

→ ESA'S WATER MISSION

smos newsletter

Issue 5 | July 2013



SMOS satellite
launched on 2 November 2009

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Highlights

SMOS Level 2 sea surface salinity "catch-up" reprocessing completed

The first SMOS Level 2 sea surface salinity "catch-up" reprocessing campaign has been completed and the data set covering the period from 22 December 2011 to 31 December 2012 has been released to the SMOS user community. With the release of this data set the SMOS users now have a consistent dataset of sea surface salinity measurements from the beginning of the SMOS mission in January 2010 until December 2012 (REPR data type). For further information on this reprocessing campaign and how to access the data please see the published news on the ESA SMOS web portal:

<https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/smos/news/-/article/smos-level-2-sea-surface-salinity-catch-up-reprocessing-completed>.

The **SMOS-AQUARIUS science workshop** took place on 15-17 April at IFREMER (France). The workshop was jointly organised between ESA, NASA and IFREMER, with support from CNES and the EC's COST action SMOS-MODE. More than 120 scientists from research institutes worldwide attended the

workshop, with more than 80 contributions being submitted. Presentations and a summary/recommendations are available on <http://www.smosaquarius2013.org/>.

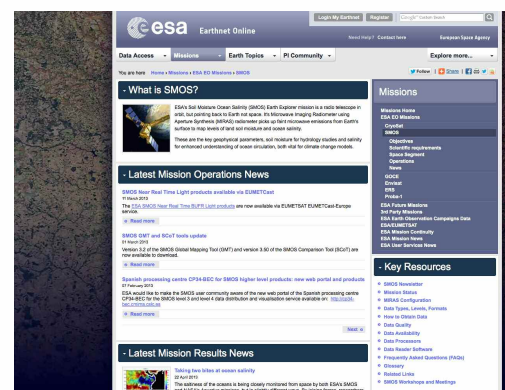
SMOS Level 2 soil moisture "catch-up" reprocessing is on-going

The reprocessed soil moisture dataset currently available was generated using the L2 soil moisture processor V5.01 which uses a different geophysical forward model to that used in V5.51 which has been deployed in the operational chain since April 2012; the former uses the dielectric constant formulation by Dobson and the latter, Mironov. This results in differences in the retrieved soil moisture data product. To provide a consistent and homogeneous dataset since the start of the SMOS mission, ESA is reprocessing data covering the period from January 2010 up to April 2012 with version 5.51 of the Level 2 soil moisture processor. This "catch-up" dataset will be available to the users by August 2013. The delivery of this dataset will be announced via the ESA SMOS web portal news page and throughout the SMOS data dissemination mailing list.

The ESA SMOS web portal provides a comprehensive access point for all SMOS related information. Users are encouraged to visit the SMOS portal for announcements, updates on ground segment operations and scientific mission achievements. Recent SMOS newsletters are available on the ESA web portal:

<https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/smos/newsletter>.

Stay up-to-date with the ESA SMOS web portal <http://earth.esa.int/SMOS>



SMOS sea ice thickness data: preliminary evaluation release

Although not originally designed for looking at sea ice, SMOS data are being evaluated to monitor Arctic sea ice thickness. The ice thickness data product is derived from level 3 brightness temperatures as generated at the University of Hamburg by the Center for Marine and Atmospheric Sciences (ZMAW). The dataset is now accessible for preliminary evaluation by the science community on the ftp server:

ftp://ftp-projects.zmaw.de/seaice/SMOS/PRELIMINARY_EVALUATION_RELEASE_JUNE_2013/.

The users should carefully read the information provided on the ftp server in the README.txt before using the data. Feedback and comments on this dataset can be provided directly to the ZMAW development team (email address available on the README.txt file on the ftp web server).

Special section in the Journal of Geophysical Research (Oceans): call for papers now open

The call for papers for a special section entitled Early scientific results from the salinity measuring satellites Aquarius/SAC-D and SMOS, is now open and accessible on the Wiley Online website:

http://onlinelibrary.wiley.com/journal/10.1002/%28ISSN%292169-9291/homepage/call_for_papers.htm.

The submission window will be open for six months and close on 31 December, 2013.

New information and tools available on line

A NetCDF converter for SMOS data is available on the SMOS ESA web portal. The SMOS NetCDF conversion tool is implemented as a Graph Processing Tool (GPT) operator and integrated into the BEAM framework. It can either be accessed from within the VISAT Graphic User Interface or be used as a GPT-

Operator for batch-processing using the command line. The SMOS NetCDF conversion tool converts SMOS L1C and L2 data products in Earth Explorer format into NetCDF-4. For more information and to download the tool see: <https://earth.esa.int/web/guest/-/data-reader-software-7633>.

Using G-POD for processing SMOS data: reminder for call for proposals

ESA would like to remind the SMOS user community of the availability of the Grid Processing-on-Demand (G-POD) service [<http://gpod.eo.esa.int>] for conducting Earth Science research activities. G-POD is offered by ESA's Research and Service Support [http://wiki.services.eoportal.org/tiki-custom_home.php].

G-POD SMOS proposals need to be submitted directly onto the following Web site: <http://eopi.esa.int/G-POD>. This is an open call, i.e. proposals can be submitted at any time.

Data and Processors

Data availability

The SMOS instrument – MIRAS – is operating nominally with the exception of some well-known on-board anomalies [see description of anomalies https://earth.esa.int/c/document_library/get_file?folderId=118493&name=DLFE-5407.pdf]. The cumulative data loss due to instrument unavailability since the beginning of the routine operations phase in May 2010 amounts to 0.11% and the degraded data amounts to 1.42%. A detailed list of instrument anomalies is compiled on a weekly basis and is available on https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/smos/content?p_r_p_564233524_assetIdentifier=mission-status-7060.

No data loss has occurred during the acquisition of MIRAS raw data at the ground stations since the beginning of the routine operations phase in May 2010. This result has been achieved by implementing an on-board data recording overlap strategy.

Instrument Calibration

Several calibration activities are regularly performed on board and an overview on the calibration strategy implemented for the MIRAS instrument can be found on:

https://earth.esa.int/c/document_library/get_file?folderId=118493&name=DLFE-1732.pdf.

During calibration activities, science data are not available hence data users should consult the calibration plan available on:

<https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/smos/available->

[data-processing](#) for data availability.

Since the issue of newsletter #5, calibration activities were performed in accordance with the routine calibration plan and calibration results are within the nominal range. The last Flat Target Response (FTR) acquired in June 2013 does not show any significant deviation from the one used in the Level 1 ground processor (acquired in summer 2011) and therefore no update of the FTR has been implemented in the ground processor.

On 5 March 2013, an on board calibration activity beyond the nominal calibration plan has been executed. The calibration involved the commanding of the MIRAS instrument into internal calibration mode and hence caused some data unavailability. Precise information on the timing of this calibration is available in the SMOS Quality Report of March 2013 [https://earth.esa.int/documents/10174/402425/SMOS_Public_Monthly_Rep_March2013_v1_signed.pdf/e521282e-6776-43dd-9aa7-1833816adf2a?version=1.0]. The data acquired during this calibration exercise has been used to monitor the in-orbit front end Noise Injection Radiometer (NIR) antenna losses.

The evolution of the calibration parameters since the beginning of the mission is available in the SMOS quality reports accessible on the following web page:

<https://earth.esa.int/web/guest/-/data-quality-7059>.

Data quality

A monthly report summarising significant events in the SMOS flight and ground segment and the SMOS data quality status can be found on:

<https://earth.esa.int/web/guest/-/data-quality-7059>.

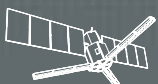
Since the issue of newsletter #5, no new anomaly has been identified in the level 1 and level 2 data generated by the Data Processing Ground Segment.

For the Near Real Time data (NRT) on 10 May 2013 a change in the internal configuration of the NRT processor has been implemented to remove the generation of corrupted snapshots containing brightness temperatures with very large negative values or values outside the expected natural variability as reported in the previous newsletter #4.

Figure-1 and -2 show global maps of minimum brightness temperatures before (November 2012) and after (June 2013) the reconfiguration of the NRT processor (v5.05).

The NRT production is constantly monitored and no reoccurrence of this problem has been detected since the reconfiguration.

For further details on the SMOS data quality, please see the product quality disclaimer section in the latest monthly report available on: <https://earth.esa.int/web/guest/-/data-quality-7059>.



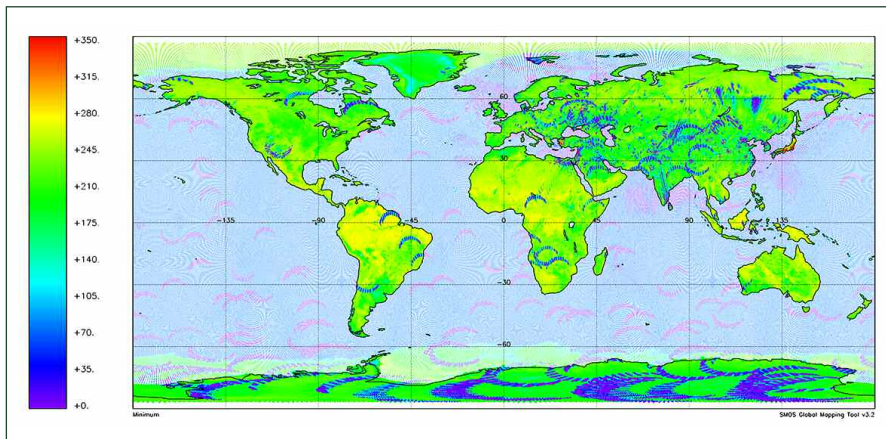


Figure 1: NRT brightness temperatures in X-polarization in the antenna frame for November 2012. The map shows the minimum value of the brightness temperature. The areas affected by the corrupted snapshots are the semi-circle areas with the lowest (dark blue over land) or negative values (violet over the sea) for the brightness temperature. The remaining areas with lowest, highest or negative values for the brightness temperature are affected by RFI contamination.

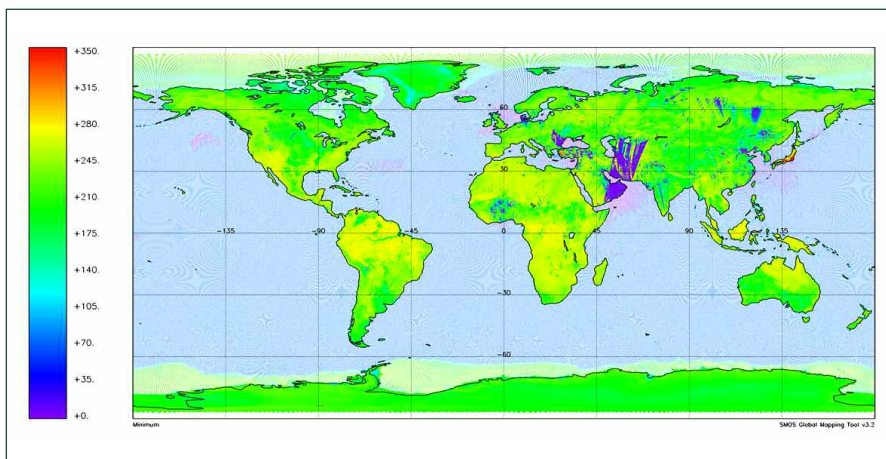


Figure 2: NRT brightness temperatures in X-polarization in the antenna frame for June 2013 after the NRT reconfiguration. The map shows the minimum value of the brightness temperature. In the figure, the areas with lowest, highest or negative values for the brightness temperature are only affected by RFI contamination.

Updates on operational processors

The current versions of the operational processors installed in the SMOS ground segment are:

from the reconfiguration of NRTP v5.05. Therefore, the algorithm baseline and data quality are as reported for the SMOS newsletter #3 issued in October 2012.

Level 2 Ocean Salinity: No change has been implemented in the Level 2 Ocean Salinity processor during the period October 2012 – July 2013. Therefore, the algorithm baseline and data quality are as reported for the SMOS newsletter #3 issued in October 2012.

Processor	Current version	In operations since
Level 1A	V5.04	14 November 2011
Level 1B	V5.04	14 November 2011
Level 1C	V5.05	21 March 2012
Near Real Time processor (NRTP)	V5.05	7 March 2012
Level 2 soil moisture	V5.51	24 April 2012
Level 2 ocean salinity	V5.50	15 December 2011

Further information on the SMOS data quality can be found in the products read-me-first notes available on the web page: https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/smos/content?p_r_p_564233524_assetIdentifier=data-processors-7632. The SMOS data users are invited to consult the read-me-first note before using the SMOS data for their research activities.

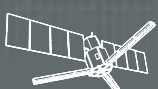
Below are further details on the current versions of the operational processors:

Level 1 NRTP: No new version has been implemented in the Level 1 processor during the period October 2012 – July 2013, apart

Level 2 Soil Moisture: No change has been implemented in the Level 2 Soil Moisture processor during the period October 2012 – July 2013. Therefore, the algorithm baseline and data quality are as reported for the SMOS newsletter #3 issued in October 2012.

Radio Frequency Interference (RFI)

Illegal RFI sources operating in the L-band adversely affect the SMOS measurements, making SMOS data products largely unusable for scientific applications when they are present. Users can check whether data are corrupted by RFI by using the quality flags, available in the SMOS data products, as



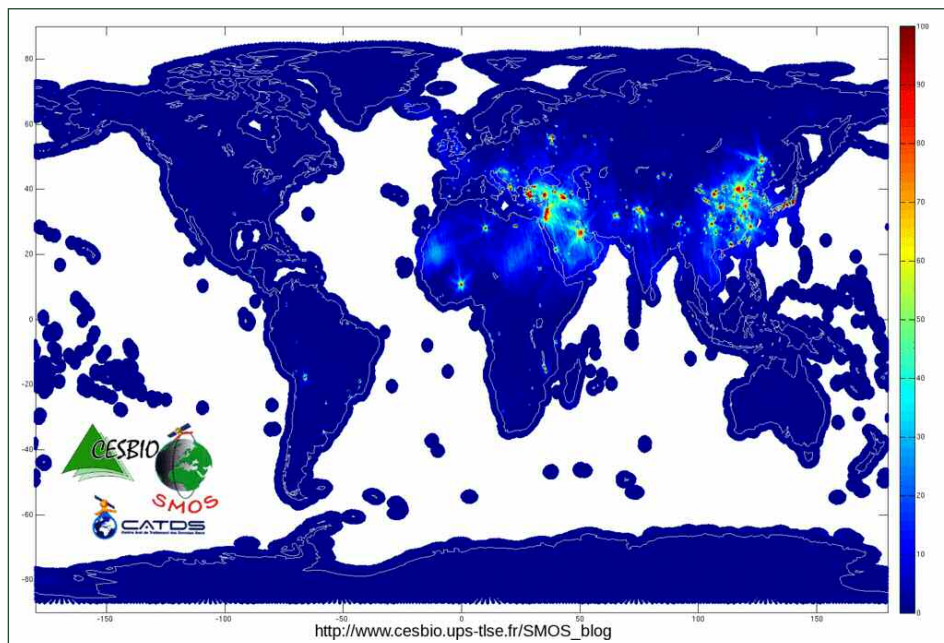


Figure 3: Probability of sustained RFI occurrences during the period 14 June – 27 June 2013 for ascending passes.

indicators. A detailed description of these flags was included in the SMOS newsletter #1 issued in May 2012. Additional information with regard to RFI contamination can be found on the RFI probability maps, generated fortnightly by CESBIO and available on the SMOS blog [http://www.cesbio.ups-tlse.fr/SMOS_blog/smos_rfi/].

The figure below shows an example of the map generated for the period centred on 20 June 2013. Thus the user can visually inspect the map to identify areas with strong RFI presence over land.

The 3rd and 4th Stokes parameter can also be used to detect RFI. Nominal values for the 3rd and 4th Stokes parameters are expected to be very small for natural targets at L-band. Hence a larger deviation in the 3rd and 4th Stokes parameter, i.e. beyond a few Kelvin, would indicate the presence of RFI. The figure-4 below shows an example of the weekly map of the 4th Stokes parameter for the week of 26 May – 3 June 2013. The map identifies the presence of a strong RFI over the North Pacific ocean occurred on 30 May 2013. The user can visually inspect the map to identify areas with possible RFI presence

over Sea (i.e. third and fourth Stokes parameters above 10 K in absolute value). Weekly maps of 3rd and 4th Stokes parameter are presented in the SMOS Monthly QC Report available on the following web page: <https://earth.esa.int/web/guest/-/data-quality-7059>.

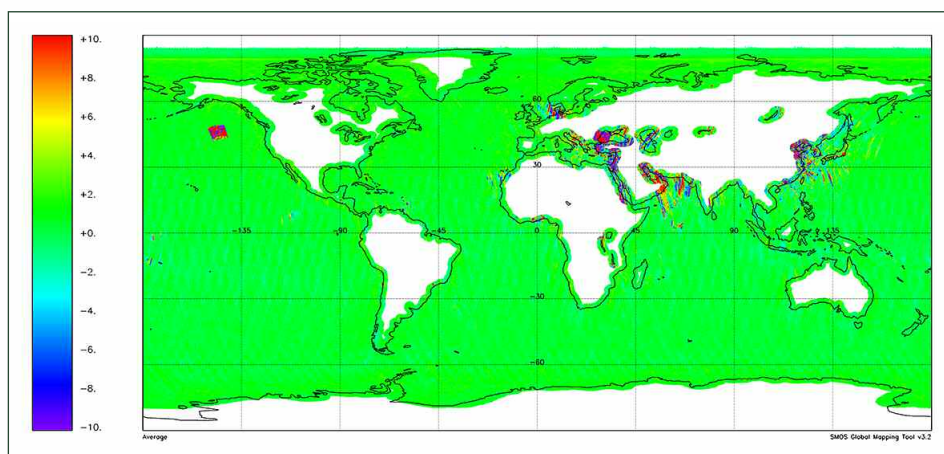


Figure 4: Weekly average of the 4th Stokes parameter over the Ocean during the period 26 May – 3 June 2013. Areas affected by strong RFI show a 4th Stokes parameter above 10K in absolute value as shown in the map for the North Pacific area.



■ Upcoming Meetings

SMOS sessions at IGARSS, 21-26 July, Melbourne, Australia.

Dedicated sessions on SMOS results over land and ocean have been organised for the IGARSS conference in 2013, see www.igarss2013.org for further details.

ESA Living Planet Symposium 9-13 September 2013, Edinburgh, UK

The ESA Living Planet Symposium 2013 will be held in Edinburgh, United Kingdom from 9 to 13 September 2013 and it is organised with the support of the UK Space Agency.

SMOS data users are invited to present and discuss their results on the on-going science activities. A detailed description of the programme and the organization is available here: <http://lp2013.congrexprojects.com>.

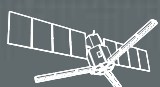
■ Data Access

If you wish to access science data please see the following link for the procedure to follow: [https://earth.esa.int/web/guest/missions/esa-operational-ee-missions/smos/content?p_r_p_564233524_assetIdentifier=how-to-obtain-data-7329].

If you wish to access SMOS Near Real Time (NRT) "Light" (BUFR) products via EUMETSAT's EUMETCast service (by a standard Digital Video Broadcast technology to acquire data over the European region) see <http://www.eumetsat.int/Home/Main/DataAccess/EUMETCast/index.htm?l=en>

SMOS registered users will be granted access to the service after registration on the EUMETSAT Earth Observation Portal: <https://eoportal.eumetsat.int/userMgmt/>

If you wish to access near-real time data "Full" (BUFR) or "Light" (BUFR) product by network over the entire Earth region, please send an email to Susanne.Mecklenburg@esa.int.



→ SMOS OVER LAND

New applications for ESA's water mission



New data products provided by SMOS
have been opening the door for novel
applications (Image - MetroTiff)



→ SMOS OVER LAND

New applications for ESA's water mission

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Yann Kerr

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After three years in space, the number and variety of applications of ESA's water mission SMOS have exceeded expectations. Novel data products have been opening the door for new application areas.

Launched in 2009, SMOS, standing for Soil Moisture and Ocean Salinity, is observing key elements of Earth's water cycle. SMOS is the second Earth Explorer Opportunity mission to be developed as part of ESA's Living Planet Programme. Designed to operate for three years in orbit, SMOS is in very good shape technically at the end of its nominal mission lifetime and is thus able to continue to provide data beyond 2012.

One of its main features is a pioneering instrument called MIRAS, the first synthetic aperture L-band radiometer ever operated from space. This instrument works on the same principle as an array of astronomical radio telescopes – but it points back to Earth, not out into space. It features 69 separate radiometer receivers assembled on three arms in a Y-shaped configuration. As well as demonstrating the use of this new instrument, the data acquired from this mission will contribute to furthering our knowledge of Earth's water cycle.

Soil moisture and sea-surface salinity are two variables in Earth's water cycle that scientists need on a global scale for a variety of applications, such as oceanographic,

The SMOS satellite with the Y-shaped antenna arms of the MIRAS instrument (ESA/AOES Medialab)



meteorological and hydrological forecasting, as well as research into climate change.

Moisture and salinity decrease the 'emissivity' of soil and seawater respectively, and thereby affect microwave radiation emitted from Earth's surface. To observe soil moisture over Earth's landmasses and salinity over

the oceans, SMOS effectively measures the microwave radiation emitted from Earth's surface. MIRAS picks up faint microwave emissions to map levels of moisture in the ground and the saltiness of the oceans, and these are provided as 2D images, or 'snapshots', of 'brightness temperature'. SMOS makes these measurements in the L-band (electromagnetic waves with a wavelength of 21 cm)



The enthusiasm in the corresponding scientific communities with the number and variety of applications has clearly exceeded our expectations.





because it is particularly well suited for observing the ocean and land surfaces.

Measurements made in this band are hardly affected by the atmosphere and clouds, and even vegetation looks transparent over large regions of the world. Because this radiation partly originates from inside the water and the soil, the properties of the top layers can be determined down to a depth of several centimetres.

SMOS is also the first ESA Earth Explorer mission with a dedicated near-real-time processing chain for its brightness temperature observations in its operational ground segment. This means that the observations have to be delivered to

the end user within 180 minutes of sensing. This fast data processing is a prerequisite for many users who produce forecasts, such as weather centres and hydrological agencies.

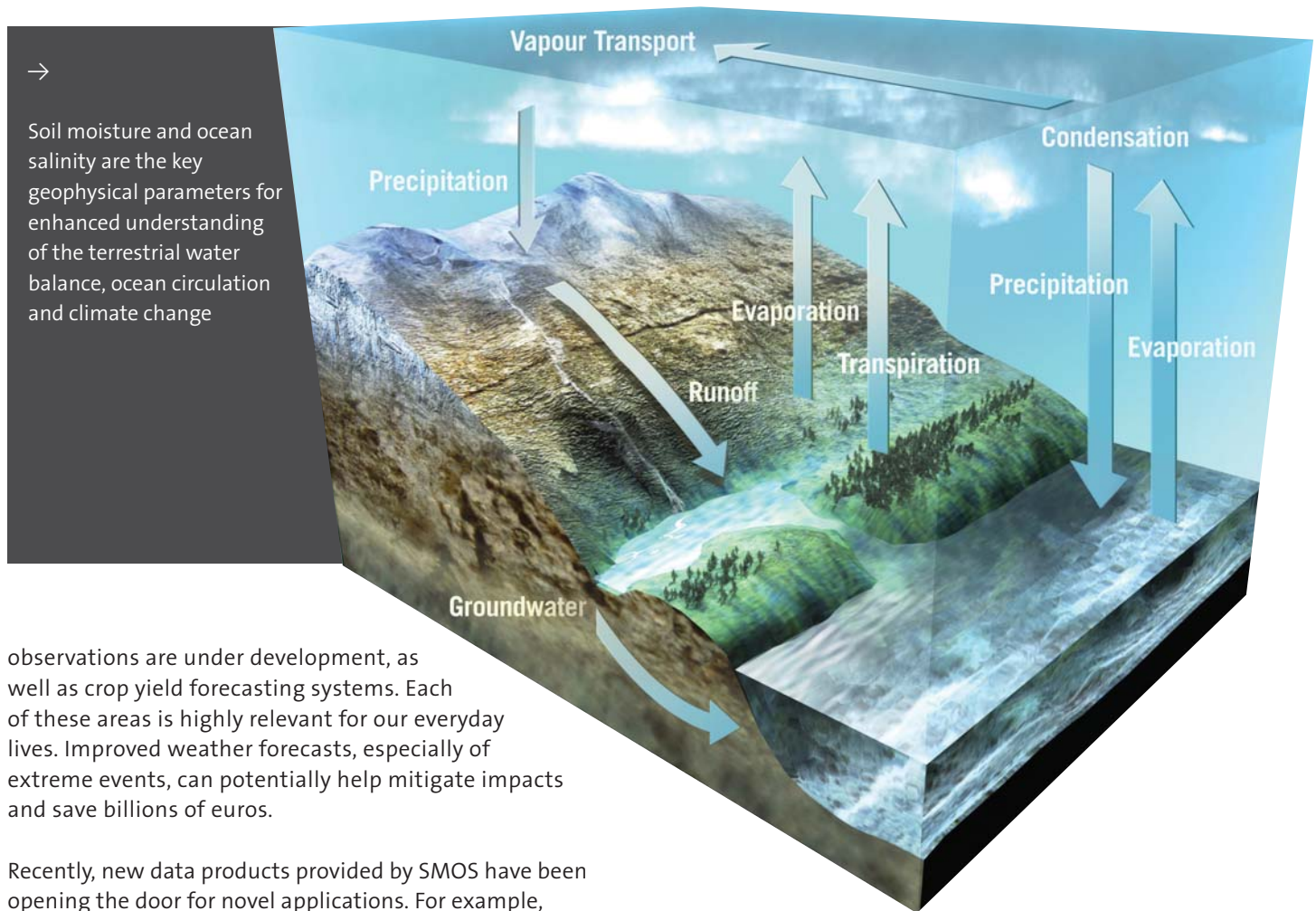
To date, SMOS is performing very well according to its system requirements for the satellite and the ground segment. The derived Level 2 soil moisture datasets meet the mission requirements and have been widely used by the science community.

However, a measure of success for an Earth Explorer satellite mission could also be its potential impact for operational applications and on its added socio-economic value.

SMOS data are currently being used in weather and flood forecasting. Drought monitoring systems based on SMOS



Soil moisture and ocean salinity are the key geophysical parameters for enhanced understanding of the terrestrial water balance, ocean circulation and climate change



observations are under development, as well as crop yield forecasting systems. Each of these areas is highly relevant for our everyday lives. Improved weather forecasts, especially of extreme events, can potentially help mitigate impacts and save billions of euros.

Recently, new data products provided by SMOS have been opening the door for novel applications. For example, it was found that the freeze-thaw cycle of soils can be determined, and this could result in the improved monitoring of the active surface layer in permafrost regions and a more accurate description of the gas exchange between land surfaces and the atmosphere, which is highly relevant for our climate system.

Applications

Soil moisture is a key variable determining the exchange of water and energy between the land surface and the atmosphere. SMOS soil moisture data have their own scientific value, because they provide an independent estimate of the current state of the land surface. Monitoring the spatial and temporal global dynamics of soil moisture is important for a variety of applications, such

as water resources management, weather forecasting, agriculture, flood prediction and climate research. An additional socio-economic value of these Earth observation data comes from their use in forecasting systems and the subsequent decision-making process.

To reduce forecasting uncertainty, satellite observations can be used in data assimilation systems to improve the accuracy of the initial conditions. For our daily weather forecasts, out to a few days ahead, soil moisture mainly influences the development of air temperature and humidity in the lower atmosphere. Locally, convection, the formation of clouds and subsequent precipitation events, can be modified or triggered by the amount of water in the soil and its availability for the atmosphere as well.



Improved weather forecasts, especially of extreme events, can potentially help mitigate impacts and save billions of euros.





↑ The drought-stricken Debar Lake, 150 km west of Skopje in Macedonia. The western Balkans have been hit by an ongoing heat wave this September that has seen temperatures over 42°C, triggering hundreds of wildfires (Miller and Farmer Assoc.)

Early studies by ECMWF indicated that the use of satellite-derived soil moisture estimates reduces the errors in the temperature and humidity forecasts and influences a variety of weather parameters.

Soil moisture also plays an important role in long-range forecasts, such as in monthly and seasonal weather prediction. For example, it could be shown that the 2003 heatwave in Europe followed a very dry spring. Low soil moisture contents over large parts in Europe influenced the onset and the duration of this very extreme event, which led to the deaths of over 30 000 people and damage costing an estimated €11 billion in the farming, livestock and forestry industries alone. Using SMOS data in seasonal forecasting systems will be addressed in a future scientific study starting in 2013.

The dynamics of surface soil moisture are an important source of uncertainty in flood forecasting models as well. Floods, as a consequence of too much water runoff, can be generated through saturation excess overland flow and infiltration excess overland flow. In the first case, soil moisture determines how much water can be stored in the soil before runoff and flooding starts. In the second case, soil moisture determines the infiltration capacity and the moment when runoff starts. Knowing the soil moisture distribution before an expected heavy rainfall event will in both cases help to determine whether the water reaching the land surface can infiltrate and be stored in the soil or will cause flooding.

Combining information on storm tracks, the corresponding precipitation forecasts and SMOS soil

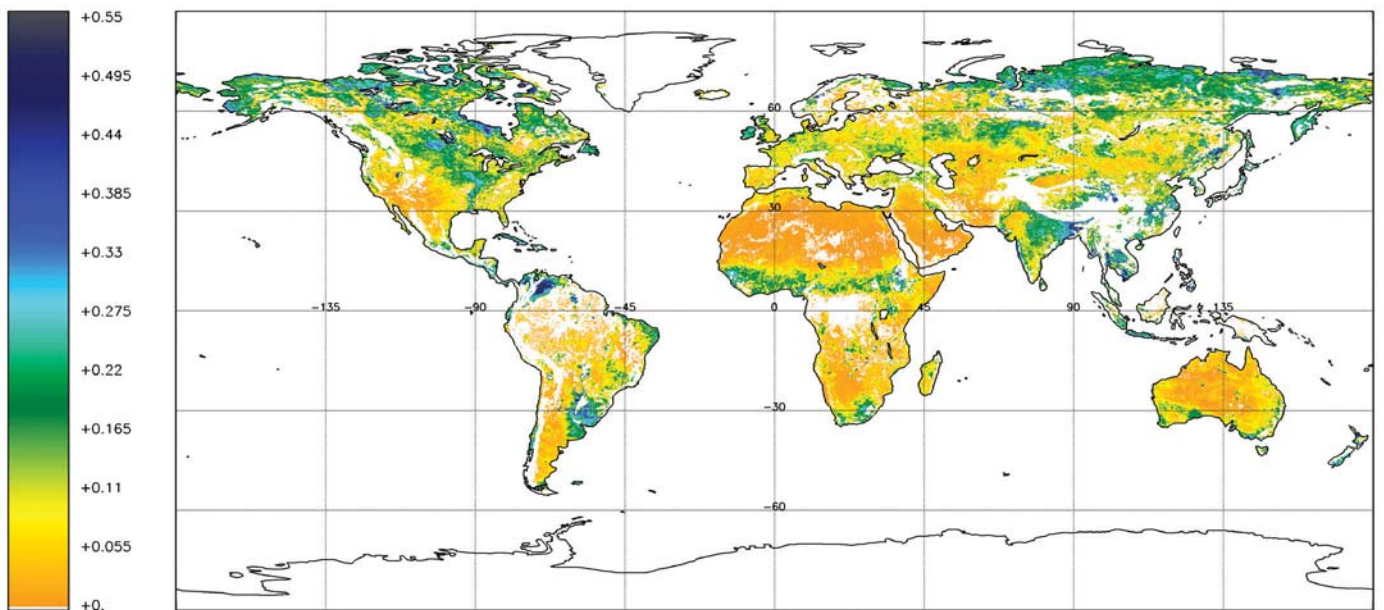


↑ Roofs of houses are visible above flood waters in Brisbane, Australia, during disastrous floods in early 2011 (Reuters/T. Wimborne)

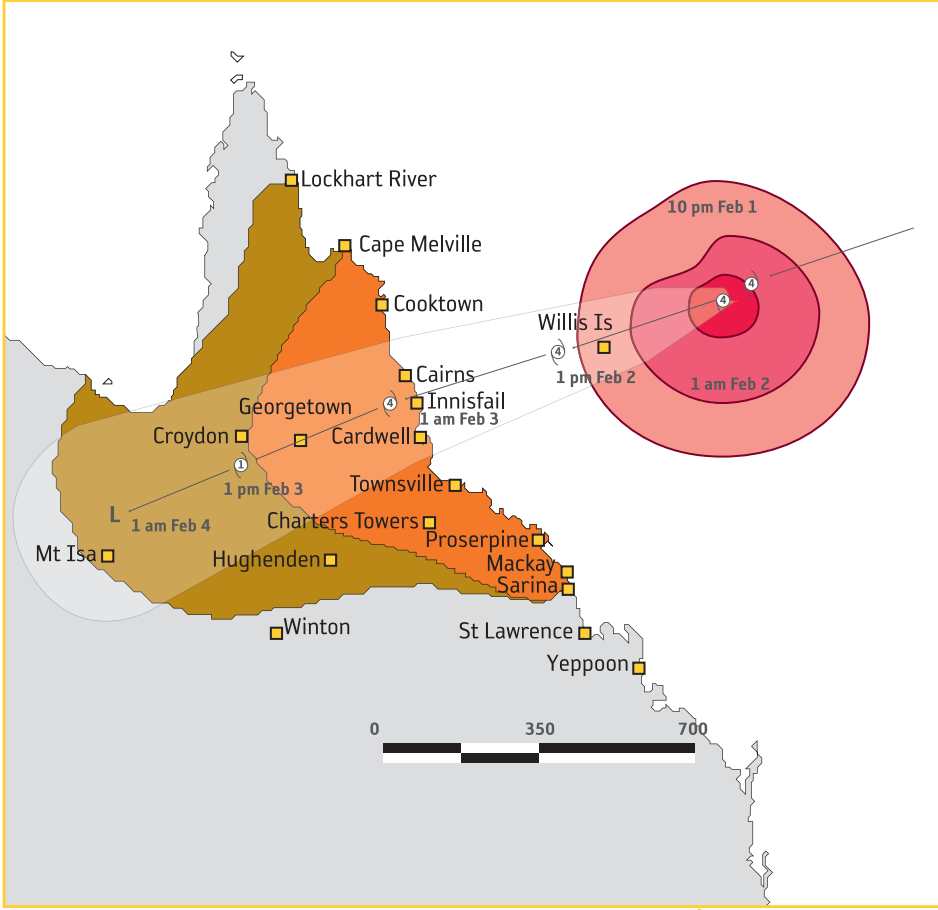
moisture maps can give us flood risk maps, which can be used to mitigate the effects of extreme weather events. The concept was demonstrated using data over Australia's east coast in 2011 and which is being further developed by an international consortium through the 'SMOS +

Hydrology' study within ESA's Support to Science Element (STSE) programme.

The growth of vegetation is intrinsically dependent on the amount of plant-available soil moisture for photosynthesis

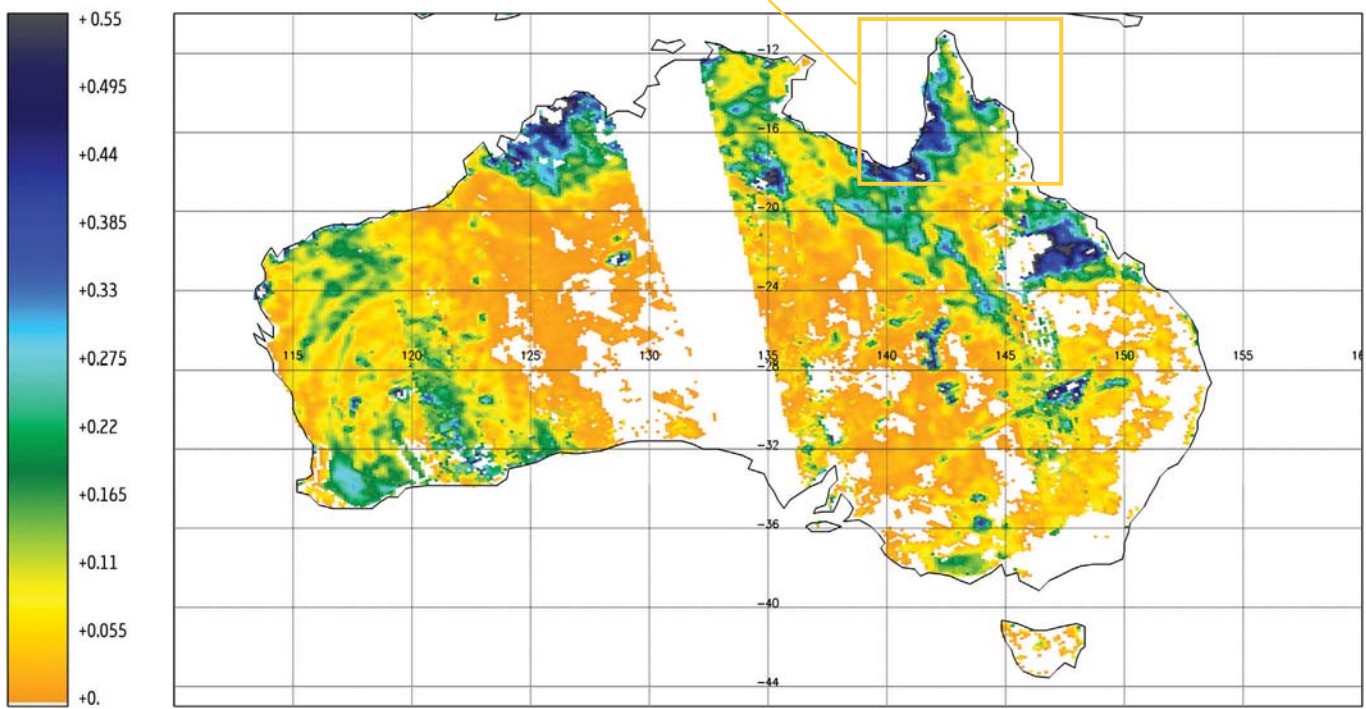


↑ Global surface soil moisture fields for June 2011, with moisture in m^3/m^3 (CESBIO/Y. Kerr)



←

The forecast storm track issued by the Bureau of Meteorology shows that the centre of the storm was expected to hit the coast on 3 February with heavy rainfall. By combining information from the weather forecast and the soil moisture state from SMOS, the risk of severe flooding could be assessed. Here, the risk was assumed to be low because the rain from this storm could be largely absorbed by the relatively dry soil. If the storm had hit the coast further south, where the soil was already saturated, the risk of severe flooding would have been high



↑ SMOS-derived soil moisture conditions in Australia for 29–31 January 2011, just before a tropical storm system hit the northeast coast, with moisture in m^3/m^3 (CESBIO/Y. Kerr)

→ How do we verify SMOS data?

Brightness temperature data

The key data produced for the user communities are geolocated 'brightness temperatures' for the individual orbits of the satellite. Radiative transfer calculations are needed to extract the information on geophysical parameters, such as surface soil moisture, vegetation opacity or soil frost depth.

Three brightness temperature (Level 1) data streams have been implemented in the ground segment: (1) a near-real time product providing operational power users (such as the European Centre for Medium-range Weather Forecasts, ECMWF) with global observations within three hours of sensing, (2) a near-realtime 'light' product with a reduced spatial coverage over land areas for hydrological applications, and (3) the nominal Level 1C product received by the user within 12 to 48 hours.

Data products have been made available to users operationally since the end of the SMOS commissioning phase in May 2010 and the payload data ground segment is performing to expectations.

Verification and quality control

Verifying these top-of-the-atmosphere brightness temperature observations and assessing the products' accuracy is extremely difficult and is done independently from the in-orbit instrument calibration.

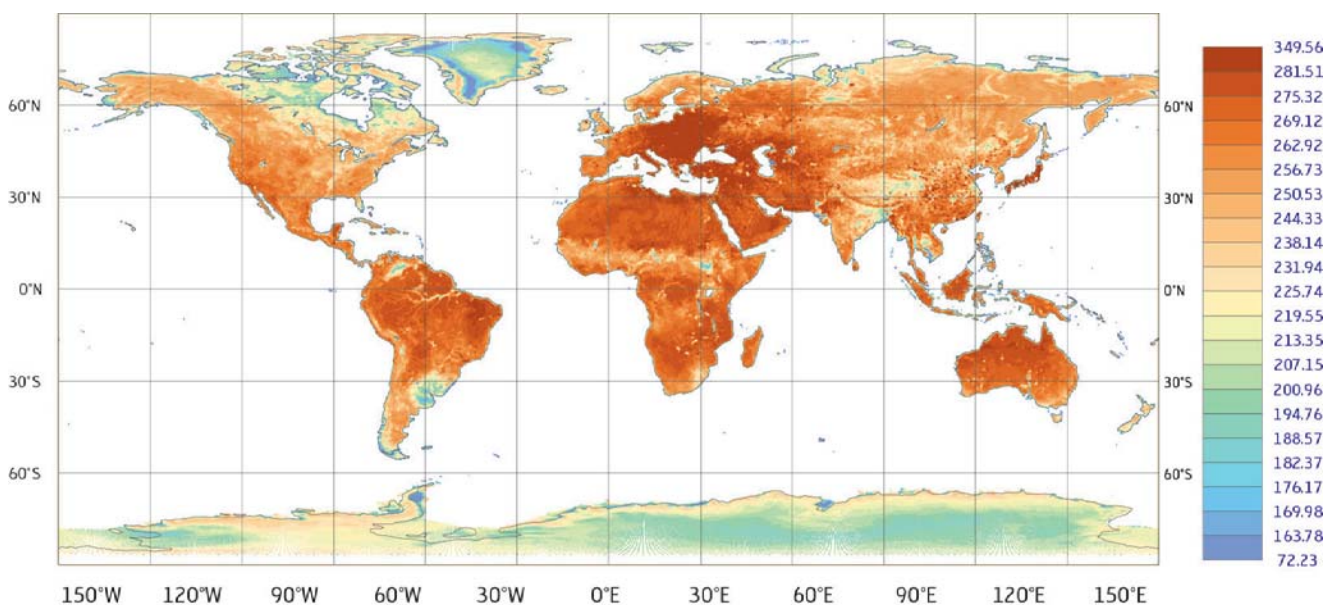
An external homogeneous target is needed, one that is large enough to represent an individual observation of about 2500 km², and with dielectric properties that hardly vary with time. This target should also be well positioned with respect to the instrument's observation geometry to ensure systematic and frequent revisits.

One such area that fits these requirements is the East Antarctic Plateau, specifically the area near the Italian/French base of Concordia. This site is particularly well suited for Level 1 product verification because the extinction of radiation of dry snow is low, the upper ice sheet layer is almost transparent for low-frequency microwave observations and the observed signal mainly originates from the thermally stable deep ice layers.

For the evaluation of the satellite data, a radiometer operating at the same frequency was installed on a tower at Concordia and operated from 2008 to 2010. Both instruments, the tower-based radiometer and the SMOS MIRAS, provided data for a direct comparison. Time-series indicate an excellent agreement between the satellite observations and the ground truth.

However, operating a ground-based radiometer over Antarctica is expensive and only feasible for limited periods when there are dedicated campaigns. The ECMWF is performing day-to-day quality control of the brightness temperature observations

↓ Mean SMOS brightness temperatures in Kelvin for September to October 2012 as monitored by ECMWF (www.ecmwf.int/products/forecasts/d/charts)





↑ A view of the tower-based radiometer RadomeX and ice-sheet area at Concordia Station (G. Macelloni/IFAC-CNR)

within their data-monitoring framework. Together with more than 100 million observations per day delivered from satellites, aircrafts, ships, buoys, radiosondes and weather stations, the SMOS observations are compared against modelled brightness temperatures based on the daily weather forecast.

Although this approach does not allow an absolute validation of the SMOS product, trends, jumps and spikes

in the satellite observations can be detected against a stable reference, meaning statistics derived from the global forecast fields. In addition, the ECMWF monitoring allows a comparison against similar satellite data, for example from the Special Sensor Microwave/Imager. More than 600 images are produced each day and published for public access through the ECMWF web site for the SMOS quality control only.

and the assimilation of carbon. When soil moisture becomes a limiting factor for these processes, information on this anomaly can provide a leading signal for subsequent problems in vegetative health and a shortfall in plant productivity. Consequently, soil moisture information is commonly used in operational drought forecasting activities. For example, the US Department of Agriculture's Foreign Agricultural Service predicts end-of-season

global crop yields for commodity crops. The accuracy of these forecasts is partly limited by the quality of rainfall accumulation data used in the model to predict soil moisture in the plant's root zone. With the data derived from the SMOS mission we should see a significant expansion in our ability to forecast ecosystem productivity and/or agricultural yields by using remotely sensed soil moisture information directly.

Level 2 soil moisture and verification

A radiative transfer model is used to compute multi-angular brightness temperatures based on a set of 'first guess' geophysical parameters including surface soil moisture. These model values are compared against the observations, using the sum of the squared weighted differences in the so-called 'cost function'. Finding the optimal soil moisture value then minimises the differences. The resulting Level 2 product is volumetric soil moisture representing the top centimetres of the soil on a swath-by-swath basis. From these data, higher-level products can be calculated, for example maps showing the daily distribution of soil moisture or monthly averages.

Verifying these soil moisture products is again a challenge. There are many different ways of taking *in situ* measurements. Soil moisture can be determined by first weighing a soil sample, oven drying it at 105°C and then reweighing it. Knowing the density of water and the sample's volume the loss in mass can be easily transformed into volumetric water content. Other methods comprise electrical resistance blocks, neutron moisture meters, and capacitance and time-domain reflectometry. However, taking and collecting these measurements is time-consuming and costly. In addition, these point measurements do not necessarily support the coarse resolution satellite observations due to the heterogeneity of the soil and the vegetation cover.

In order to collect, quality control and harmonise the local and regional soil moisture data sets, the Technical University of Vienna and ESA established the International Soil Moisture Network (ISMN). The Global Energy and Water Cycle Experiment (GEWEX) coordinate this international initiative in cooperation with the Group of Earth Observation (GEO) and the Committee on Earth Observation Satellites (CEOS). As of now, observations from more than 1200 stations can be downloaded and visualised through the ISMN's web interface



↑ Taking *in situ* soil moisture measurements during a five-week campaign in southeast Australia to validate SMOS data (Univ. Melbourne)

under a free and open data policy. The ISMN has more than 500 registered users and has become the world's largest database for *in situ* soil moisture observations. Comparisons between the SMOS derived soil moisture estimates and the *in situ* measurements indicate a good overall performance in line with the expectations.

Frontiers

Soil moisture and ocean salinity have been the two key geophysical parameters driving the SMOS mission concept and its design. The corresponding validation activities and some of the applications have been carefully addressed and planned during the mission preparation phases on the ground and in orbit. However, as the observations have become available, new parameters and exciting applications have been analysed and developed by scientists.

Over the oceans, research into sea-ice thickness and extreme wind speeds associated with storms and hurricanes has

been performed successfully. Over land, monitoring the freeze-thaw cycle of soil and detecting frost depth seem feasible. Soil freezing, wintertime evolution of soil frost and thawing are important characteristics influencing the hydrological and climate processes of the large land areas of North America and northern Eurasia.

Changes in the seasonal behaviour of frost have a major effect on the surface energy balance, as well as on the intensity of carbon dioxide (CO₂) and methane (CH₄) fluxes. CH₄ releases from wetlands have been found to increase during recent decades, for example in Siberia because of



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Tundra ponds in Alaska. Because of permafrost (up to 500–600 m thick in places), the land is frozen and holds a lot of water on the surface (Omniterra Images)



←
Networks and stations providing *in situ* measurements for the International Soil Moisture Network database. Data are available at www.ipf.tuwien.ac.at/insitu (Wagner, TU Vienna)

the thickening of the seasonally thawed active layer above the permafrost. On the other hand, it has been shown how to relate this information to changes in CO₂.

In the case of boreal forests, the annual CO₂ balance has been found to be highly dependent on conditions during autumn and early winter.

The first soil frost depth datasets based on SMOS observations were derived by the Finnish Meteorological Institute for two consecutive winter periods starting in 2010. Key elements, such as the southward progression of soil freezing in autumn and

early winter, were monitored successfully as well as the late onset of winter in northern Europe in 2011.

These results are potentially interesting for climate applications because they could enhance our understanding of the temporal behaviour of the active layer in permafrost regions and the gas exchange process.

More research involving the climate modelling community will be dedicated to this topic over the next few years when multi-year time-series of SMOS observations will allow the analysis of seasonal and inter-annual variations. ■