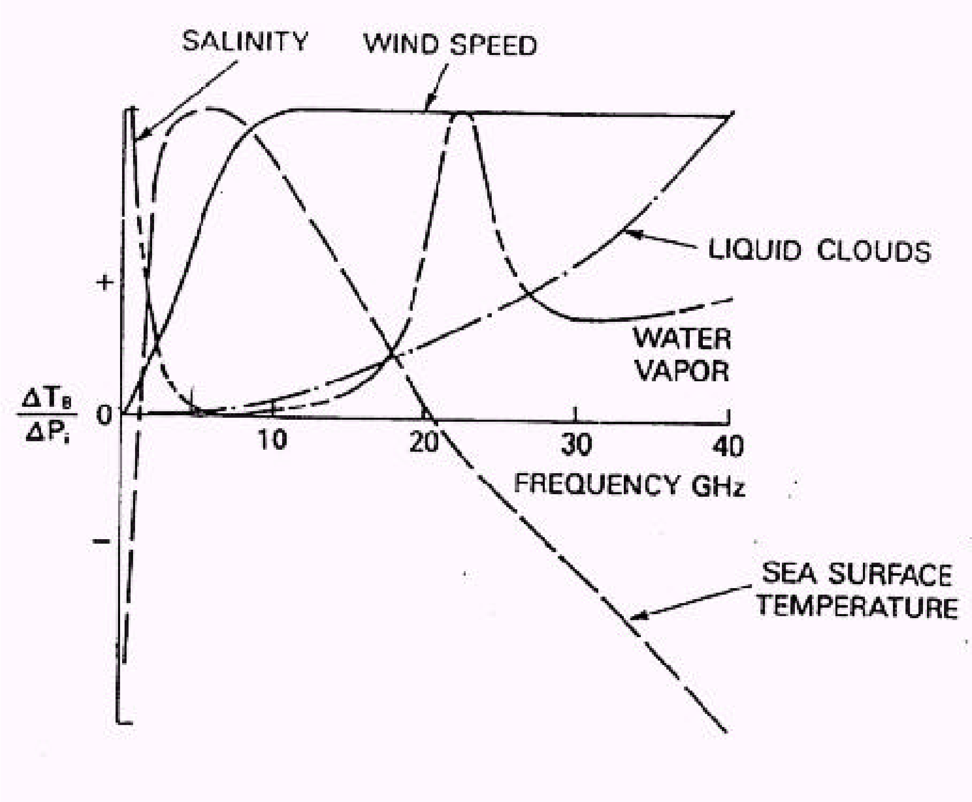
Microwave frequencies used for Earth Exploration Satellite: passive at 1.4 GHz: soil moisture and sea salinity (SMOS)





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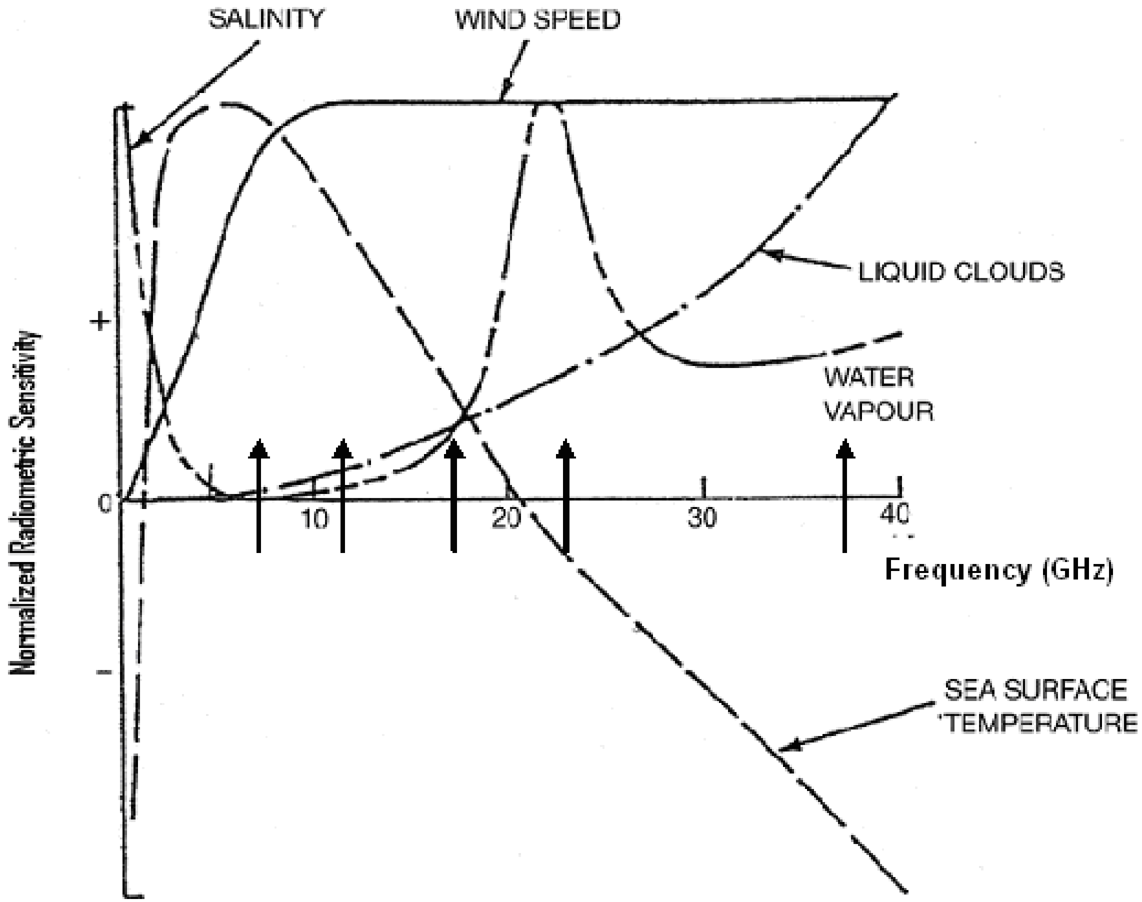
SENSITIVITY OF PHYSICAL PARAMETERS IN OCEANOGRAPHY AND METEOROLOGY WITH RESPECT TO FREQUENCY AND THE OPTIMUM CHANNELS: passive remote sensing



Sea surface emission at L-band

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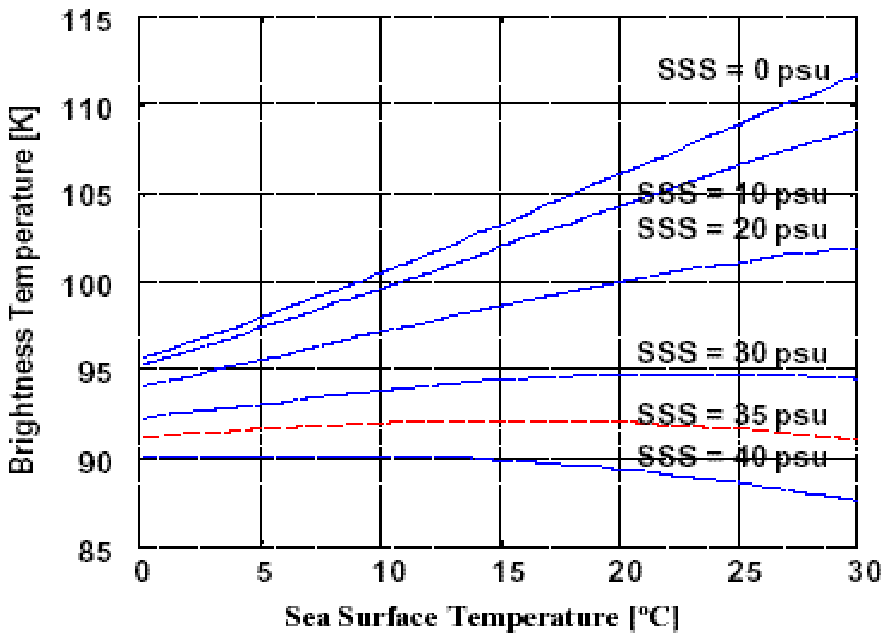
$$T_{h,v}(\theta,SST,SSS) \approx \left(1-\Gamma_{h,v}(\theta,SST,SSS)\right)\cdot SST + \Delta T_{h,v}(\theta,U_{10})$$

emissivity of flat sea

$$\Delta T_{h/v} \approx 0.23\,\mathrm{K}\left(1 \mp \theta/55^\circ\right)U_{10[m/s]}$$

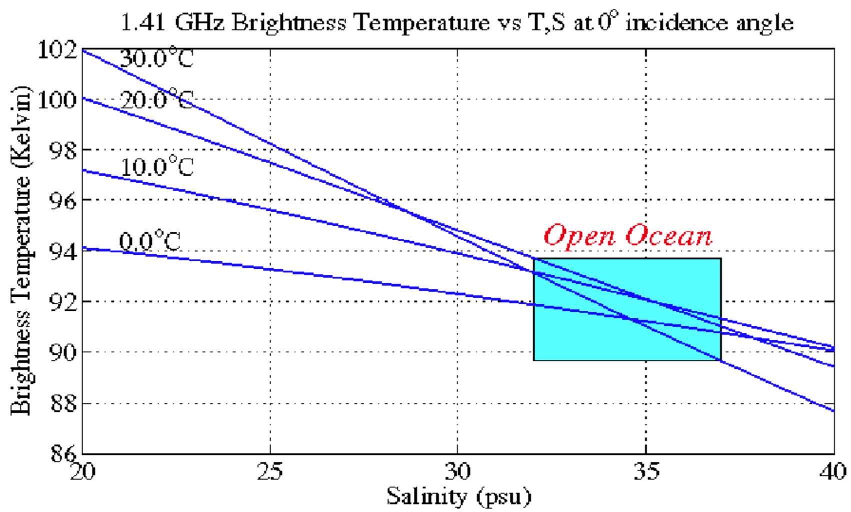
increase due to wind



at 0° incidence and flat sea

(Lagerloef et al., 1995)

sensitivity of Tb to S: 0.5 to 0.25 K/psu



Computation of the SMOS data

- The SMOS instrumentation will not provide SSS data $\Rightarrow$ inversion from temperature brightness (TB) data to ocean salinity.
- TB is a non-trivial function of sea surface temperature (SST) and salinity (SSS) and parameters determining the interaction between the atmosphere and the ocean. This makes the inversion to salinity complex and difficult.
- Another potential use of the TB data: assimilation directly into dynamical ocean circulation models used for ocean monitoring and prediction.
- Thus, in combination with in-situ data, Earth Observation data have gradually become an important contribution to improve our understanding of the Earth system and the associated model development and validation. The skill of model representations of the marine climate and environmental systems has therefore improved dramatically over the last decade

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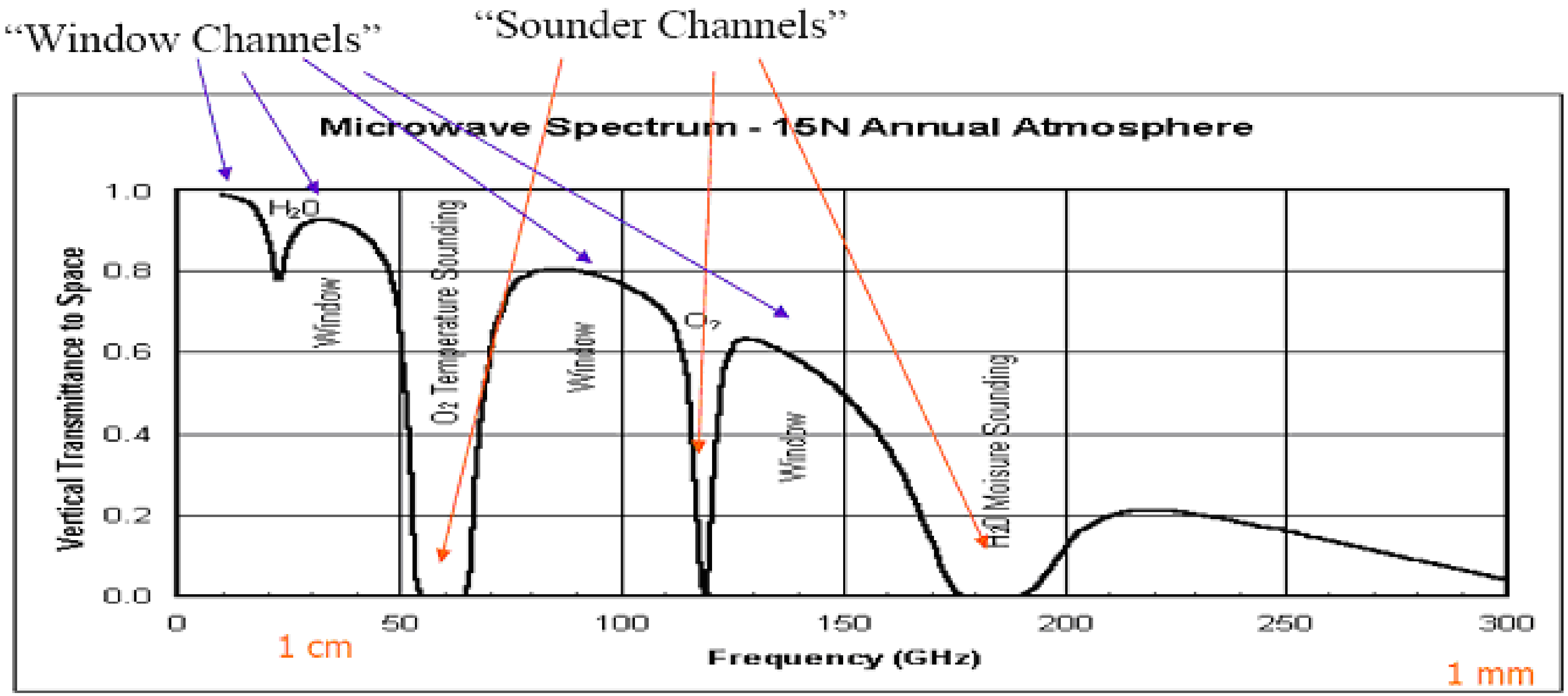
WINDOW AND SOUNDER CHANNELS: passive remote sensing



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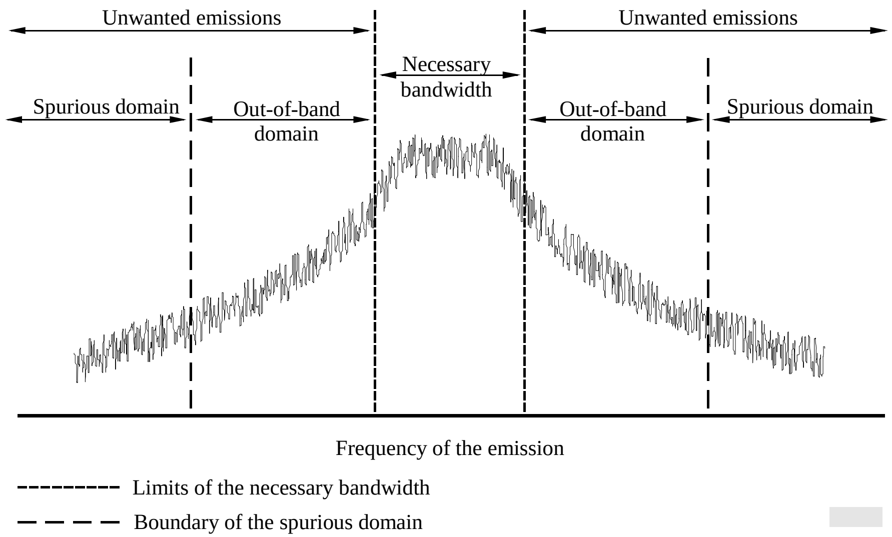
PROTECTION OF PASSIVE MICROWAVE FREQUENCY BAND

- The frequency band 1400 -1427 MHz is protected by RR article 5.340: All emissions are prohibited
- This footnote does not prohibit unwanted emissions in adjacent bands to fall within this passive band.

FIGURE 1

Out-of-band and spurious domains



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IMPROVEMENT OF THE RR: PROTECTION OF 5.340 BANDS FROM UNWANTED EMISSIONS

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

The World Radiocommunication Conference (Geneva, 2007),

Considering

.../…

b) that unwanted emissions from active services have the potential to cause unacceptable interference to EESS (passive) sensors;

resolves

1 that unwanted emissions of stations brought into use in the bands and services listed in Table 1-1 below shall not exceed the corresponding limits in that table, subject to the specified conditions;

2 to urge administrations to take all reasonable steps to ensure that unwanted emissions of active service stations in the bands and services listed in Table 1-2 below do not exceed the recommended maximum levels contained in that table, noting that EESS (passive) sensors provide worldwide measurements that benefit all countries, even if these sensors are not operated by their country

• Band 1400-1427 MHz: adoption of recommended limits for: Radiolocation, Fixed, Mobile, Space Operation

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CONCLUSION

- SMOS will be the first **mission** providing global data on a regular basis for soil surface moisture and sea salinity data.
- It is also the first mission using interferometry.
- Launch to be planned 2 November 2009.
- **Protecting the passive band at 1.4 GHz is a major issue.**
- Concerning climate change issues, a better forecast due to the integration of the SMOS data will not change the current situation. It is just a thermometer!