



BR-224
June 2004



ESA'S WATER MISSION

SMOS

ESA'S EARTH OBSERVATION MISSIONS



METEOSAT - In 1977 the first of seven Meteosat meteorological satellites was launched to monitor the weather over Europe and Africa from a vantage point high over the Equator. The success of the first satellites led to the formation of the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) in 1986. Meteosat-7, the last in the series, was launched in 1997.



ERS-1 and 2 - ERS-1, launched in 1991, was ESA's first remote-sensing satellite; it carried a comprehensive payload including an imaging Synthetic Aperture Radar (SAR), a radar altimeter and other powerful instruments to measure ocean surface temperature and winds at sea. ERS-2, which overlapped with ERS-1, was launched in 1995 and added the Global Ozone Monitoring Experiment (GOME) for atmospheric ozone level research.



ENVISAT - Launched in 2002, is the largest Earth-observation satellite ever built. It carries 10 sophisticated optical and radar instruments to provide continuous observation and measurement of the Earth's oceans, land, ice caps and atmosphere for the study of various natural and man-made contributors to climate change. It also provides a wealth of information needed for the management of natural resources.



MSG (Meteosat Second Generation) - MSG is a joint project between ESA and EUMETSAT and follows up the success of the first generation Meteosat with satellites of higher performance. Four satellites are planned at present, the first of which was launched in 2002.



CRYOSAT - An Earth Explorer Opportunity mission, due for launch in 2004, will determine variations in the thickness of the Earth's continental ice sheets and marine ice cover. Its primary objective is to test and quantify the prediction of thinning polar ice due to global warming.



METOP (Meteorological Operational) - Europe's first polar orbiting satellite system dedicated to operational meteorology. MetOp is a series of three satellites to be launched sequentially over 14 years, starting in 2005, and forms the space segment of EUMETSAT's Polar System (EPS).



GOCE (Gravity Field and Steady-State Ocean Circulation Explorer) - An Earth Explorer Core mission, due for launch in 2006, will provide the data set required to accurately determine global and regional models of the Earth's gravity field and the geoid. It will also advance research in the fields of steady-state ocean circulation, physics of the Earth's interior, geodesy and surveying and sea-level change.



ADM-Aeolus (Atmospheric Dynamics Mission) - An Earth Explorer Core Mission, due for launch in 2007, will make novel advances in global wind profile observation. It is intended to provide much-needed information to improve weather forecasting and climate research.



SMOS (Soil Moisture and Ocean Salinity) - An Earth Explorer Opportunity Mission, due for launch in 2007, will provide global observations of soil moisture and ocean salinity to improve modelling of the weather and climate. It will also monitor vegetation water content, snow cover and ice structure.

Prepared by:

Michael Berger, Ralf Bock,
Mark Drinkwater & Helge Rebhan

Published by:

ESA Publications Division
ESTEC, PO Box 299
2200 AG Noordwijk
The Netherlands

Editors: Honora Rider, Michael Rast &
Bruce Battrick

Design & Layout:

AOES Medialab & Jules Perel
Illustrations: AOES Medialab

Price: 10 Euros

ISSN No.: 0250-1589

ISBN No.: 92-9092-735-6

<http://www.esa.int/earthobservation>
<http://www.esa.int/livingplanet>



SMOS: ESA'S WATER MISSION

Contents

SMOS: Soil Moisture and Ocean Salinity mission	2
The water cycle - damp soil and salty oceans	4
Why measure moisture and salinity?	6
How the SMOS mission works	8
The instrument	10
The satellite	12
Tuning in for SMOS	14
SMOS overview	16

SMOS: Soil Moisture and Ocean Salinity mission



Flooded paddy field in Asia. Waterlogged soils nurture one of the world's most important food sources. Since rice is a semi-aquatic grass, the soil has to be flooded before the crop is planted.

The amount of water held in the Earth's soil is constantly changing. It comes as no surprise to learn that variability in soil moisture is mainly governed by different rates of evaporation and precipitation, so that for example, severe drought can result in features such as hard dry cracked soil, while floods and landslides can be a consequence of very heavy rainfall. Less obvious perhaps, is the fact that some parts of the Earth's oceans are significantly 'saltier' than others. Changes in the salinity of surface seawater are brought about by the addition or removal of freshwater, mainly through evaporation and precipitation, but also, in polar regions, by the freezing and melting of ice. Variability in soil moisture and ocean salinity is due to the continuous exchange of water between the oceans, the atmosphere and the land - the Earth's water cycle. However, despite the water cycle being one of the most important processes operating on our planet - sustaining life and controlling our climate - this fundamental system is still relatively poorly understood.

Although soil only holds a small percentage of the total global water budget, soil moisture plays an important role in the water cycle. Currently, precise in-situ measurements of soil moisture are sparse, but if we are to better understand the water cycle so that the forecasting of climate, weather and extreme events can be improved, more data are urgently required. The same goes for ocean-surface salinity, for which there are virtually no historical measurement data, and only a small fraction of the ocean is currently sampled on any regular basis. Salinity and



temperature determine the density of seawater, and in turn density is an important factor driving the currents in our oceans. Ocean circulation plays a crucial role in moderating climate by, for example, transporting heat from the Equator to the poles. Comprehensive data on ocean salinity would not only contribute to a better understanding of the water cycle, but also arguably have the single most revolutionary impact on the knowledge of conditions that influence global ocean circulation and thus climate.

ESA's Soil Moisture and Ocean Salinity (SMOS) mission has been designed to observe soil moisture over the Earth's landmasses and salinity over the oceans for a period of at least 3 years. An important aspect of this mission is that it will demonstrate a new measuring technique by adopting a completely different approach in the field of remote sensing. A novel instrument has been developed that is capable of observing both soil moisture and ocean salinity by capturing images of emitted microwave radiation around the frequency of 1.4 GHz (L-band). SMOS will carry the first-ever polar-orbiting satellite-borne 2-D interferometric radiometer.

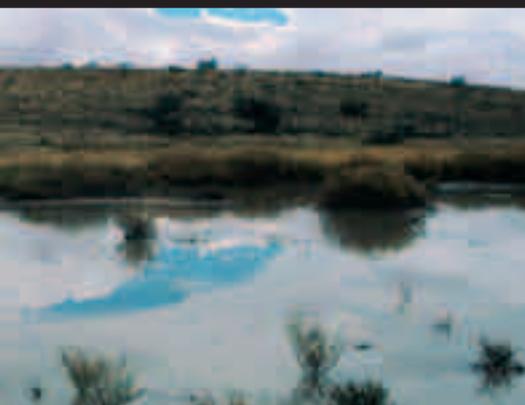
Scheduled for launch in early 2007, SMOS is the second Earth Explorer Opportunity mission to be implemented as part of ESA's Living Planet Programme. Opportunity missions are small research missions that focus on a specific aspect of the Earth's environment and/or demonstrate new remote-sensing technologies. The SMOS mission is a direct response to the

current lack of global observations of soil moisture and ocean salinity.

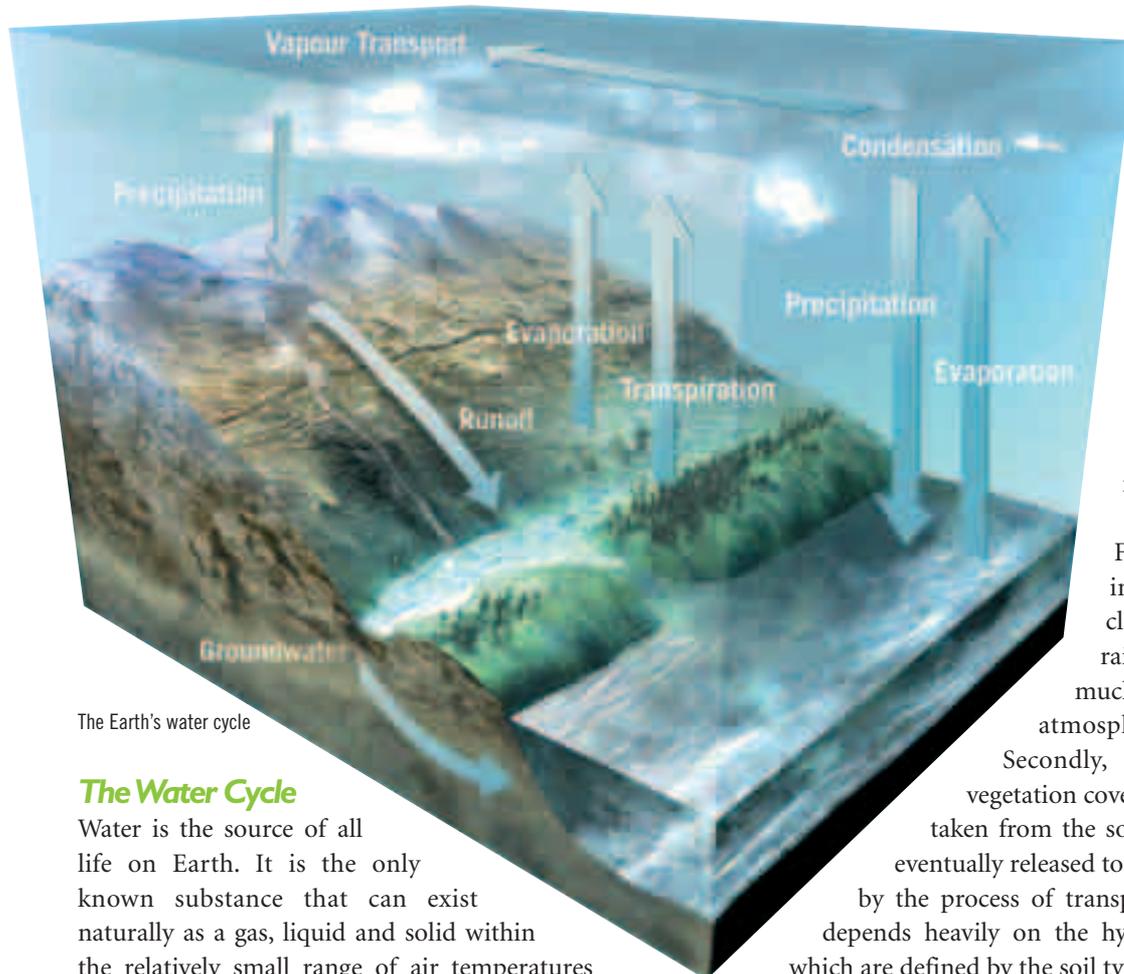
As well as demonstrating the use of the new radiometer, the data obtained from this mission will contribute to furthering our knowledge of the water cycle. SMOS data will further lead to better weather and extreme-event forecasting and contribute to seasonal-climate forecasting. As a secondary objective, SMOS will provide observations over regions of ice and snow, contributing to studies of the cryosphere.



Salt-pans in India. These pans illustrate how much salt there is in seawater, which is allowed to evaporate from shallow pools, leaving behind a residue of salt which is then collected and refined.



The water cycle damp soil and salty oceans



The Earth's water cycle

The Water Cycle

Water is the source of all life on Earth. It is the only known substance that can exist naturally as a gas, liquid and solid within the relatively small range of air temperatures and pressures found on the surface of the Earth. The total amount of water present on the Earth is fixed and does not change. However, powered by the Sun, water is continually being circulated between the oceans, the atmosphere and the land. This circulation and conservation of the Earth's water, known as the water cycle, is a crucial component of our weather and climate.

More than 96% of the water on Earth is stored in the oceans. Therefore, evaporation from the oceans is the primary vehicle for driving the surface-to-atmosphere portion of the water cycle. The atmosphere actually holds less than 0.001% of the Earth's water, which may seem remarkable since water plays such an important role in the weather. While around 90% of this atmospheric water vapour comes from the oceans, the remaining 10% is provided by plant transpiration and evaporation from soil.

Soil Moisture

Soil moisture is actually quite difficult to define because it exists in different forms - it can be bound by chemical composition, attached to soil grains and stored as free water within the soil, and it also varies with depth and time. The amount of water that can be stored in any given soil depends on a number of factors.

Firstly, and perhaps most importantly, the prevailing climate dictates the amount of rainfall the soil receives and how much water is cycled back to the atmosphere through evaporation. Secondly, the amount and type of vegetation cover influences how much water is taken from the soil through the plant roots and eventually released to the atmosphere from the leaves by the process of transpiration. Thirdly, soil moisture depends heavily on the hydraulic properties of the soil, which are defined by the soil type. The soil type describes what the soil is composed of, such as sand or clay, and how porous it is. These properties dictate the rate at which water percolates through the soil layers, the surface run-off into streams and rivers, or whether the soil retains moisture up to its maximum storage capacity.

In most parts of the world, the amount of water present in the soil is the dominant factor that affects plant growth. However, the retention of water in the soil is crucial not only to sustain primary production, but is also intrinsically linked to our weather and climate. This is because soil moisture is a key variable controlling the exchange of water and heat energy between the land and the atmosphere through evaporation and plant transpiration. As a result, soil moisture plays an important role in the development of weather patterns.



Did you know?

The highest recorded ocean surface salinities of around 40 psu are found in the Red Sea. However, the Dead Sea is the saltiest sea on Earth. High evaporation has caused the surface salinity to reach around 300 psu, making the water so dense that you can float and read at the same time.

Between latitudes of 35°N and 35°S, the Earth receives more heat from the Sun than it loses to space. Poleward of these latitudes it loses more heat than it receives. The tropics would keep getting hotter and the poles would keep getting colder if heat were not carried from the tropics by winds and ocean currents.

About 334 000 cubic kilometres of water are evaporated from the ocean each year, to return as precipitation on land and sea.

There is enough salt in the oceans to make a cubic block of salt 100 x 100 x 100 metres for every human on Earth.

The total amount of salt in a given volume of seawater varies from place to place, but the relative proportions of the different kinds of salt (chlorides of sodium, magnesium, potassium and calcium) remain almost constant.

The freezing point of seawater depends on its salt content. Seawater with the average salinity of 35 psu freezes at -1.9°C.

The Atacama Desert in Northern Chile is probably the driest and most lifeless place on Earth. In the extreme arid core region of this desert even Cyanobacteria, green photosynthetic micro-organisms that live in rocks or under stones in most other deserts, are absent.

About one-third of the Earth's land surface is desert.

The average residence times of a water molecule in a particular reservoir are approximately as follows:

The atmosphere - 12 days

The ocean - 4 000 years

Soil moisture - 2 weeks to 1 year

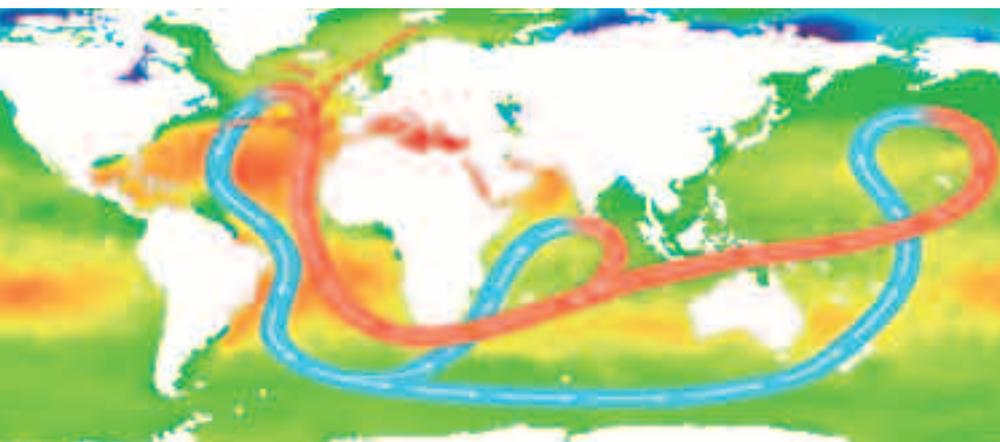
Ground water - 2 weeks to 10 000 years

Ocean Salinity

The average concentration of dissolved salt in the oceans, the salinity, is about 35 practical salinity units (psu), which simply means that 35 grams of various salts are dissolved in 1 kilogram (about 1 litre) of water. The salinity of surface seawater is controlled largely by a balance between evaporation and precipitation, so that, although seawater has an average salinity of 35, the salinity of surface waters in the open ocean typically ranges from 32 to 38. Salinity is at a maximum in sub-tropical latitudes, where evaporation exceeds precipitation - these regions correspond to deserts that exist at similar latitudes on land. Surface waters are generally less saline around the Equator because of greater rainfall, and towards higher latitudes due to melting ice and snowfall.

In the surface waters of the oceans, temperature and salinity alone control the density of seawater - the colder and saltier the water, the denser it is. As water evaporates from the ocean, the salinity increases and the surface layer becomes denser. In contrast, precipitation results in reduced density, and stratification of the ocean. The processes of seawater freezing and melting are also responsible for increasing or decreasing the salinity of the polar oceans, respectively. As sea-ice grows during the winter, the freezing process extracts fresh water in the form of ice, leaving behind dense, cold, salty surface water.

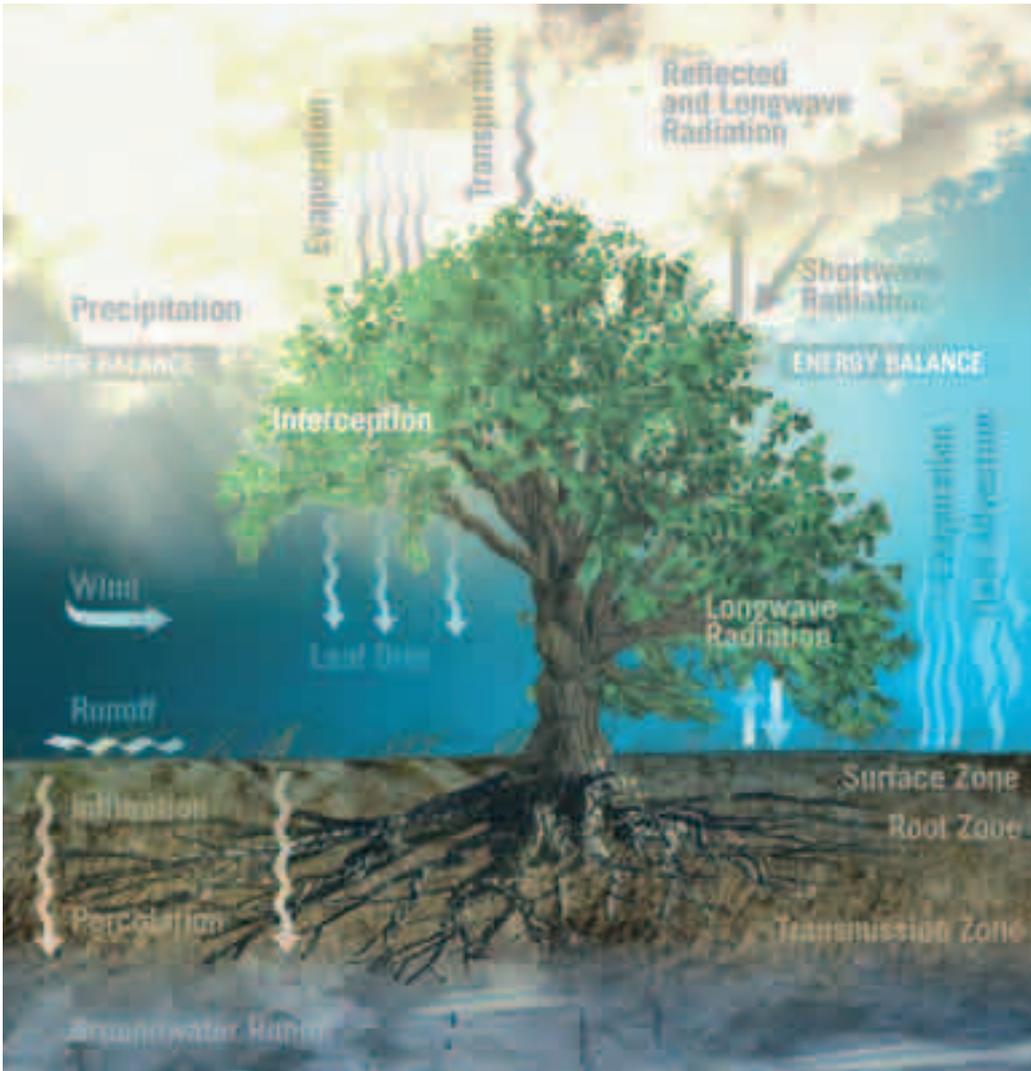
If the density of the surface layer of seawater is increased sufficiently, the water column becomes gravitationally unstable and the denser water sinks. Vertical circulation in the oceans is a key component of the temperature- and salinity-driven global



ocean circulation known as the 'thermohaline circulation'. This conveyor-belt-like circulation is an important component of the Earth's heat engine, and crucial in regulating the weather and climate.

Map showing average distribution of sea-surface salinity values. Areas of red indicate regions of high salinity and areas of green regions of low salinity. The map is overlaid with the simplified global circulation pattern called the 'thermohaline circulation'. The blue arrows indicate cool deeper currents and the red indicate warmer surface currents. Temperature (thermal) and salinity (haline) variations are key variables affecting ocean circulation.

Why measure moisture and salinity?



Energy and water balance of the physical climate system including the terrestrial and atmospheric components of the water cycle

Water in the soil and salt in the oceans may seem to be unconnected, but in fact they are both intrinsically linked to the Earth's water cycle and climate. Currently, there are very few datasets on either soil moisture or ocean salinity. As a result, the SMOS mission has been designed to provide much needed observational data on both variables from space. This information will not only improve our understanding of the water cycle, but will also advance weather and climate prediction. In particular, soil moisture data will be important for extreme-event forecasting such as floods, landslides and droughts.

Precipitation, soil moisture, percolation, run-off, evaporation from the soil, and plant transpiration are all components of the terrestrial part of the water cycle. Soil moisture is an important variable in the climate system and has long been of interest to hydrologists, soil scientists, meteorologists and ecologists. It is also of interest to agriculturalists because water is essential to human existence and its availability is the first requirement for any settlement or agriculture. There is a direct link between soil moisture and atmospheric humidity because dry soil contributes little or no moisture to the atmosphere and saturated soil contributes a lot. In extreme circumstances, large land surfaces that become flooded can create a closed-loop as

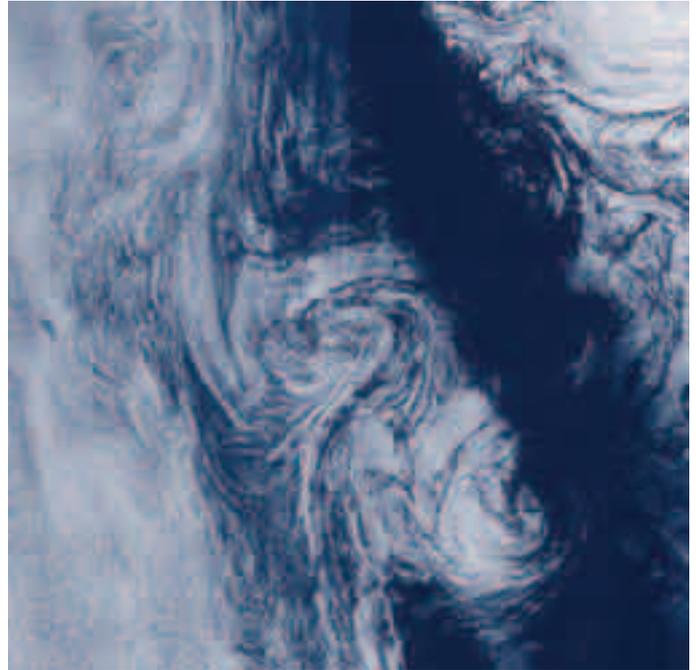


the evaporated moisture forms local clouds that replace water in the system via continuing precipitation. Moreover, because soil moisture is linked to evaporation it is also important in governing the distribution of heat flux from the land to the atmosphere. In this manner, areas of high soil moisture not only raise atmospheric humidity but also lower temperatures locally. This is clearly demonstrated, for instance, by the immediate cooling effect that is felt after watering the garden on a hot summer's day.

Soil moisture, therefore, is a critical component of temperature and precipitation forecasts. Such forecasts require soil moisture measurements down to depths of 1 to 2 metres, an area often referred to as the 'root zone'. Since SMOS will provide data on soil moisture content to a depth of only a few centimetres, modelling techniques have been developed to derive the moisture content within the root zone from time series of near-surface soil moisture. These techniques require surface soil moisture observation at least every three days, and at dawn when the thermal gradient and moisture balance between the soil surface and the root zone are optimal.

The importance of estimating soil moisture in the root zone is paramount for improving short- and medium-term meteorological modelling, hydrological modelling, the monitoring of photosynthesis and plant growth, as well as contributing to the forecasting of hazardous events such as floods.

Variations of both sea-surface temperature and salinity drive global three-dimensional ocean-circulation patterns. In turn, ocean circulation regulates our climate. For instance, the warm



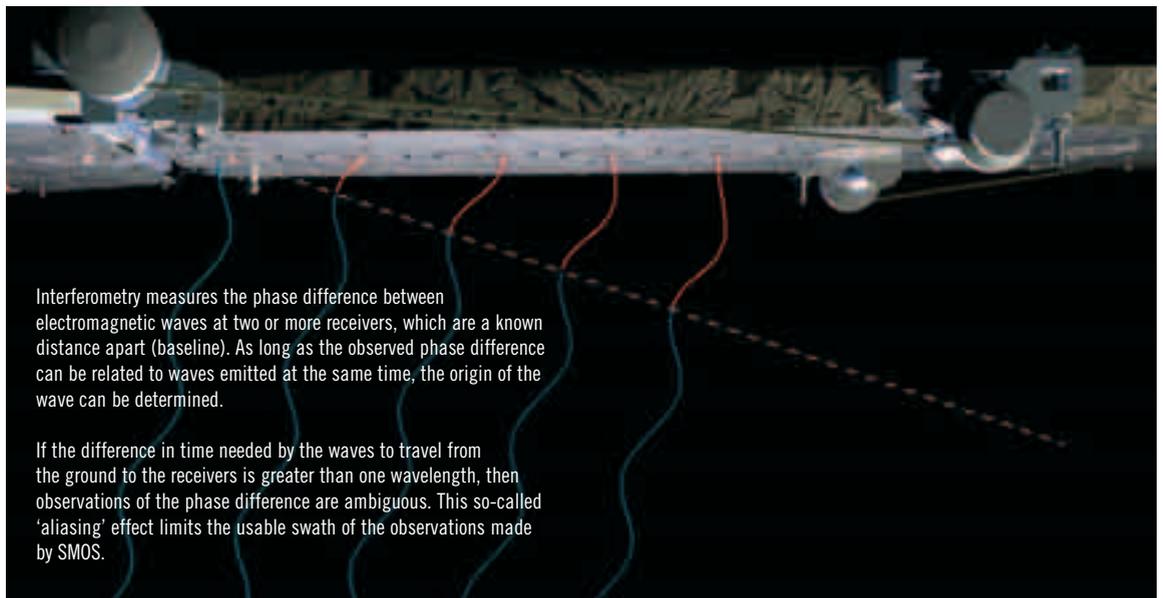
ERS image of a 100 km square North Atlantic region off the southwest coast of Norway, where the warm Gulf Stream meets frigid Arctic waters. The result of these unstable ocean conditions is a spectacular surface display of swirls or vortices that indicate vigorous mixing.

salty waters of the Gulf Stream transport heat from the Caribbean to the Arctic, and this allows Europe to enjoy a milder climate than it would otherwise experience. Sea-surface salinity is therefore one of the key variables driving the global oceanic circulation pattern, which, in itself, is an important indicator for climate change.

Ocean surface salinity is closely correlated to estimates of net Evaporation minus Precipitation (E-P), and this is especially true for warm tropical regions. As water evaporates, the salinity of the sea surface increases. This causes the top layer of water to sink, which causes the water masses to mix vertically.

The E-P balance is difficult to measure accurately over the ocean with conventional means, so satellite-based maps of ocean salinity would provide a tool for more accurate E-P estimates at the global scale. This will not only facilitate a better insight into the process driving the thermohaline part of ocean circulation, but will also allow better estimations of the heat flux from the oceans to the atmosphere and thus better atmospheric forecasts.

How the SMOS mission works



Interferometry measures the phase difference between electromagnetic waves at two or more receivers, which are a known distance apart (baseline). As long as the observed phase difference can be related to waves emitted at the same time, the origin of the wave can be determined.

If the difference in time needed by the waves to travel from the ground to the receivers is greater than one wavelength, then observations of the phase difference are ambiguous. This so-called 'aliasing' effect limits the usable swath of the observations made by SMOS.

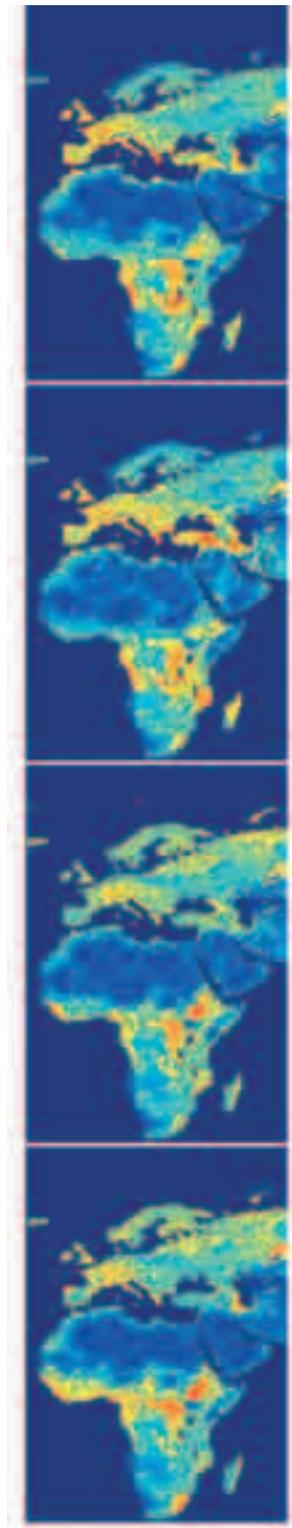
SMOS is designed to observe both soil moisture and ocean salinity with just one instrument - but how will this be achieved given that the water in the soil and the salt in the oceans are completely different components of the Earth system?

The key to being able to measure both components using one technique is related to the fact that moisture and salinity strongly affect the electrical properties of matter. All matter emits energy in the form of electromagnetic radiation. However, the amount of radiation that can be emitted from any material depends on the electrical properties of that material. A material can be defined as having a certain value of 'emissivity', and this value defines how much radiation a particular substance can emit. The SMOS mission will take advantage of the fact that moisture and salinity decrease the emissivity of soil and seawater, respectively.

Simulated seasonal soil moisture maps (starting with winter at the top) of Europe and Africa. The units are 'cubic metre of water per cubic metre of soil'. These soil moisture maps were simulated by means of a soil-vegetation-atmosphere transfer scheme using climatological data.

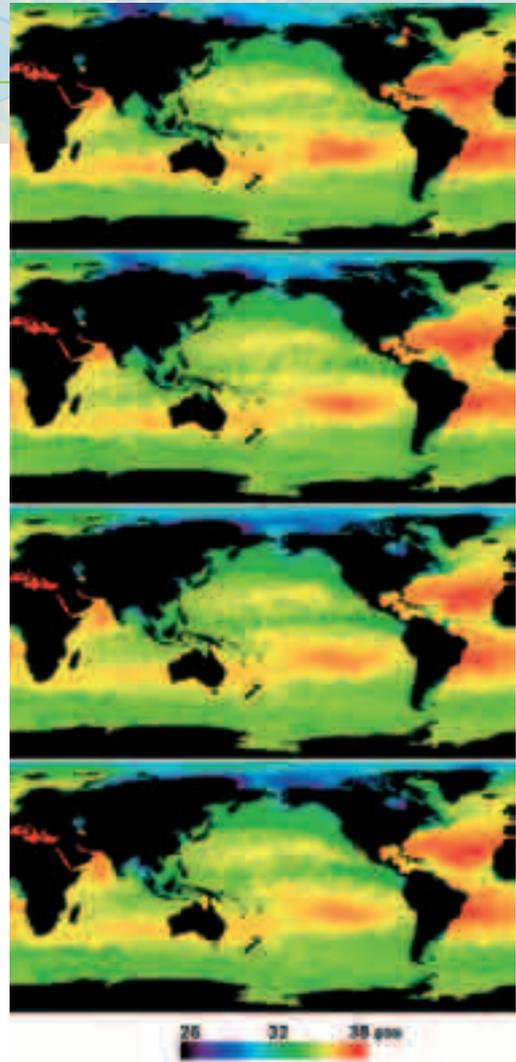
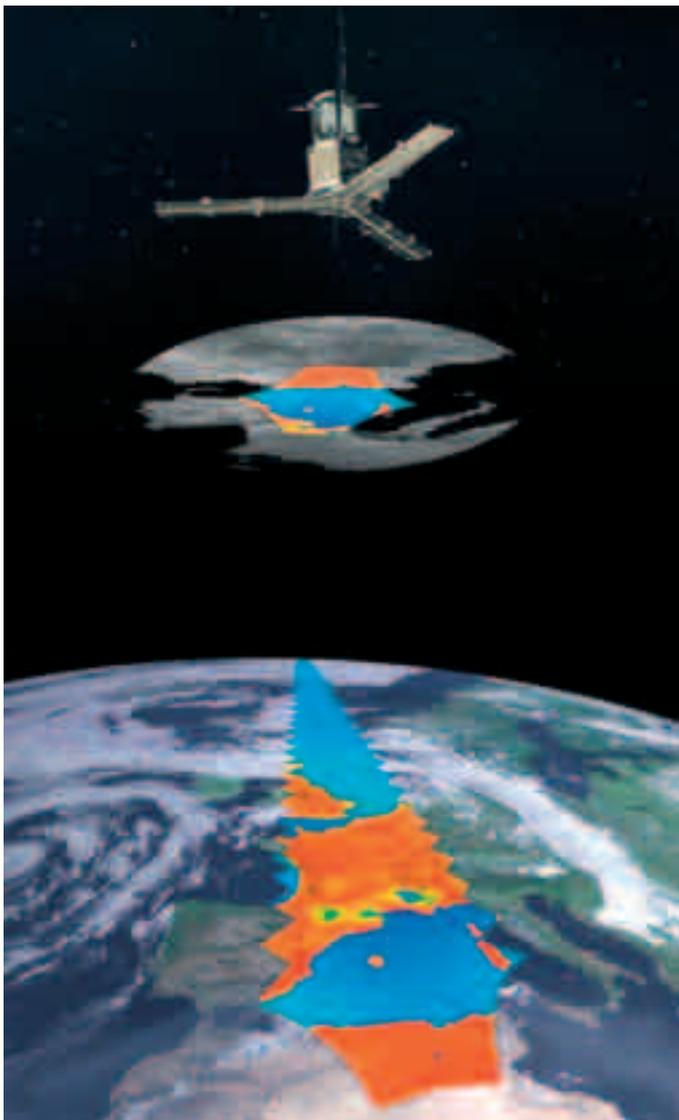
For optimum results, SMOS will measure microwave radiation emitted from the Earth's surface at L-band (1.4 GHz). Observations made at this frequency are less affected by vegetation cover, the weather and the atmosphere than if the observations were made at other frequencies. When making observations of the Earth in the L-band microwave range, a large rotating antenna would normally be required to achieve adequate coverage and spatial resolution. However, for a spacecraft, this approach would lead to a costly and heavy payload. An elegant solution has been found by employing an interferometric radiometer, which by way of a number of small receivers will measure the phase difference of incident radiation. The technique is based on the cross-correlation of observations from all possible combinations of receiver pairs. A two-dimensional 'measurement image' is taken every 1.2 seconds. As the satellite moves along its orbital path each pixel is observed under all possible viewing angles.

From an altitude of 763 km, the antenna will view an area almost 3000 km in diameter. However, due to the interferometry measurement principle and the Y-shaped antenna, the field of view is limited to



a hexagon-like shape about 1000 km across - called the 'alias-free zone'. This area corresponds to observations where there is no phase-difference ambiguity. The chosen orbit will result in global coverage every three days, which is required to track the quick-drying period on land after rainfall.

In summary, this novel measuring technique means that SMOS is the first-ever spaceborne mission that will provide global maps of soil moisture and ocean salinity.



Simulated seasonal sea-surface salinity maps. They exhibit only small variations, but demonstrate the uniform pattern of a saltier Atlantic compared to the Pacific. Since in-situ sampling is so difficult, currently the only way of estimating global ocean salinity is to simulate the data using complex computer models.

Moisture is a measure of the amount of water within a given volume of material and is usually expressed as a percentage. From space, the SMOS instrument can measure as little as 4% moisture in soil on the surface of the Earth - which is about the same as being able to detect less than one teaspoonful of water mixed into a handful of dry soil.

Salinity describes the concentration of dissolved salts in water. It is measured in practical salinity units (psu), which expresses a conductivity ratio. The average salinity of the oceans is 35 psu, which is equivalent to 35 grams of salt in 1 litre of water. SMOS aims to observe salinity down to 0.1 psu (averaged over 10-30 days and an area of 200 km x 200 km) - which is about the same as detecting 0.1 gram of salt in a litre of water.

The instrument

The biggest challenge the SMOS mission faces is to fly and demonstrate a completely new type of instrument - a radiometer that operates between 1400 and 1427 MHz (L-band). In order to achieve the required spatial resolution for observing soil moisture and ocean salinity, the laws of physics would normally require a huge antenna. However, the solution to this has been to synthesise the antenna aperture through a multitude of small antennae. After more than 10 years of research and development, with the objective of demonstrating key

instrument performance such as antenna deployment and image validation, the innovative SMOS instrument, called MIRAS (Microwave Imaging Radiometer using Aperture Synthesis), is now mature enough for ESA's second Earth Explorer Opportunity Mission. EADS (European Aeronautic Defence and Space)-CASA Espacio, Spain is the Prime Contractor for MIRAS.

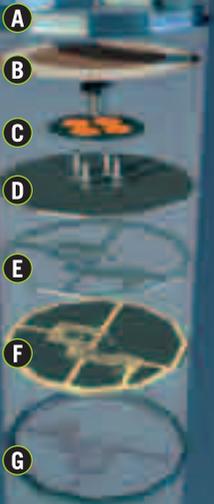
The LICEF antenna provides best performance in terms of gain, bandwidth and differentiation of horizontal and vertical polarisation components of incoming microwaves. It consists of four probes implemented as pairs, which are rotated 90° to each other so as to acquire the two different signal polarisations. Multi-layer 'microstrip' technology has been chosen for the circuit configuration. Each layer is dedicated to one polarisation. Each LICEF antenna weighs 190 g, is 165 mm in diameter and is 19 mm high.



- 1 LICEF 69 in total
- 2 Payload central structure
- 3 Root hinge with deployment speed regulator
- 4 Segment hinge with spring motor
- 5 Cable-pulleys to synchronise the deployment of all three arm segments
- 6 X-band antenna
- 7 Star-tracker assembly
- 8 Proteus satellite platform



LICEF antenna



- A** Carbon-fibre structure
- B** Patch antenna
- C** Feeding discs
- D** Cavity floor to patch antenna
- E** Aluminium spacer
- F** Feed circuits (Multi-layer microstrips on both sides of the grounding plane)
- G** Aluminium spacer

MIRAS consists of a central structure and three deployable arms, each of which has three segments. During launch these arms are folded-up, but soon after separation from the launch vehicle they are gently deployed via a system of spring-operated motors and speed regulators.

There are 69 antenna elements - the so-called LICEF receivers, which are equally distributed over the three arms and the central structure. Each LICEF is an antenna-receiver integrated unit that measures the radiation emitted from the Earth at L-band. The acquired signal is then transmitted to a central correlator unit, which performs interferometry cross-correlations of the signals between all possible combinations of receiver pairs. By pre-processing the calculations on-board, the amount of data that has to be transmitted to the ground is dramatically reduced.

MIRAS can operate in two measurement modes - dual-polarisation or polarimetric mode. The baseline is dual-polarisation mode, where all the LICEF antennae will be switched between horizontal and vertical measurements, thus permitting the measurement of the horizontal and vertical components of the received microwaves. In addition, the polarimetric mode has been implemented to acquire both polarisations simultaneously. The advantage of this enhanced mode is that it provides additional scientific

revenue; however, the amount of data that has to be transmitted to the ground is doubled. Only in-flight experience will show whether the dual-polarisation mode satisfies the scientific mission objectives, or whether MIRAS will be continuously operated in the more demanding polarimetric mode.

The LICEF receiver parameters are sensitive to temperature and ageing. Therefore, they need to be calibrated in-flight to ensure that the accuracy requirements of the mission can be met. Several times per orbit an internal calibration system injects a signal of known characteristics into all the LICEF receivers. During this short calibration period (1.2 seconds) the receivers are switched to the calibration signal instead of the signal picked-up by the antenna. In addition, every 14 days an absolute calibration with deep space or a celestial target of known signal strength will be performed - this requires the satellite to perform specific attitude manoeuvres.

To avoid any electromagnetic disturbance, which is an important feature for a highly sensitive instrument such as MIRAS, the LICEF measurement signals are transmitted through a fibre-optical harness to the heart of the payload - the control and correlator unit. In the opposite direction, the LICEFs are supplied with a stable reference clock signal. Moreover, the control and correlator unit maintains the overall instrument operation modes and provides communication with the satellite platform.

The satellite position and its orientation need to be known to properly 'geo-locate' the radiometer measurements on the ground. These data are provided by the satellite platform using a GPS receiver and star trackers.

Eventually, the scientific and housekeeping data are acquired and stored in a 20-Gbit mass memory and then transmitted to the ground via X-band every time the dedicated ground station is within range. By using on-board GPS position information this will be executed autonomously.

The satellite



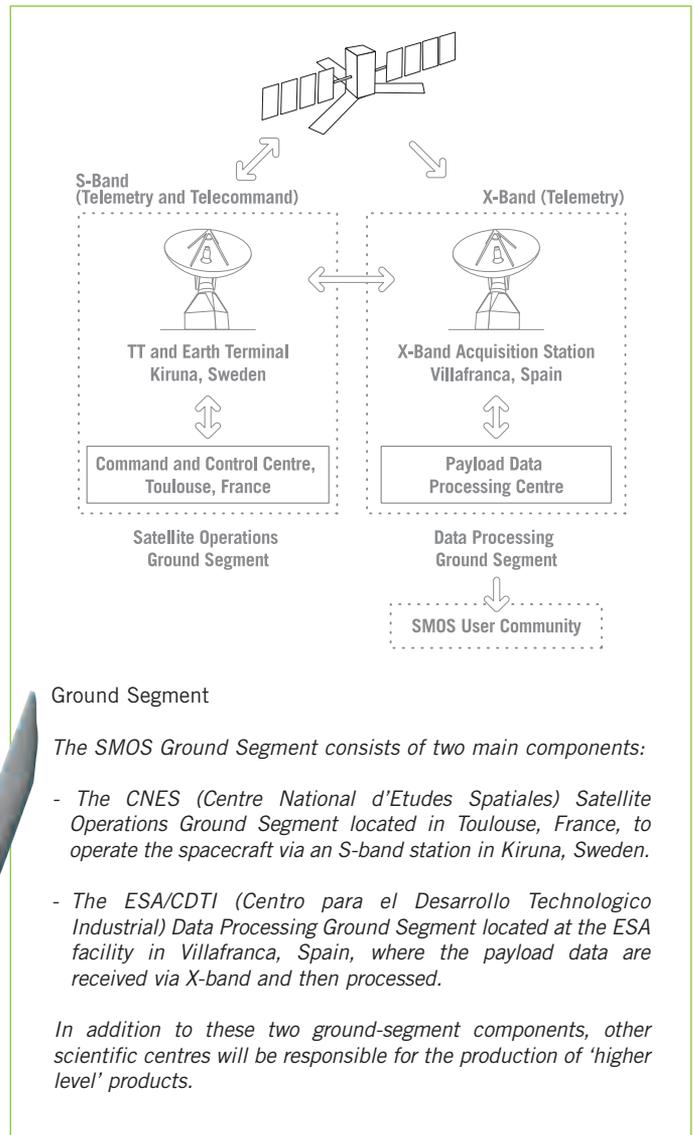
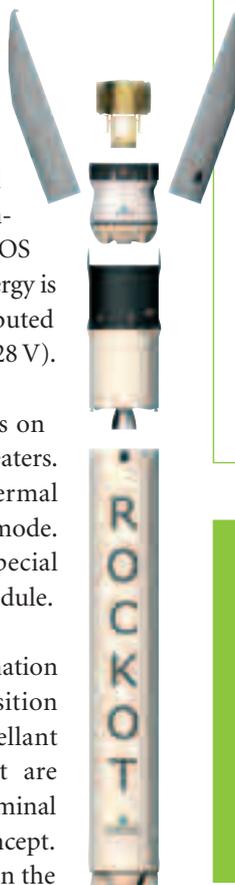
The SMOS payload will be carried on a standard 'spacecraft bus' called Proteus developed by the French space agency CNES (Centre National d'Etudes Spatiales) and Alcatel Space Industries. This is a generic platform with well-defined interfaces so that with a little tailoring the SMOS scientific instrument can be mounted on the top of the spacecraft through four interface pods.

Although the spacecraft bus is small, occupying just one cubic metre, it acts as a service module accommodating all the sub-systems that are required for the satellite to function. The SMOS spacecraft will be connected to the Rockot launcher via an interface ring. After launch, when the spacecraft has separated from the launcher, there will be an automatic start-up sequence, which results in the deployment of two symmetrical solar arrays. SMOS will fly in a low Earth orbit at an altitude of 763 km. A Sun-synchronous, dawn-dusk orbit is required to obtain the optimum scientific measurements. This also means that the solar arrays will always be illuminated, except for short eclipse periods in winter.

Two symmetrical solar-array wings, which are covered with classical silicon cells, generate the electrical power. Each wing is made up of four deployable panels; each panel measures 1.5 x 0.8 m². Since the orbit is Sun-synchronous, the wings remain static after SMOS has reached its final orbit and attitude. The energy is stored in a lithium-ion battery and distributed through a non-regulated electrical bus (average 28 V).

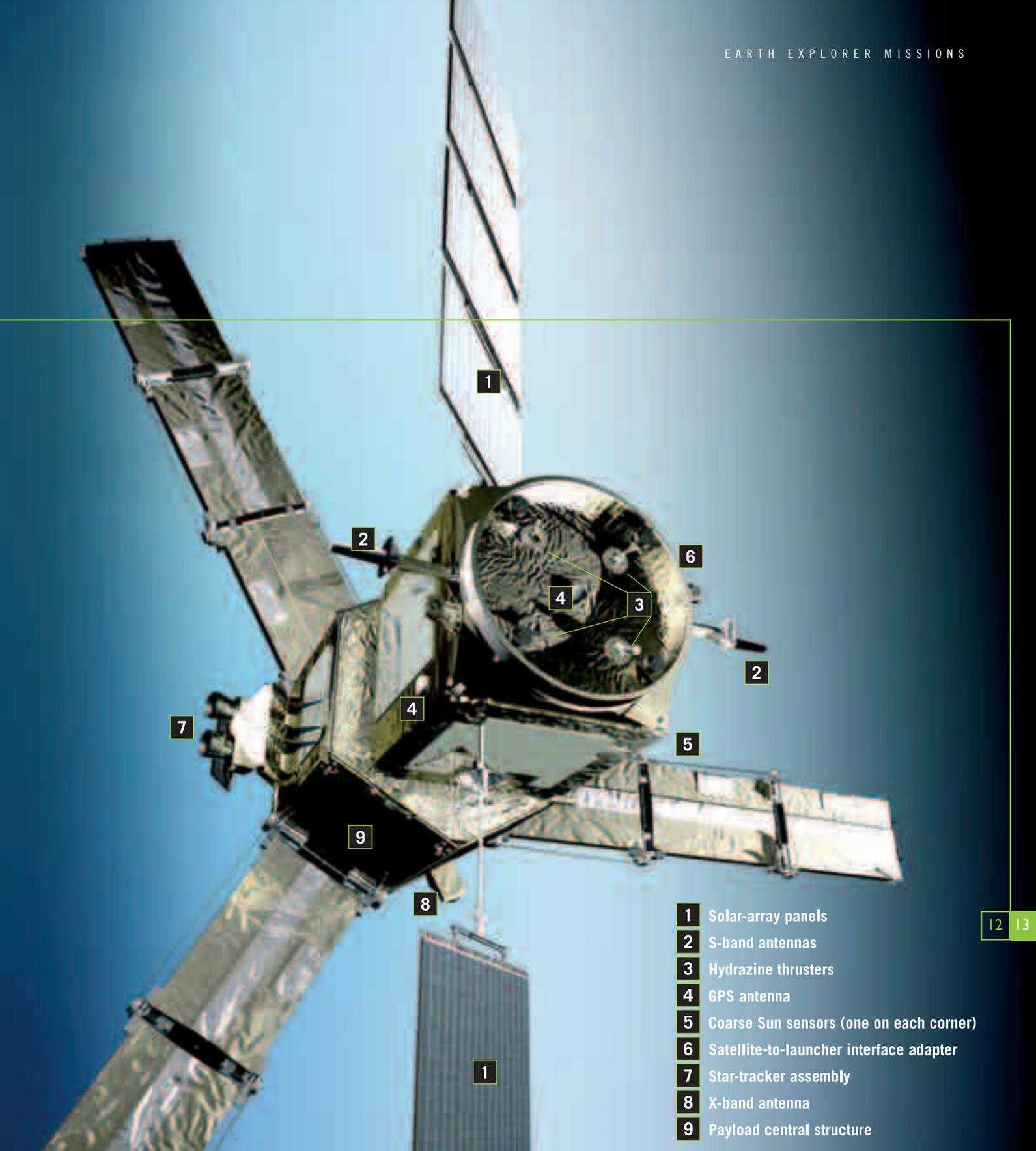
The platform thermal-control subsystem relies on passive radiators and active regulation by heaters. The SMOS payload provides its own thermal regulation except when the satellite is in safe mode. During these periods, Proteus controls special heaters that are distributed on the payload module.

Proteus uses a GPS receiver for orbit determination and control, which provides satellite position information, and a hydrazine monopropellant system with four 1-Newton thrusters that are mounted on the base of the spacecraft. Nominal attitude control is based on a gyro-stellar concept. The Star Tracker Assembly is accommodated on the



Launch Vehicle

SMOS will be launched by one of the modified Russian Intercontinental Ballistic Missile (ICBM) SS-19 launchers, which were decommissioned as a consequence of the Strategic Arms Reduction Treaty (START). The adaptation of the SS-19, called 'Rockot', uses the original two lower liquid-propellant stages of the ICBM in conjunction with a new third stage for commercial payloads. Rockot is marketed and operated by EUROCKOT, a German-Russian joint venture. Launch is from the Plesetsk Cosmodrome in northern Russia.



payload and provides accurate attitude information for both the instrument measurements and the satellite attitude control. Three 2-axis gyros are used to measure the change in the spacecraft orientation, and thus provide the accurate attitude knowledge needed to fulfil stability and pointing requirements. Four small reaction wheels generate torque for attitude adjustment. In safe mode, a less precise attitude is obtained using magnetic and solar measurements, namely with two 3-axis magnetometers and eight coarse Sun sensors, while magnetotorsers serve as the only actuators.

The electrical on-board command and data handling architecture is centralised on a Data Handling Unit. It manages the satellite operational modes, performs failure detection and recovery, monitors the housekeeping parameters, controls the communication with the ground segment and provides the power distribution to all satellite units. In addition, the Data Handling Unit interfaces with the payload central processor unit, forwarding payload commands received from the ground and supplying all auxiliary satellite data that are needed by the payload to fulfil its scientific measurements.

Tuning in for SMOS

Long-term observations of snow and ice-sheet surfaces will be conducted at Concordia Station in Antarctica in 2005. The ice sheets in this area are predicted to exhibit very stable microwave emission at 1.4 GHz. If successful, this characteristic will be exploited for external calibration and performance monitoring of the SMOS radiometer.



courtesy PNRA

An L-band radiometer being operated at a site close to Toulouse, France. The measurements, taken over several months, were used to estimate how the vegetation at different stages of growth in different soil moisture conditions influences microwave emissions.



courtesy Y. Kerr, CESBIO

The radiation emitted by the Earth and observed by SMOS is not only a function of soil moisture and ocean salinity. To ensure that the data derived from the SMOS mission are correctly converted into units of moisture and salinity, many other effects that influence the signal need to be carefully accounted for.

For example, changes occurring in the ionosphere and atmosphere while the signal travels from the ground to the satellite need to be considered, as do other perturbing signals from space. In addition, the signal emitted from Earth is influenced by many different biophysical and geophysical variables other than soil moisture and ocean salinity. When trying to measure soil moisture, these perturbing effects may originate from the vegetation, the litter layer, the soil type and the roughness of the ground. Over the oceans, the signal can be

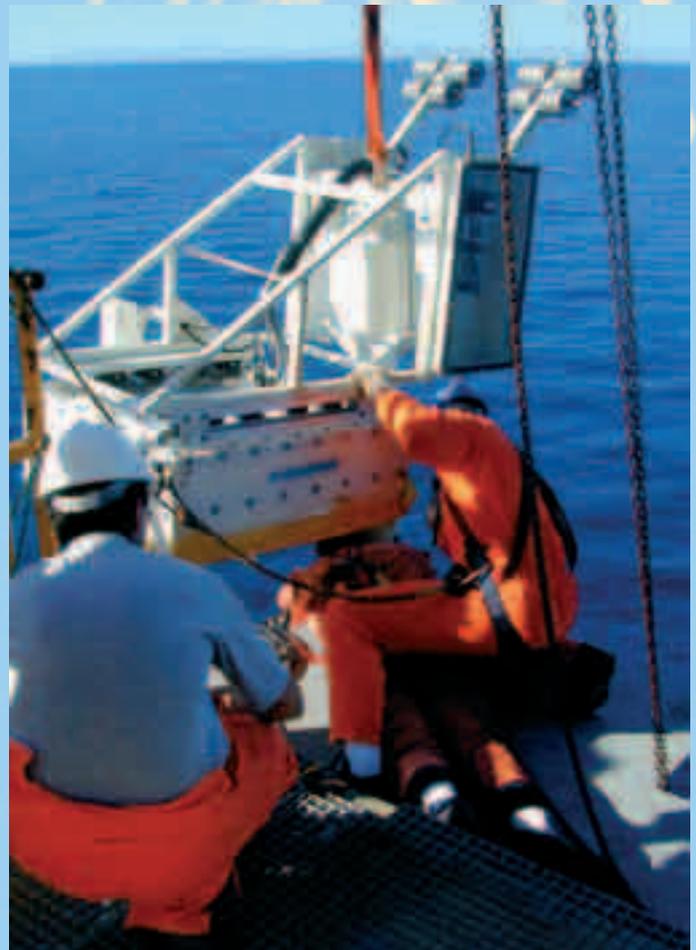
influenced by the condition of the sea, such as waves and foam. Also, the physical temperature of the land and sea surface will influence the radiation signal received by SMOS.

As a consequence, the development of the SMOS mission not only addresses the intricate process of building a novel instrument, but also requires long-term work in the field in order to study the effects on the signal in detail. Therefore, various studies accompanied by dedicated campaign activities were conducted during the feasibility and design phase of the SMOS mission. For example, extensive fieldwork was carried out from a drilling platform in the Mediterranean to examine the relationship between the radiation emitted from the sea surface at L-band (1.4 GHz) under varying sea-state conditions as a result of different wind speeds and directions, different wave types and varying foam coverage. In a number of

The Wind and Salinity Experiment, which was conducted between 2000 and 2001, aimed to measure microwave emission from the surface of the ocean for different sea-states. The experiment was performed from the Casablanca drilling platform in the Mediterranean Sea, about 50 km from Barcelona, Spain.



courtesy UPC



courtesy UPC

14 15

campaigns several instruments were operated from aircraft, measurement towers and research platforms over a range of targets such as forests, mountains and ocean to determine soil moisture and ocean salinity information. In order to analyse the impact of wind on the microwave signal retrieval over ocean, a dedicated experiment involved flying a radiometer over the North Sea.

Many detailed results were obtained from these and other activities and were vital in fine-tuning the retrieval concept so that SMOS will provide the best data possible for soil-moisture and ocean-salinity retrieval.



courtesy UNC

Image of simulated small-scale 'salt-fingering', illustrating diffusive vertical mixing between different water masses in the ocean. Salt fingering is most likely in areas where warm, salty water overlies relatively cool fresh water.

SMOS overview

The Soil Moisture and Ocean Salinity mission will provide global maps of soil moisture and ocean salinity. Soil moisture data are urgently required for hydrological studies and data on ocean salinity are vital for improving our understanding of ocean circulation patterns. Together these data will contribute to furthering our knowledge of the Earth's water cycle, and will improve climate, weather and extreme-event forecasting.

SMOS was selected in 1999 as an Earth Explorer Opportunity Mission as part of ESA's Living Planet Programme.

Mission Details

Launch: 2007

Duration: Nominally 3 years (including a 6-month commissioning phase) with an optional 2-year extension.

Mission Orbit

Type: Low-Earth, Sun-synchronous, circular, dawn-dusk

Mean altitude: 763 km

Inclination: 98.4°

Payload

- 2-D interferometric L-band radiometer (1.4 GHz);
- 69 receivers arranged on a Y-shaped deployable antenna array.

Configuration

- Satellite platform (~1m³) with deployable solar generator panels and interface towards the launch vehicle;
- The payload module (~1m³) is mounted on top of the platform;
- Overall dimensions in launch configuration fit in a cylinder 2.4 m high and 2.3 m in diameter.

Mass

Total 683 kg, comprising:

- Platform 317 kg (including 28 kg hydrazine fuel)
- Payload 366 kg

Power

- Up to 900 W (525 W maximum payload consumption);
- 78 Ah Li-ion battery.

Spacecraft Attitude and Orbit Control

- 3-axis stabilised, 32° forward tilt in flight direction, local normal pointing and yaw steering;
- Star trackers, gyros, magnetometers, GPS, Sun sensors;
- Reaction wheels, magnetotorquers, 4 x 1N thrusters.

Command and Control

Platform integrated data handling, and Attitude and Orbit Control System computer that interfaces with the payload's own control and correlator unit via a 1553 bus and serial links.

On-board Storage

- 1 Solid-State Recorder, capacity 2 x 20 Gbits;
- Payload data generated on-board: 15 Gbits/day;
- Payload data downlink autonomously planned and executed using on-board GPS information for calculation of ground station visibility periods.

Telemetry and Command

- X-band data downlink: 16.8 Mbps;
- S-band TTC link: 4 kbps uplink, 722 kbps downlink.

Launch Vehicle

Rocket (converted SS-19), launch from Plesetsk, Russia.

Flight Operations

Mission control from the CNES Proteus Control and Command Centre (CCC) in Toulouse, France via the S-band antenna located in Kiruna, Sweden. Payload operations prepared by the Payload Operations Programming Centre (ESA) and executed via the CCC.

Payload Data Acquisition and Processing

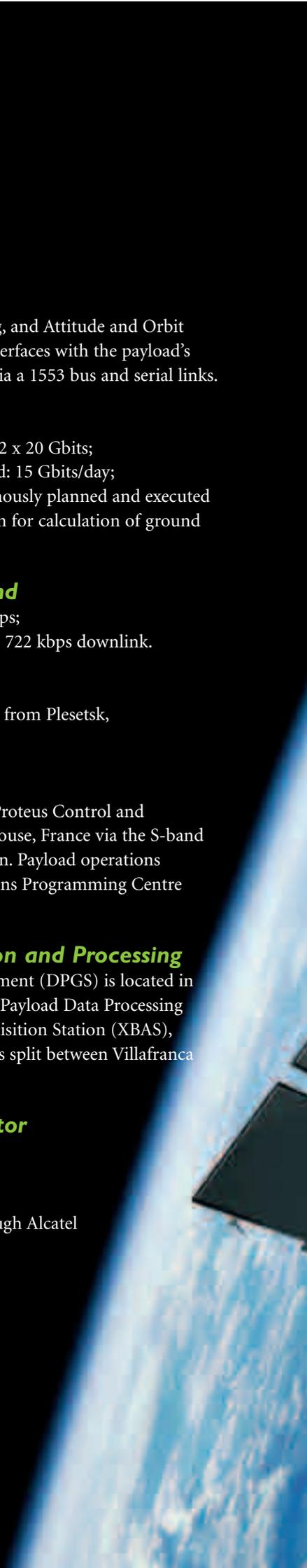
The Data Processing Ground Segment (DPGS) is located in Villafranca, Spain. It includes the Payload Data Processing Centre (PDPC), the X-band Acquisition Station (XBAS), and the SMOS User Service that is split between Villafranca and ESA-ESRIN (Italy).

Payload Prime Contractor

EADS CASA (Spain)

Platform

Provided by CNES (France) through Alcatel (France)







European Space Agency
Agence spatiale européenne

Contact: *ESA Publications Division*
c/o ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Tel. (31) 71 565 3400 - Fax (31) 71 565 5433