Soil Moisture and Ocean Salinity mission: first in-flight results

Yann H. Kerr, François Cabot, Philippe Richaume, and Jordi Font

A novel interferometric radiometer delivers frequent global measurements of surface-soil moisture and sea-surface salinity.

Soil-moisture and sea-surface-salinity (SSS) measurements are required to improve meteorological and climate predictions. Because these observables were not yet readily available globally, the European Space Agency supported and led the Soil Moisture and Ocean Salinity (SMOS) mission, with contributions from France and Spain. The satellite was launched successfully on 2 November 2009.

Previous modeling and observations had offered some insights into various crucial factors needed for improving forecasts of weather and extreme events as well as aiding water-resources management. In this context, soil moisture plays an important role because it is a water reservoir, a source of water that can be evaporated into the atmosphere through mass transfer. As a result, it is a tracer of precipitation and a factor influencing the energy budget at the surface/atmosphere interface (because evaporation requires energy and, therefore, induces a decrease in temperature). Depending on soil characteristics and surface-water content, events such as rain storms can lead to flooding and landslides. Access to accurate and timely soil-moisture data would enable better predictions of these types of hazardous events. Soil-moisture data also provides important information on water availability.

The primary scientific objectives of the ocean-salinity observations provided by the SMOS mission are to improve seasonal to interannual climate predictions by effective use of SSS data as input to coupled climate-forecast models, improve oceanic-rainfall estimates and global hydrologic budgets based on better knowledge of SSS variability, and monitor large-scale salinity events.

SMOS carries an L-band (1.4GHz) 2D interferometric radiometer that operates in the 1400–1427MHz protected band as its single payload. This frequency penetrates well through vegetation, and the atmosphere is almost transparent in this window. Consequently, the instrument probes the Earth’s surface emissivity. The latter can be related to the moisture content in the first few centimeters of soil over land and, after surface-roughness and temperature corrections as well as spatiotemporal aggregation, to SSS over oceans. SMOS achieves an unprecedented spatial resolution of better than 50km, which is perfect for weather and extreme-event forecasts and meets soil-moisture and ocean-salinity science objectives. This performance is achieved by employing a nonrotating, thinned 8m-diameter antenna (see Figure 1). The antenna’s imaging capability is implemented through aperture synthesis (similar to that used in radio astronomy). It measures multi-angular dual (or fully) polarized brightness temperatures with a revisit time of less than three days for a given location, enabling retrieval of soil moisture and ocean salinity within the requirements listed in Table 1. However, the instrument has a slightly reduced sensitivity compared to conventional radiometers.

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Table 1. Mission requirements for soil-moisture and ocean-salinity measurements. pss-78: Practical salinity scale 1978.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Accuracy</th>
<th>Spatial resolution</th>
<th>Temporal sampling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil moisture</td>
<td>0.04m/m</td>
<td>&lt;50km</td>
<td>&lt;3 days</td>
</tr>
<tr>
<td>Vegetation water content</td>
<td>0.1kg/m</td>
<td>&lt;50km</td>
<td>&lt;5 days</td>
</tr>
<tr>
<td>Sea-surface salinity</td>
<td>0.1–0.2 pss-78</td>
<td>100–200km</td>
<td>10–30 days</td>
</tr>
</tbody>
</table>

Figure 2. Typical noise obtained over the Pacific Ocean with SMOS (in the K band, 12–40GHz). x, h: Orthogonal coordinates.

SMOS is currently undergoing commissioning, which is due to last six months. After a very accurate orbital injection and a flawless deployment and switch on (on 17 November), images were available immediately. Their quality was initially not optimal because all processors were running using pre-flight estimated values, but these were adjusted to their appropriate flight performance very quickly. In fact, specifications were met in all and exceeded in many cases. Figure 2 shows the sensitivity obtained by accumulating measurements over a large area covering the Pacific Ocean.

The deep sky was observed in several instances, as well as large, stable, and known targets such as Antarctica. The instrument behaves extremely well despite the complex data reconstruction process. Figure 3 shows a map obtained over Antarctica during the first week of February 2010. Note the ‘wet’ patch (lower brightness temperatures) over eastern Australia, where significant rains occurred. However, in some countries, we encountered many instances of radio-frequency interference. Several areas are thus severely affected by emissions in the protected band, considerably hampering both calibration/validation (Cal/Val) and data use.

We conducted a large-field experiment in Australia during the first part of the commissioning phase. Other such experiments are planned for the next few months in Europe, western Africa, and Canada. We are currently analyzing the SMOS data but it is already evident that even with the most primitive version of the soil-moisture retrieval algorithm, we could obtain useful soil-moisture maps. Their absolute values are not yet consistently perfect, although in most cases the range is correct. Moreover, their spatial distribution is qualitatively representative of rainfall events. Intensive work is currently under

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way to fine tune the retrieval algorithm and perform validation studies employing Cal/Val experiments (such as the Australian Airborne Calibration/Validation Experiments for SMOS). Over the oceans, the challenge is significantly greater. Nevertheless, we produced the first SSS map obtained from space. We still need to address a few issues (such as wind-speed correction), but the global surface-salinity distribution matches the expected values very well. These results are very encouraging at this early stage in the commissioning phase.

After four months in orbit, and roughly halfway through commissioning, SMOS is behaving very well. After a perfect orbital injection and preliminary characterization, the instrument and operation teams have managed to perform all in-flight characterization maneuvers and calibration sequences. The satellite’s processors are now almost in their final stages and the data on brightness temperatures is being released to the Cal/Val teams slightly ahead of schedule. We are also implementing and verifying near real-time data setup to enable the European Center for Medium-range Weather Forecast to test SMOS data assimilation into their models. We are currently validating and calibrating the first maps of soil moisture and SSS produced by the mission. The end of the commissioning phase is foreseen for mid-May 2010. We should then be able to decide on the instrument’s operational polarization mode. Data will be made available to the community at large to foster new scientific approaches and applications in areas such as water-resources management. We are also considering new concepts for the next generation of sensors that can provide such measurements with even higher spatial resolution over land and improved sensitivity over oceans. Finally, the most challenging issue we have to deal with relates to emitters in the protected band, which will require significant attention and related action.

The authors are greatly indebted to all contributors to SMOS success: scientists, project teams, launch teams, operation teams, ground-data collectors, and others.

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References