The SMOS mission 6 months after launch: possibilities to study the water cycle in the Mediterranean region

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SMOS: ESA’s water mission

SMOS is the second Earth Explorer Opportunity Mission from ESA, within its Living Planet program.

These missions aim at:
- Demonstrating new Earth observation techniques.
- Providing new data to the science community.
- Small and flexible missions, with participation of third parties (other space agencies)

Soil Moisture and Ocean Salinity (SMOS)
- ESA + France + Spain mission
- Submitted 1999, launched 2009
- First interferometric radiometer in space
Topic: Evolution of Earth’s water cycle

- Soil moisture and ocean salinity, two key climatic variables to understand and predict Earth’s water cycle
- To provide regular space observations, never attempted before due to technical complexity

(ESA, 2007)
¿What is SMOS for?

- With the observed global warming, is the water cycle accelerating? Can this change impact on water availability for consumption and agriculture?

- SMOS can significantly help in answering to these and similar open questions

(Allen & Ingram, 2002)
Role of soil moisture in the interaction between continental surfaces and atmosphere:
- Water storage
- Water uptake by vegetation
- Evaporation
- Runoff

Important for:
- Weather forecast
- Climatic studies
- Hydric resources
- Crops management
- Extreme events
The oceans play a major role in the Earth’s water cycle and climate regulation.

Salinity links the climatic variations of the global water cycle and ocean circulation.

- Salinity is required to determine seawater density, which in turn governs ocean circulation.
- Salinity variations are governed by freshwater fluxes due to precipitation, evaporation, runoff and the freezing and melting of ice.
- 86% of the global evaporation and 78% of the global precipitation occur over the oceans.

(http://aquarius.nasa.gov/education-datatools.html)
¿What will SMOS provide?

- Global and repetitive (3 days complete coverage) observations of soil moisture over land and sea surface salinity over oceans
- Needed to **improve the efficiency of our present systems** to predict weather, climate evolution, and occurrence of natural catastrophic events
- Until now **no satellite mission** has been providing **global observations of both variables**
- **SMOS has the goal of demonstrating the feasibility of these observations** with a quality adequate for climatic and ocean large scale studies, improving weather forecasts, and the management of water resources
Examples of SMOS applications

- A detailed monitoring of soil water content in a specific region will allow improving not only the forecast of precipitation but also the floods risk, by estimating its water storage capability under heavy rainfall.

- The present ocean numerical models that forecast the occurrence, evolution and intensity of El Niño events in the Equatorial Pacific (with possible devastating climatic, economical and social consequences) can only assimilate sea surface temperature and surface height data. It has been shown that the availability of sea surface salinity information would significantly reduce the error of these forecasts.
The multiangular measurements of any point on the Earth’s surface provided by the SMOS interferometric radiometer MIRAS at each satellite overpass are aimed at:

- Determining soil moisture with a 4% accuracy, plus vegetation water content, with a spatial resolution of 50 km and a revisiting time of at least 3 days
- Determining ocean salinity with an accuracy of the order of 0.1 practical salinity units, 100 – 200 km spatial resolution and 10 – 30 days temporal resolution
Moisture and salinity

- The radiation emitted by the Earth surface and captured by SMOS depends on the dielectric properties of the emitting body, related to the amount of water in the soil and the amount of salt in the ocean.

- Microwave L-band: most suited frequency 1.413 GHz in a protected bandwith

(from Kerr, 2009 and Wilheit, 1980)
A new technical approach

- Trade-off between land and ocean requirements
- Moderate spatial resolution implies large antennas
- Interferometric approach: a synthetic antenna obtained from an array of small antennas
- A single image reconstructed from correlations between all pairs of received signals
- MICrowave Radiometer with Aperture Synthesis (MIRAS): 69 individual antennas in 3 Y-shaped arms

Antenna aperture synthesis, as used in radioastronomy: an array of receivers constitute a Very Large baseline Antenna and generate an image by interferometry
Observation characteristics

- SMOS field-of-view: irregular 1000 km x 1000 km hexagon; variable incidence angles, pixel size and radiometric sensitivity
- As the satellite advances a single spot is seen in different positions within the instrument field-of-view

Many fully polarised Tb values to retrieve a single SM or SSS value
Launched 2 Nov. 2009 from Plesetsk (Russia)

Instrument: MIRAS

Platform: PROTEUS

Thales Alenia, France

EADS CASA, Spain

Launcher: former SS-19

Rockot, Russia
SMOS brightness temperature images

by I. Corbella, UPC, Barcelona, February 2010
SMOS Sea Surface Salinity retrieval

- Retrieval from brightness temperature through a convergence loop
- Comparing model (guessed SSS) with measurements at all incidence angles
- Sea surface emissivity model (top 1 cm) including roughness effects
- Other contributions from external sources and atmospheric effects
- Need for auxiliary data to describe environmental conditions

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T_{b,p} = T_{b,p \ flat} (\theta, \text{SST, SSS}) + \Delta T_{b,p \ rough} (\theta, \Phi \text{ wind waves, swell, other wave characteristics, foam coverage, foam emissivity, rain})
\]
Comparing SSS map generated with 3 days of SMOS data (ascending orbits 29-31 Jan 2010) and Levitus climatology for January
- No data averaging
- Degraded results in field-of-view borders, near coast, and in areas of strong wind
Amazon plume detected by SMOS

- SMOS descending orbits, March 2010

- In situ climatology
Soil moisture: impact of a rain event

- SM retrieval based on emissivity models for different soil types + additional information (land cover, topography, atmospheric conditions ...)
- Australia: a good site for SMOS land products validation. No radio frequency interferences. In situ campaign spring 2010
SMOS mission status

- Launch 2 November 2009
- Commissioning phase completed 20 May 2010
- Brightness temperature data available in NRT (3 h) from Svalbard station. Now delivered to ECMWF
- Level 1 (Tb) products delivered to Calibration/Validation teams from late March 2010
- Level 2 (SM and OS) products from ESAC to be delivered to Cal/Val teams by mid June 2010
- Open access to level 2 for research community by early September 2010
- Category-1 (science) projects can be submitted to ESA Earth Observation Principal Investigator portal http://eopi.esa.int/esa/esa
What about the Mediterranean?

- Original MIRAS measurements in pixels of 30 – 60 km
- Remapped to 15 km (ISEA4H9 georeferentiated grid)
- Soil moisture retrieval more robust (80 – 100 K range)
- Keeping full spatial resolution, plus pixel disaggregation using additional information (e.g. MODIS) for SM retrieval
- Lower sensitivity for ocean salinity (about 5 K range)
- Single orbit salinity retrieval expected at 1-2 psu accuracy
- Temporal and spatial averaging to reduce noise and fulfill the mission requirements: 0.1 psu, 100-200 km, 10-30 days
- Small ocean basins: problem of land contamination
- Ocean validation project in the Mediterranean accepted by ESA (OGS Trieste, INGV Bologna, ICM Barcelona, lead by P.M. Poulain): in the limits of SMOS capabilities?
Thank you for your attention!