



The SMOS antenna at ESAC, Spain

## → GETTING DOWN TO BUSINESS

### SMOS operations and products

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**SMOS will be the first satellite mission to provide global measurements of two key variables in the water cycle – soil moisture and ocean salinity – but how do we get from the first observations to meaningful data on the various characteristics of Earth's surface?**

#### **The SMOS ground segment**

SMOS is an ESA Earth Explorer mission with significant national contributions provided by the French and Spanish

space agencies, CNES and CDTI. The collaborative approach for the development of the SMOS mission will be continued in the operations phase, with the ground segment consisting of different stations covering various functions. For the operations phase, ESA will be responsible for the overall coordination of the mission and the ground segment operations, and CNES will be operating the spacecraft.

The main stations for day-to-day running will be ESA's European Space Astronomy Centre (ESAC), in Spain, hosting the main part of the Data Processing Ground Segment

(DPGS), and CNES at Toulouse, hosting the Satellite Operations Ground Segment (SOGS). Global soil moisture data are important variables for operational meteorological applications. ESA member states therefore approved in 2006 an add-on to the original mission configuration by introducing another X-band receiving station at Svalbard, Norway, which will guarantee this service. Above the Arctic Circle, Svalbard will provide 10 out of the 14 orbits per day that ESAC is not able to acquire in real-time due to its geographical location.

The Near-Real-Time (NRT) data will in the first instance be provided to the European Centre for Medium-range Forecasts (ECMWF) in the UK and MétéoFrance, which are already now working on integrating these data in their predictive models, testing the improvements SMOS data will be able to make to meteorological forecasts.

Once the data reach the DPGS at ESAC they will be calibrated, processed, archived in the Fast Processing Centre and disseminated to the SMOS data users. There will be two parallel processing chains for the scientific and NRT data products, the latter being distributed to the operational users within three hours of sensing. The DPGS also hosts



SMOS ground segment elements: in addition to ESA facilities, various functions will be supported by industrial contracts

facilities to check on the performance of the overall system as well as ensuring SMOS data provided to the users will have the appropriate quality. Throughout the mission lifetime, as our knowledge about the SMOS mission and data advances, the algorithms used to process the SMOS data will improve. Once a new version of these algorithms will be released some previously acquired data may need to be reprocessed. These reprocessing campaigns will be done at the Reprocessing Centre at Kiruna, Sweden, which will also host the Long-Term Archive and perform distribution of reprocessed data.

The User Services, based at ESRIN, will implement the data request coming from the SMOS user community using the existing Multi-Mission User Services interact with the users in case of problems in the data handling. Another very important function sits with the ESA Post-launch Support Office, which will be responsible for preventive and corrective maintenance of satellite and payload performances. This is the team investigating anomalies and reacting quickly in case non-nominal performances are discovered.

An important group of teams supporting the calibration of the MIRAS data and the development of the retrieval algorithms to derive SMOS Level 2 data for soil moisture and sea-surface salinity are the Expert Support Laboratories

(ESLs), which have already been in place throughout the development phase.

The ESLs are consortia consisting of industrial and scientific groups, and comprise companies such as ACRI in France, ARGANS in UK and ARRAY in Canada, as well as the expertise of the scientific groups (Centre d'Etudes Spatiales de la Biosphère (CESBIO), Institut National de la Recherche Agronomique, Laboratoire d'Océanographie et du Climat: Expérimentations et approches numériques, Institut Français de Recherche pour l'Exploitation de la Mer, Observatoire du Pic du Midi from France, the University of Tor Vergata from Italy, the Institut de Ciències del Mar (ICM) and Universitat Politècnica de Catalunya from Spain, and the UK's University of Reading. These consortia will continue to support the SMOS mission in the operations phase.

In addition, there will be strong national efforts to develop Level 3 (global, single-instrument) and 4 (global, multi-instrument) SMOS data products through the French Centre Aval de Traitement des Données SMOS (CATDS) and the Spanish SMOS Level 3/4 Processing Centre (CP34). As for the ESLs, the CATDS and CP34 will support the SMOS mission by providing their expertise with regard to calibration, processing algorithms, observation modes, image reconstruction for the Level 3 and 4 data products based on the SMOS data provided by the DPGS.

### Calibration and validation of SMOS data

The following SMOS data products will be available:

- Level 1A product: calibrated visibilities between receivers prior to applying image reconstruction.

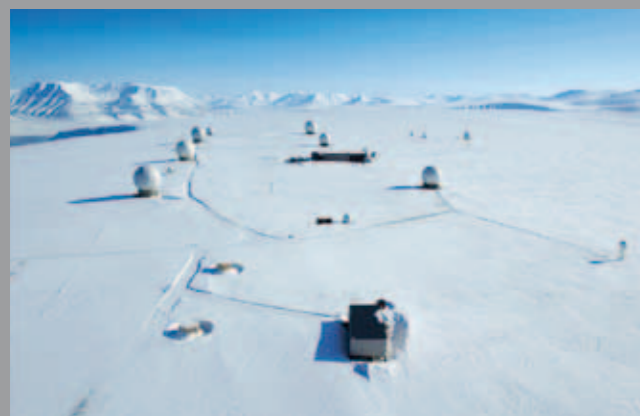
- Level 1B product: output of the image reconstruction of the observations and comprising the Fourier component of the brightness temperature in the antenna polarisation reference frame.

- Level 1C product: multi-angular brightness temperatures at the top of the atmosphere, geolocated in an equal-area grid system. Two different Level 1C products are generated according to the surface type: one containing only sea and the other only containing land pixels. Two sets of information are available: pixel-wise and snapshot-wise. For each Level 1C product there is also a browse product containing brightness temperatures for an incidence angle of 42.5°.

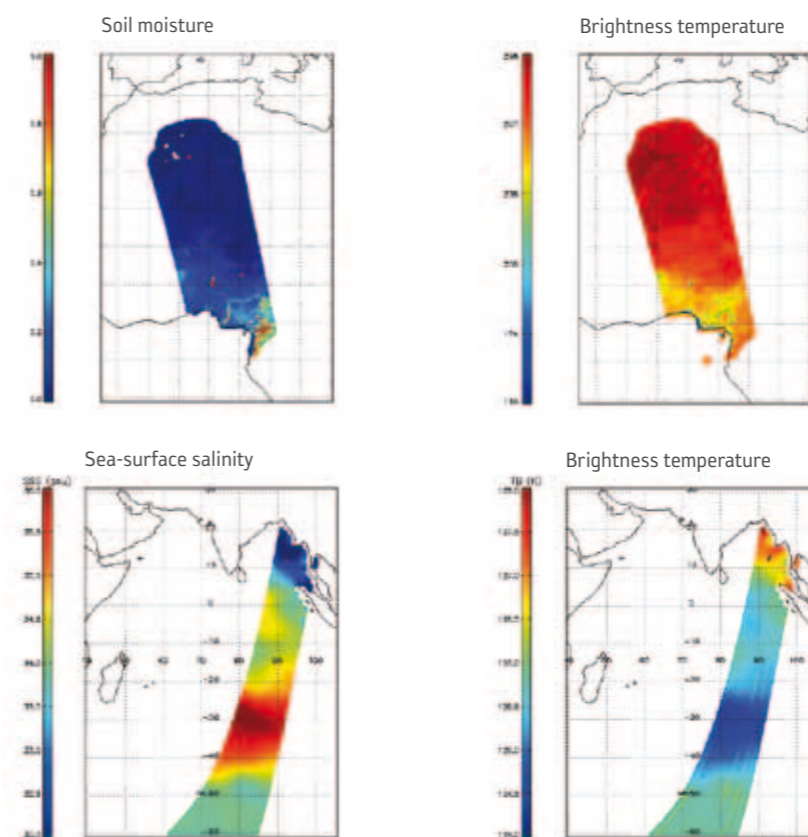
- Level 2 soil moisture product: containing not only the soil moisture retrieved, but also a series of ancillary data derived from the processing (nadir optical thickness, surface temperature, roughness parameter, dielectric constant and brightness temperature retrieved at top of atmosphere and on the surface) with the corresponding uncertainties.

- Level 2 ocean salinity product: containing three different ocean salinity values derived from retrieval algorithms using different assumptions for the surface roughness correction and the brightness temperature retrieved at the top of atmosphere and on the sea surface (with the corresponding uncertainties).

- Near-real time product: similar to the Level 1C product but adjusted to requirements of operational meteorological agencies such as ECMWF and MétéoFrance, available three



(Top) The European Space Astronomy Centre in Spain (Below) The Svalbard ground station, Norway (B.L. Heitmann)



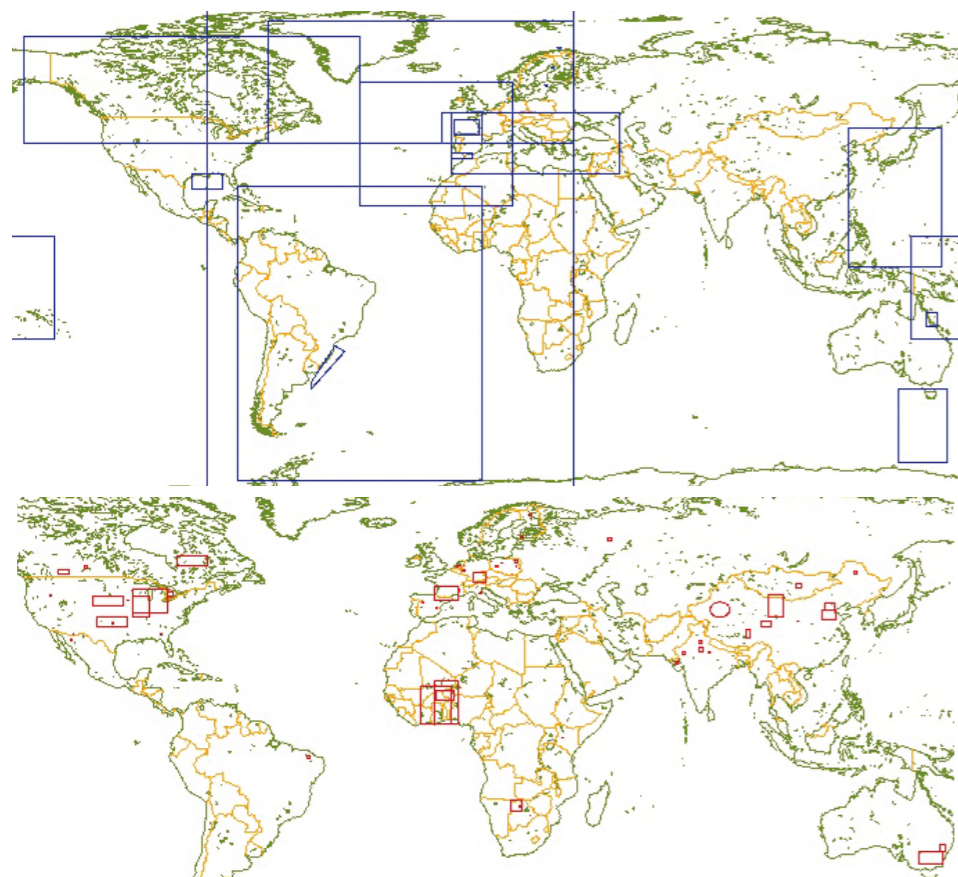
Simulated soil moisture and sea surface salinity data as expected from SMOS



Soil moisture (simulated) retrieved over Africa (left) and corresponding brightness temperature at 42.5° at surface for same overpass (CESBIO)



Sea-surface salinity (simulated) (left) and corresponding brightness temperature at 42.5° at surface for same overpass (ACRI)



Areas of interest for calibration and validation activities over ocean and land as identified by the projects selected in response to the SMOS calibration and validation Announcement of Opportunity in 2005.

hours from sensing. It will contain brightness temperatures at the top of the atmosphere on an ISEA grid with reduced spatial resolution over the ocean.

A major undertaking in any environmental science related satellite mission is the calibration and validation activity. Once the data reach the ground, they need to be checked for quality and whether they can be used for scientific research. Calibration is an important prerequisite to the performance verification, demonstrating that the instrument meets its requirements. It is also important for the validation of geophysical parameters, such as soil moisture and sea surface salinity. The calibration of the MIRAS instrument will include corrections for internal effects, such as temperature variations on the LICEF receivers, as well as external effects, such as direct or reflected sun and moon radiation, galactic glint, etc.

The validation of the data will be handled through a combination of ESA-led activities and national efforts. The SMOS Validation and Retrieval Team (SVRT) comprises the scientific contributions that will be made by the projects selected in response to the SMOS calibration and validation Announcement of Opportunity in 2005, as well as the two Level 2 Expert Support Laboratories involved in the development of the soil moisture and sea-surface salinity data processors. These two consortia are strongly linked and scientifically led by the SMOS Principal Investigator Yann Kerr, from CESBIO, and the Co-Principle Investigator Jordi Font, from ICM.

The step from Level 1C data, being multi-angular brightness temperatures at the top of the atmosphere, to retrieving Level 2 data products (soil moisture and sea-surface

salinity), is a rather significant step involving a lot of scientific knowledge, assumptions and thus also the related uncertainties. The majority of the uncertainties are linked to our limited knowledge of L-band processes over a spatial scale of 50 km and the radiometric sensitivity of the instrument over changing surfaces.

Over land, the retrieval of soil moisture from emitted radiation, expressed in brightness temperatures, has to consider a number of instrument parameters (radiometric sensitivity and accuracy, calibration stability, interferometric image reconstruction), surface characteristics (soil surface roughness and texture, land cover, surface heterogeneity, dew, intercept, snow, topography, litter effect, surface water) and radio frequency interference. Given the large pixel size of SMOS, we will also need to consider the *in situ* sampling strategy in relation to the models that will be needed to generate the validation match-ups.

Over the oceans, the two main issues influencing the retrieval of sea-surface salinity are the radiometric accuracy and the sea-surface state. The absolute sensitivity of the brightness temperature to sea-surface salinity changes is low, also depending on temperature: 0.2K (at 0°C) to 0.8K (at 30°C) per practical salinity unit (psu). So it is more demanding to retrieve sea-surface salinity in colder waters, i.e. at higher latitudes. Furthermore, the low radiometric sensitivity limits the accuracy for salinity estimates from a single pass, which makes temporal and spatial averaging necessary.

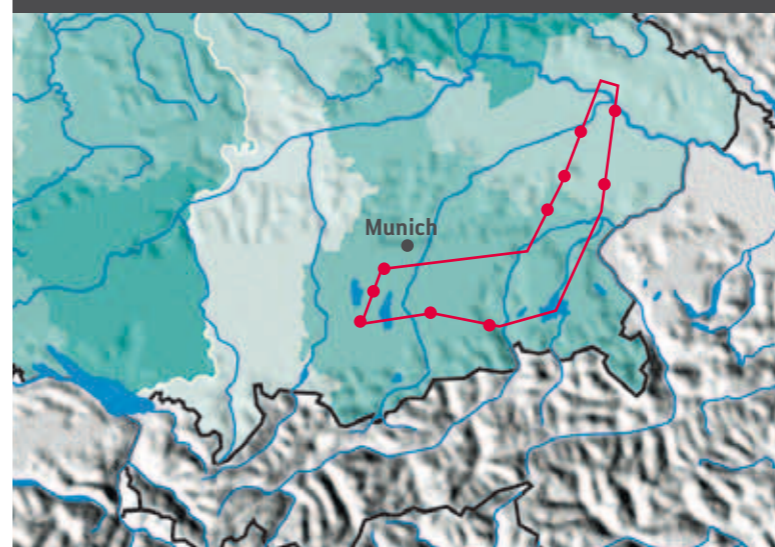
For the validation of the soil moisture data products, ESA's activities will focus on two main sites, the Valencia Anchor Station, in eastern Spain, and the Upper Danube



ESA will focus its efforts for the validation of soil moisture data on two key sites: the Valencia Anchor Station and the Upper Danube Catchment. The Valencia Anchor Station (below) is a typical Mediterranean sparse vegetation ecosystem, mainly characterised by bare soil and limited vegetation. The vegetation consists mainly of vineyards, pine trees and shrub and is thus comparatively uniform with regard to hydrological parameters. The site is well instrumented and has been the location of other field campaigns (Ernesto Lopez, Univ. Valencia)



The Upper Danube Catchment in contrast is a typical temperate continental ecosystem covering an area of 77 000 km<sup>2</sup> in Germany. The map shows overflight track (red) for the SMOS dress rehearsal campaign in spring 2008. Dots are measurement stations (Alexander Loew, Univ. Munich)



Catchment, in southern Germany. In preparation for the SMOS commissioning phase, airborne rehearsal campaigns were conducted in spring 2008 over both these key sites. These will be coupled with an SMOS match-up generation exercise to verify that the methodology proposed actually meets the foreseen performances. Other activities include the deployment of the ground-based ESA-funded ELBARA radiometers, two of which will be dedicated to the characterisation of the ESA soil moisture validation sites, and one will be made available for specific dedicated campaign activities aiming at better understanding open scientific issues that are relevant to the retrieval of soil moisture.

Also, in collaboration with the Portuguese Meteorological Institute in Lisbon, currently hosting the Eumetsat Land-SAF, ESA is supporting the establishment of a soil moisture network data hosting facility in support to the SMOS calibration and validation activities. This facility will interface with the Coordinated Energy and Water Cycle Observations Project (CEOP) and, if possible, with the GEO Prototype for Earth observation data portals.

The validation of sea-surface salinity data products will be a challenging task requiring a highly accurate and stable instrument calibration. At local scales, the foreseen validation activities are focused on a better understanding of the interaction of L-band radiation with the sea surface through dedicated airborne campaigns, whereas validation at global scales will rely on buoy networks and basin-scale ocean models. Close collaboration with the NASA Aquarius team will further contribute to the validation of sea-surface salinity data products measured from space.

### Campaigns

In support of the calibration and validation efforts a variety of campaigns have been (and will be) performed to investigate uncertainties in the soil moisture and sea surface salinity retrieval and the calibration of the SMOS data. The major aspects to investigate with regard to soil moisture are the influence of the various types of vegetation and their seasonal variability, as well as the influence of surface roughness, dew and frost. Over oceans, the impact of sea-surface state on the polarimetric radiometric signal is the main issue. The effects of foam, roughness, temperature, and also sun and galactic glints have to be considered.

### Access to data

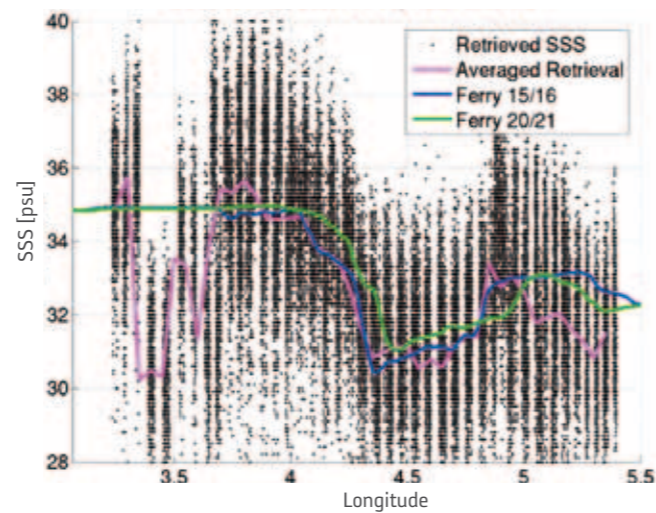
ESA's data policy foresees to make Earth observation data as widely and freely available as possible. Therefore all described data will be made available through the ESA category-1 procedure, either through dedicated Announcements of Opportunities or, for users who have not participated in the past Announcements, a registration service online (<http://eopi.esa.int>). To date, approximately 50 different research groups have indicated their interest in SMOS data, together with about 40 proposals supporting the calibration and validation activities.

SMOS calibration and validation data will be available through <http://calvalportal.ceos.org/CalValPortal/welcome.do>. *In situ* soil moisture data will be made available through the SMOS Soil Moisture Network Data Hosting under

development at the Portuguese Meteorological Institute  
 ESA campaign data are available via the campaign database  
<http://earth.esa.int/campaigns> and through the SMOS Cal/  
 Val portal.



Sea-surface salinity (SSS) retrieved using the L-band radiometer EMIRAD across a salinity gradient in the Norwegian Sea during the Cosmos-2006 airborne campaign. The blue and green curves show data retrieved by ferries crossing from Stavanger to Newcastle in April 2006 (Nicolas Reul, IFREMER)



SMOS Campaigns: ESA campaign data are available via the campaign database <http://earth.esa.int/campaigns> and through the SMOS Cal/Val portal. Most of the SMOS campaign data will be available via the campaign database

<b>WISE 2000/2001</b>	Wind and Salinity Experiment in 2000, at offshore oil drilling platform near Barcelona to provide multi-angular polarimetric brightness temperature under different wind/wave conditions
<b>LOSAC</b>	Ocean salinity airborne campaign in 2001, with L-band radiometer EMIRAD from Technical University of Denmark, several flights with variable wind conditions; discovery of 'wiggles', investigating azimuthal dependence of the two first Stokes parameters
<b>FROG</b>	Foam Rain Oil Slicks and GPS reflections in 2003, measuring L-Band polarimetric emission under controlled (foam and rain) conditions (campaign not funded by ESA)
<b>SMOSREX</b>	Surface Monitoring of the Soil Reservoir Experiment near Toulouse (campaign not funded by ESA)
<b>COSMOS-2006</b>	Airborne campaign in Norway (Norwegian Sea) in 2006 to acquire data under different oceanographic conditions for sea-surface salinity retrieval
<b>SEA-ICE</b>	Airborne campaign in the Gulf of Bothnia (Finland) in March 2007 to acquire L-band measurements over sea ice and test the retrieval of ice types and ice thickness
<b>Demonstrator 2007</b>	Airborne campaign in August 2007 to perform dual-pol measurements and assess absolute accuracy of HUT2D, the interferometric radiometer of Helsinki University of Technology, and demonstrate the retrieval of a sea-surface salinity gradient off the coast of Helsinki
<b>DOMEX</b>	Tower-based radiometric measurements in Antarctica, calibration of brightness temperature over the Dome Concordia area
<b>EUROSTARRS 2001</b>	US Salinity Temperature and Roughness Remote Scanner (STARRS) was exploited during airborne campaign over France and Spain in 2001 providing airborne L-band observations over large areas
<b>COSMOS-2005</b>	Airborne campaign in cooperation with the Australian's National Airborne Field Experiment (NAFE 05) at the Goulburn River Catchment in November 2005; site extensively monitored and studied for soil moisture
<b>Validation Rehearsal</b>	Airborne campaign in April 2008 over the key soil moisture validation sites of SMOS, in Germany and Spain



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