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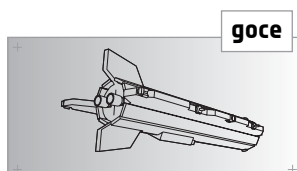
→ ESA'S WATER MISSION



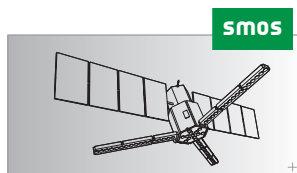
ESA'S EARTH EXPLORER MISSIONS

The Earth Explorer series of Earth observation missions focuses on the science and research elements of ESA's Living Planet Programme. Developed in direct response to issues identified by the scientific community, they aim to improve our understanding of how the Earth system works and the impact human activity is having on natural Earth processes. Earth Explorers are also designed to demonstrate breakthrough technology and remote sensing techniques and, together with the scientific questions addressed, form the basis for the development of new applications for Earth observation data.

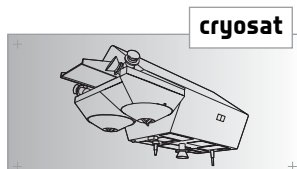
As a result of the continuing, user-driven approach for realising Earth Explorers, six missions have been selected so far for implementation:



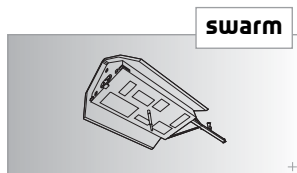
GOCE (Gravity field and steady-state Ocean Circulation Explorer) Launched in March 2009, GOCE is dedicated to measuring Earth's gravity field with unprecedented accuracy and spatial resolution. The resulting model of the geoid – the surface of equal gravitational potential defined by the gravity field – will advance our knowledge of ocean circulation, sea-level change and Earth-interior processes. GOCE will also make significant advances in geodesy and surveying.



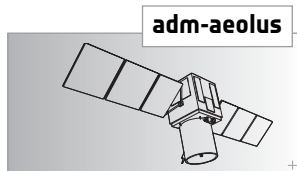
SMOS (Soil Moisture and Ocean Salinity) Launched in November 2009, SMOS is making global observations of soil moisture over landmasses and salinity over the oceans. The data will result in a better understanding of the water cycle and, in particular, the exchange processes between Earth's surfaces and the atmosphere. Data from SMOS will help to improve weather and climate models, and also have practical applications in areas such as agriculture and water resource management.



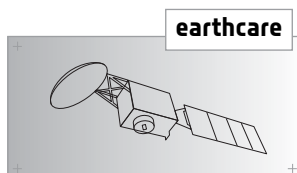
CRYOSAT The first mission to be selected, CryoSat will determine variations in the thickness of floating sea-ice so that seasonal and interannual variations can be detected. The satellite will also survey the surface of continental ice sheets to detect small elevation changes. Information on precise variations in ice thickness will further our understanding of the relationship between ice and climate change. The CryoSat-2 satellite replaces the original CryoSat, which was lost due to a launch failure in October 2005.



SWARM Swarm is a constellation of three satellites to provide high-precision and high-resolution measurements of the strength and direction of Earth's magnetic field. The models of the geomagnetic field resulting from the mission will provide new insights into Earth's interior, further our understanding of atmospheric processes related to climate and weather, and will have practical applications in areas such as space weather and radiation hazards.



ADM-AEOLUS (Atmospheric Dynamics Mission) Aeolus will be the first space mission to measure wind profiles on a global scale. The mission will improve the accuracy of numerical weather forecasting and advance our understanding of atmospheric dynamics and processes relevant to climate variability.



EARTHCARE (Earth, Clouds, Aerosols and Radiation Explorer) EarthCARE is being implemented in cooperation with the Japan Aerospace Exploration Agency. The mission addresses the need for a better understanding of the interactions between clouds and the radiative and aerosol processes that play a role in climate regulation.

Further information about ESA's Earth Explorer missions can be obtained via:
www.esa.int/livingplanet





SMOS: ESA'S WATER MISSION

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→ 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.



Scale showing different amounts of moisture in soil (top) and salinity in water (bottom). The scale gives an indication of how moisture in soil varies with land type and how salinity in water varies – from a fresh mountain spring to the Dead Sea.

The amount of water held in 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, for example, severe drought can result in hard, dry, cracked soil, while floods and landslides are a consequence of very heavy rainfall. Less obvious perhaps, is the fact that some parts of 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 – 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 holds only a small percentage of the total global water budget, soil moisture plays an important role in the water cycle. Currently, there are relatively few precise in situ measurements of soil moisture, but if we are to understand the water cycle better so that the forecasting of weather and climate can be improved, global datasets are urgently required. The same goes for sea-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, which in turn is an important factor driving ocean currents. 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.

The Soil Moisture and Ocean Salinity (SMOS) mission – also known as ESA's Water Mission – has been designed to make observations of soil moisture over Earth's landmasses and salinity over the oceans for a period of at least three years. Data from SMOS will result in global soil moisture maps at least every three days and maps of ocean salinity at least every 30 days.

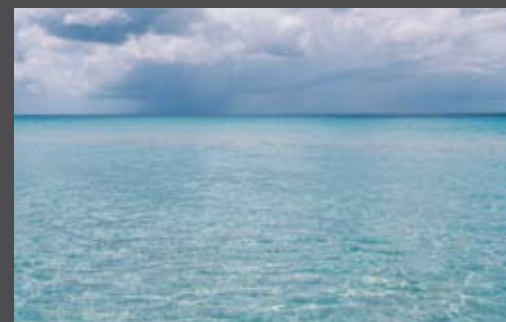
An important aspect of this mission is that it will demonstrate a completely new measuring technique. A novel instrument has been developed that is capable of observing both soil moisture and ocean salinity by capturing images of emitted microwave radiation around the frequency of 1.4 GHz/ wavelength of 21 cm (L-band). SMOS carries the first polar-orbiting spaceborne 2D interferometric radiometer.

SMOS is one of a series of ESA's Earth Explorer missions, which are developed in direct response to scientific challenges

identified by the science community. The SMOS mission has been developed because of the need for global observations of soil moisture and ocean salinity to improve our knowledge of the water cycle and understand more about how a changing climate may be affecting patterns of evaporation over the ocean and land. Data on salinity in the surface waters of the oceans will advance our knowledge of ocean circulation. As a secondary objective, SMOS could provide observations over cold regions, 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 Water Cycle

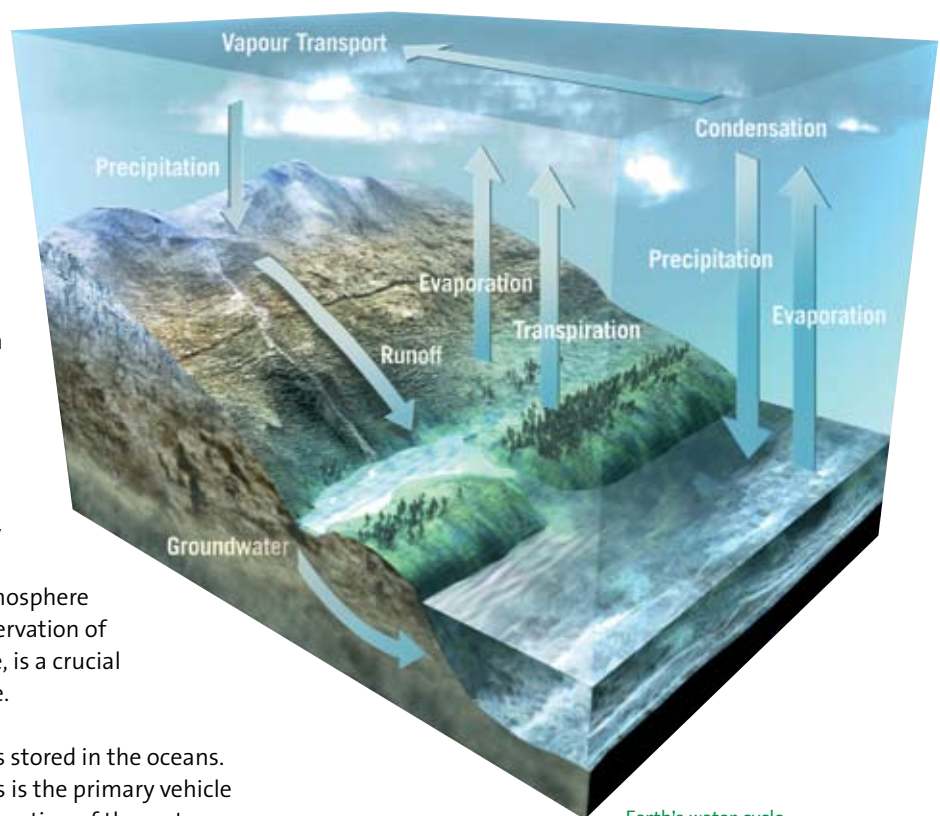
Water is the source of all life on Earth. It is the only known substance that can exist naturally as a gas, liquid and solid within the relatively small range of air temperatures and pressures found on the surface of Earth. The total amount of water present on Earth is fixed and does not change. However,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

In general, soil moisture refers to the water held in the spaces between soil particles. Moisture stored in surface soils is an important component of the water cycle as it is crucial for regulating water and energy exchanges between the land and lower atmosphere. Therefore, as a variable in the weather and climate system, soil moisture has long been of interest to hydrologists, soil scientists, meteorologists and ecologists.

There is a direct link between soil moisture and atmospheric humidity because dry soil can contribute little or no moisture to the atmosphere and saturated soil can contribute 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 through



Earth's water cycle

continued 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 with high soil moisture raise atmospheric humidity and 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.

In most parts of the world, the amount of water present in the soil is the dominant factor that affects plant growth and crop yield. Through the process of photosynthesis and respiration, plants regulate carbon dioxide gas exchanges from and to the atmosphere – and this process is fundamentally controlled by water available to the plants.

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



DID YOU KNOW?

The highest recorded sea-surface salinities of around 40 practical salinity units (psu) are found in the Red Sea. However, the Dead Sea is the saltiest sea on Earth. High evaporation and the fact that it is an enclosed sea have led 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 25°N and 35°S, 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 km³ of water evaporates from the ocean each year, to return as precipitation on land and sea.

There is enough salt in the oceans to make a block of salt about 100×100×100 m 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 central region of this desert, even cyanobacteria, which are green photosynthetic micro-organisms that live in rocks or under stones in most other deserts, are absent.

About one-third of 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 – 4000 years
- Soil moisture – 2 weeks to 1 year
- Ground water – 2 weeks to 10 000 years

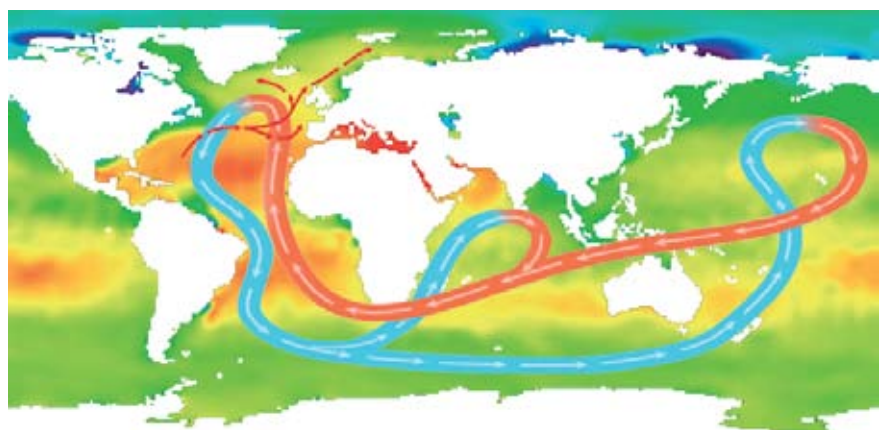
evaporation and precipitation, so that, although seawater has an average salinity of 35, the salinity of surface waters in the open ocean typically ranges from 32 to 38. Salinity is at a maximum in subtropical latitudes, where evaporation exceeds precipitation – these regions correspond to deserts that exist at similar latitudes on land. Surface waters are generally less saline around the equator because rainfall exceeds evaporation, and also towards higher latitudes due to rain, snowfall and ice melt.

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, salinity increases and the surface layer becomes denser. In contrast, precipitation leads to a reduction in density and stratification of the ocean. The processes of seawater freezing and melting are also responsible for the salinity of the polar oceans increasing and decreasing, respectively. As sea ice grows during the winter, the freezing process extracts fresh water from the oceans and forms ice, leaving behind dense, cold, salty surface water.

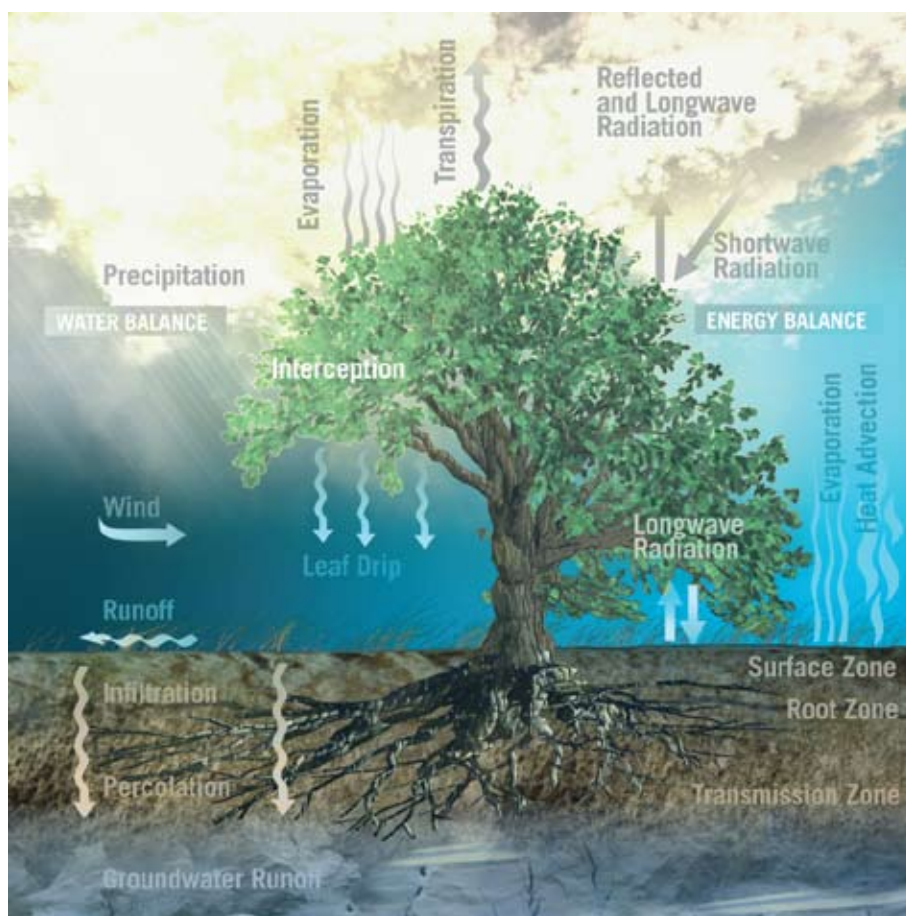
If the density of the surface layer of seawater increases sufficiently, the water column becomes gravitationally unstable and the denser water sinks. Vertical circulation in the oceans is a key component of the temperature- and salinity-driven global ocean circulation known as the 'thermohaline circulation'.

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

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. The red arrow flowing northwards indicates the surface waters of the Gulf Stream and North Atlantic Drift.



→ WHY MEASURE MOISTURE AND SALINITY?

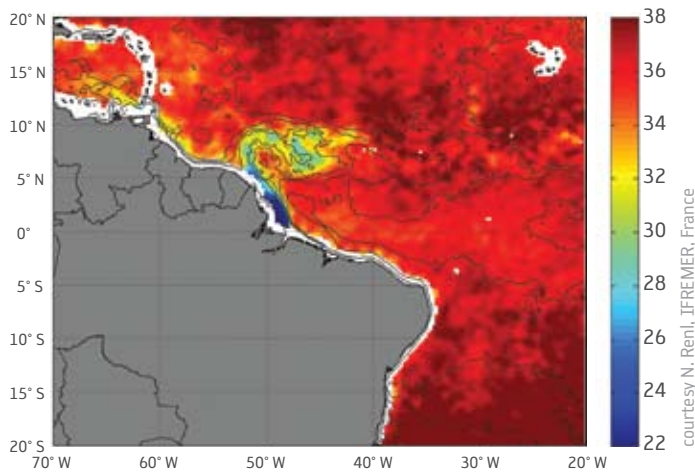


Energy and water balance of the physical climate system including the terrestrial and atmospheric components of the water cycle.

Water in the soil and salt in the oceans may seem to be unconnected, but in fact they are both key variables linked to Earth's water cycle, affecting weather and climate. Currently, there are relatively few global datasets on either soil moisture or ocean salinity but the SMOS mission will fill this gap by providing much-needed observational data on both variables from space. This information will not only improve our understanding of the water cycle, but will also lead to an advance in weather and climate modelling. Data on soil moisture will also be useful for applications in areas such as agriculture and water resource management.

Soil moisture is a critical component in temperature, humidity and precipitation forecasts. SMOS will provide a global image of surface-soil moisture every three days. These data, along with numerical modelling techniques, will result in estimates of water content in soil down to depths of one to two metres. This layer is referred to as the 'root zone', which is the reservoir from which plants can extract water and eventually release it to the atmosphere through the leaves by the process of transpiration.

The estimation of soil moisture in the root zone is paramount for improving short- and medium-term meteorological forecasting,



Example of sea-surface salinity measured from space in 2003 with the C- and X-band channels of the Advanced Microwave Scanning Radiometer – Earth Observing System (AMSR-E). The image shows how the vast amounts of freshwater flowing from the Amazon and Orinoco rivers dilute the salinity of the surface ocean waters. This kind of observation will be improved with the L-band radiometer carried on SMOS.

Sea-surface salinity is closely correlated with 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.

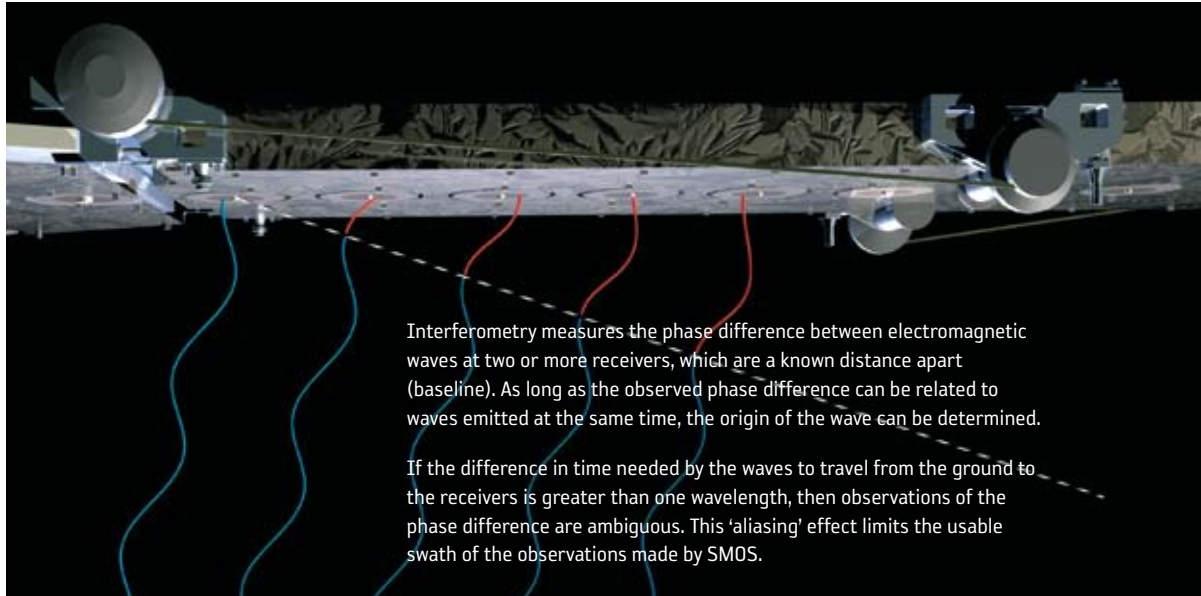
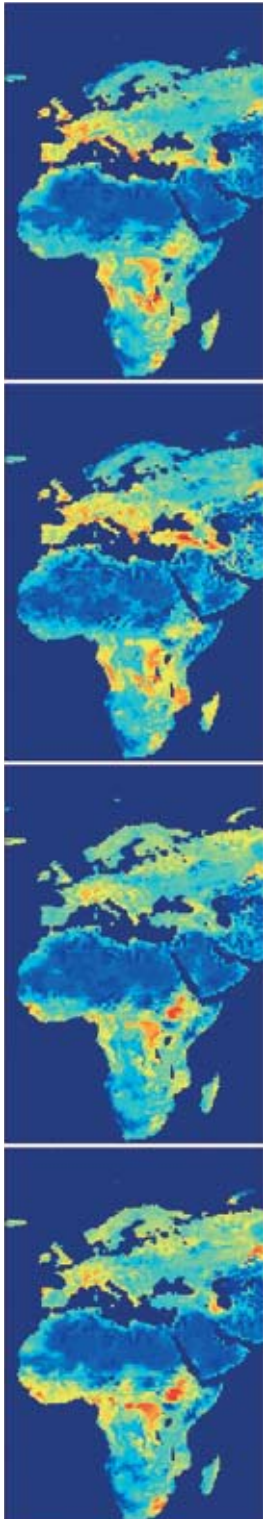
The ($E - P$) balance is difficult to measure accurately over the ocean with conventional means, so satellite-based maps of ocean salinity will provide a tool for more accurate ($E - P$) estimates on a global scale. This will allow for better insight into the process driving the thermohaline part of ocean circulation and better estimates of heat flux from the oceans to Example of sea-surface salinity measured from space in 2003 with the the atmosphere, leading to better atmospheric forecasts.

hydrological modelling, monitoring of photosynthesis and plant growth, and estimating and monitoring the terrestrial carbon cycle. Timely estimates of soil moisture are also important for contributing to the forecasting of hazardous events such as floods, droughts and heat waves.

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 salty waters of the Gulf Stream transport heat from the Caribbean to the Arctic. 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.



→ 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 'aliasing' effect limits the usable swath of the observations made by SMOS.

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.

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

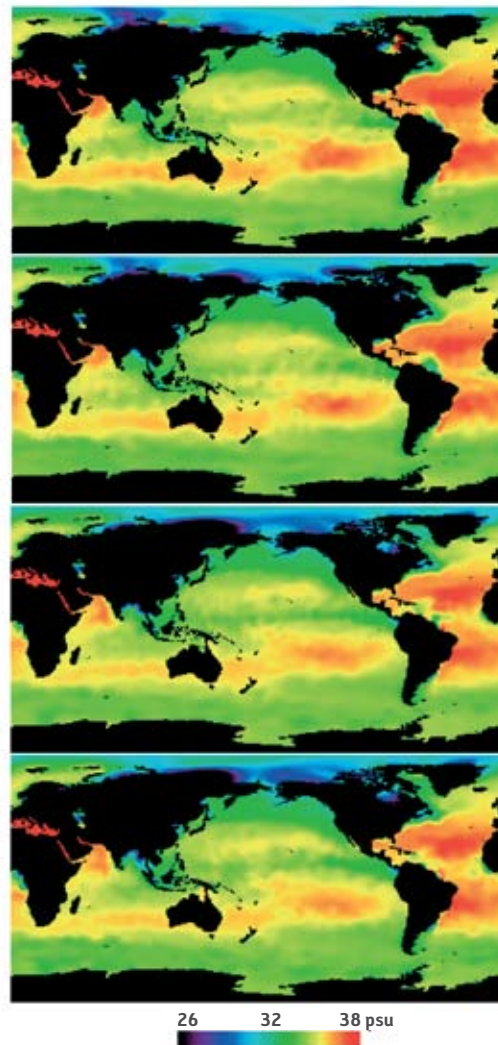
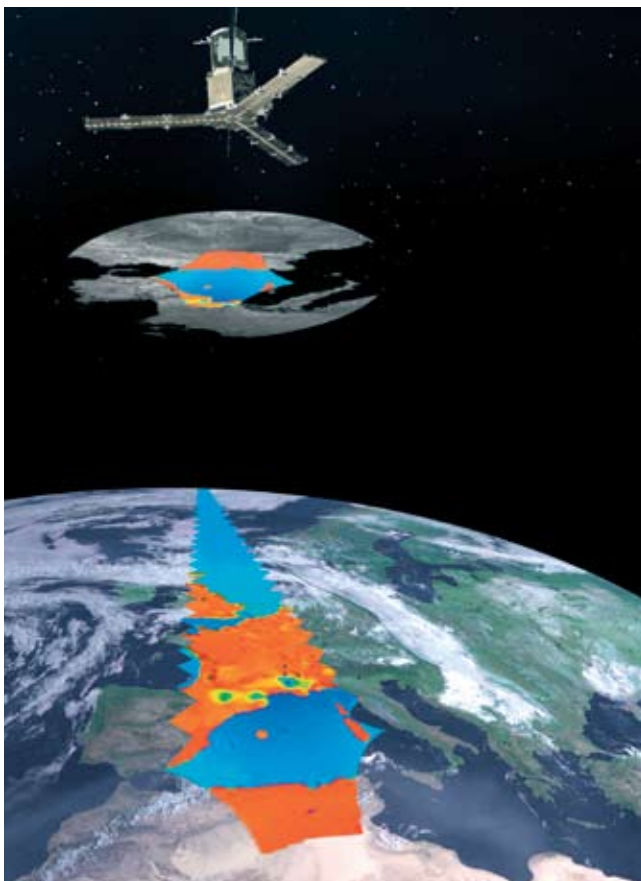
The key to being able to measure both components using one technique is related to the fact that both moisture and salinity strongly affect the electrical properties of matter. All matter emits energy in the form of electromagnetic radiation. However, the amount of radiation that can be emitted from any material depends on the electrical properties of that material. A material can be defined as having a certain value of 'emissivity' and this describes 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.

For optimum results, SMOS will measure microwave energy emitted from Earth's surface at L-band, which has a frequency of 1.4 GHz/wavelength of 21 cm. 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 Earth in the L-band microwave range, a rotating antenna measuring tens of metres across would normally be required to achieve adequate coverage and spatial resolution. However, for a satellite, 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 measurement area on the ground is observed under a range of viewing angles by each antenna receiver.

From an altitude of about 758 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. Given the SMOS orbit, this will result in global coverage every three days.

In summary, this novel measuring technique means that SMOS is the first dedicated 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 sea-surface salinity is to simulate the data using complex computer models.

Moisture is a measure of the amount of water within a given quantity of material and is usually expressed as a gravimetric or volumetric percentage. Values of soil moisture can range from a few percent in dry areas to around 40% in damp conditions. From space, the SMOS instrument can measure volumetric moisture in surface soil within an accuracy of 4% at a spatial resolution of about 50 km – which is the same as being able to detect a teaspoon of water in a handful of soil. Global data coverage will be obtained every three days.

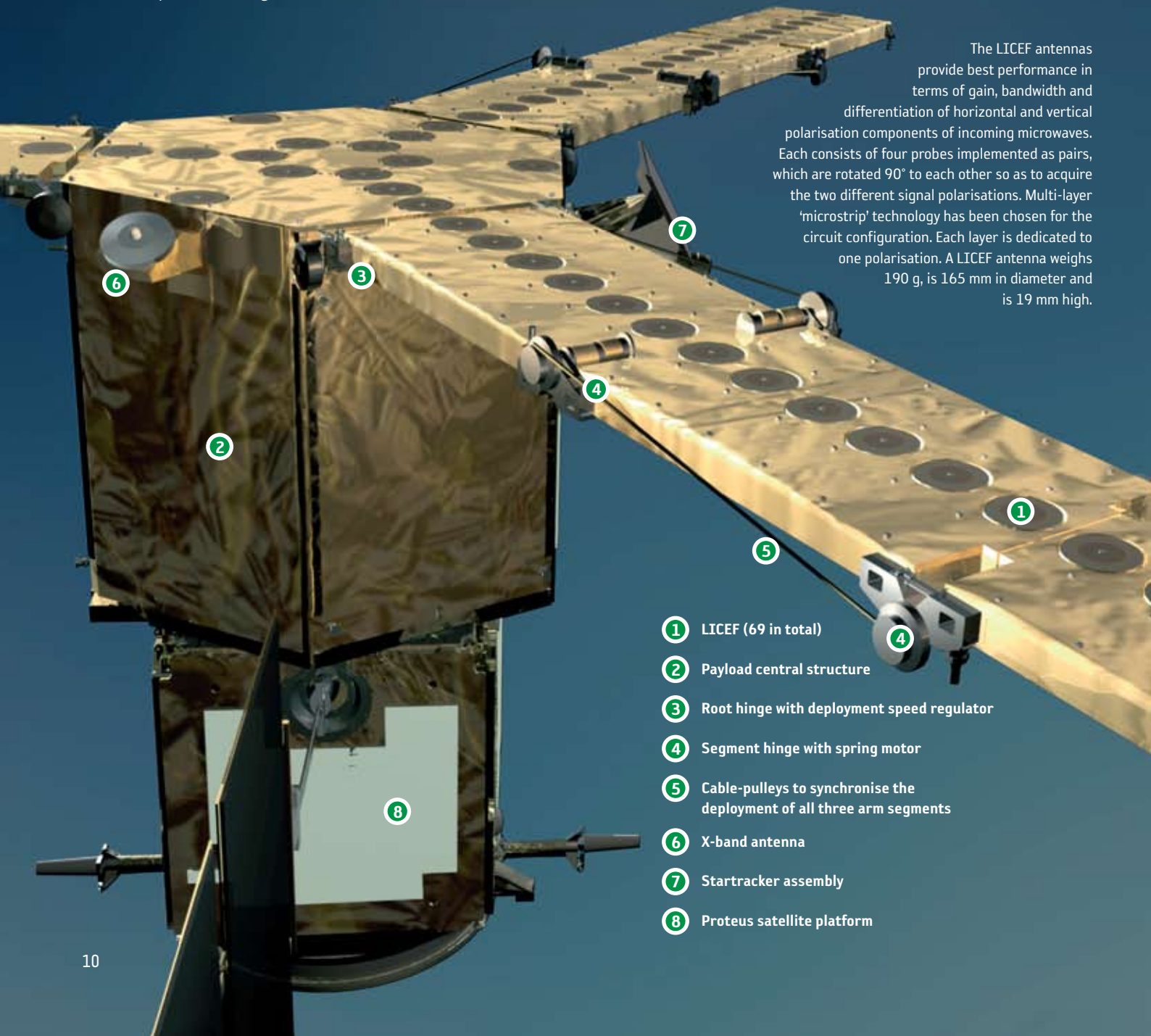
Salinity describes the concentration of dissolved salts in water. It is measured in practical salinity units (psu), which expresses a conductivity ratio. The average salinity of the oceans is 35 psu, which is equivalent to 35 grams of salt in 1 litre of water. SMOS aims to observe salinity down to 0.1 psu (averaged over 10–30 days and an area of 200x200 km) – which is about the same as detecting 0.1 gram of salt in a litre of water.

→ THE INSTRUMENT

One of the biggest challenges faced by the SMOS mission is to fly and demonstrate a completely new type of instrument – an interferometric radiometer that operates between 1.400 GHz and 1.427 GHz (L-band). In order to achieve the spatial resolution required for observing soil moisture and ocean salinity, the laws of physics mean that a huge antenna would have been needed. The solution was to synthesise the antenna aperture through a multitude of small antennas.

After more than 10 years of research and development, with the objective of demonstrating key instrument performances such as antenna deployment and image validation, the innovative SMOS instrument, called MIRAS (Microwave Imaging Radiometer using Aperture Synthesis), is mature enough for the mission. EADS (European Aeronautic Defence and Space) CASA Espacio, Spain is the Prime Contractor for MIRAS.

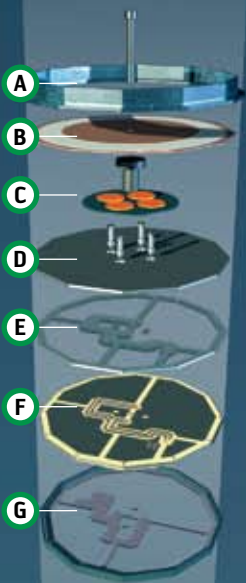
The LICEF antennas provide best performance in terms of gain, bandwidth and differentiation of horizontal and vertical polarisation components of incoming microwaves. Each consists of four probes implemented as pairs, which are rotated 90° to each other so as to acquire the two different signal polarisations. Multi-layer 'microstrip' technology has been chosen for the circuit configuration. Each layer is dedicated to one polarisation. A 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 Startracker assembly
- ⑧ Proteus satellite platform



LICEF antenna



- A**
- B**
- C**
- D**
- E**
- F**
- G**

- 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 called LICEF receivers, which are equally distributed over the three arms and the central structure. Each LICEF is an antennareceiver integrated unit that measures the radiation emitted from 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. In dual polarisation mode, the LICEF antennas are 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 acquires both polarisations simultaneously. The advantage of this enhanced mode is that it provides additional scientific revenue; however, the quantity of data that has to be transmitted to the ground is doubled. Only flight experience will show whether the dual-polarisation mode satisfies

the scientific mission objectives, or whether MIRAS will be continually 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 of 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-optic 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 startrackers.

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. In backup mode, this is executed autonomously using onboard GPS information.

→ THE SATELLITE



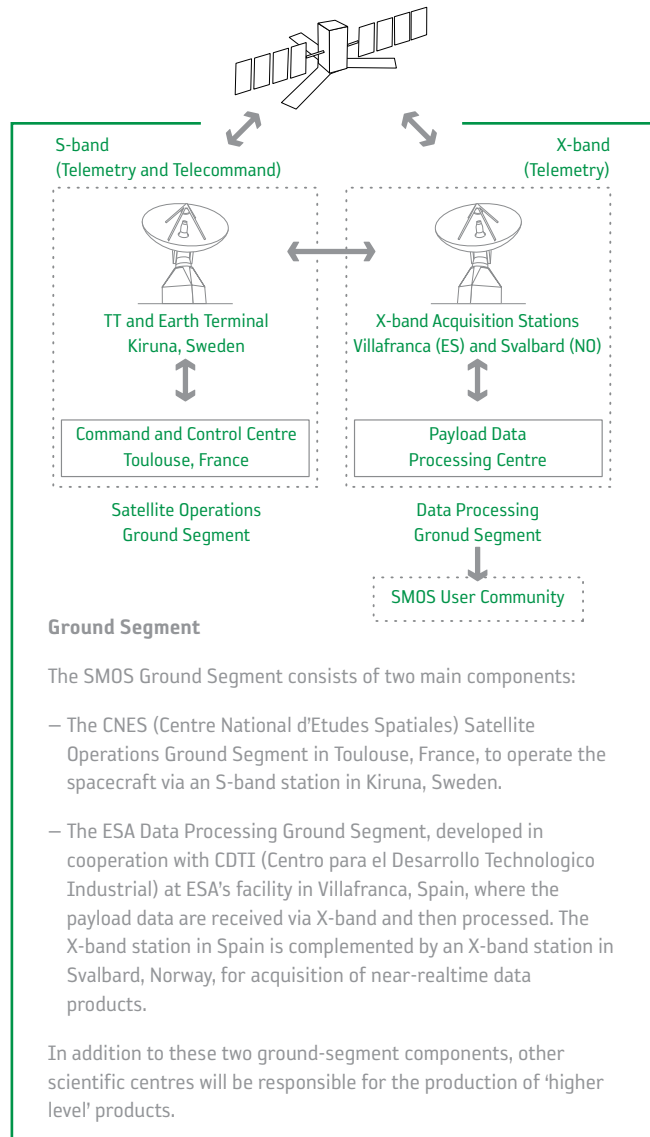
The SMOS payload is carried on a standard 'satellite bus' called Proteus, developed by the French space agency Centre National d'Etudes Spatiales (CNES) and Thales Alenia Space in France. Since Proteus is a generic platform with well-defined interfaces, it has taken just a little tailoring and four interface pods to mount the SMOS scientific instrument on the satellite.

Although the satellite bus is small, occupying just one cubic metre, it acts as a service module accommodating all the subsystems required for the satellite to function. The SMOS satellite was connected to the Rockot launcher via an interface ring. After launch, when the satellite separated from the launcher, there was an automatic start-up sequence, which resulted in the deployment of two symmetrical solar array wings. SMOS is in a low Earth, polar orbit at an altitude around 758 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 m. Since the orbit is Sun-synchronous, the wings remain static once SMOS has reached its final orbit and attitude.

The platform's 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. It also has a hydrazine monopropellant system with four 1-N thrusters mounted on the base of the satellite. Attitude control is based on a gyro-stellar concept. The startracker assembly is accommodated on the payload and provides accurate attitude information for both the instrument



Launch Vehicle

SMOS was launched on a modified Russian Intercontinental Ballistic Missile (ICBM) SS-19 launcher. 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. ESA's Proba-2 (Project for On-Board Autonomy-2) was launched along with SMOS. Proba-2 serves as a testbed for 17 new technological developments and carries experiments to observe the Sun and contribute to research into space weather.



The SMOS payload and Proteus platform in the cleanroom at Thales Alenia Space in Cannes, France

Solar-array panels

S-band antenna

GPS antenna

GPS antenna

Startracker assembly

Payload central structure

X-band antenna

Satellite-to-launcher interface adapter

Hydrazine thrusters

S-band antenna

Coarse Sun sensors (one on each corner)

Solar-array panels

measurements and the satellite attitude control. Three two-axis gyros are used to measure the change in the satellite's 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 three-axis magnetometers and eight coarse Sun sensors, while magnetotorquers serve as the only actuators.

The electrical onboard 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 communication with the ground segment and provides the power distribution to all of the 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 the auxiliary satellite data that are needed by the payload for the scientific measurements.

→ TUNING IN FOR SMOS

University of Valencia, Spain



Taking calibration measurements of sea-surface salinity and temperature in the Mediterranean Sea. Simultaneous measurements were taken from a campaign aircraft flying overhead.



courtesy Y. Kerr, CESBIO

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.

Radiation observed by SMOS is not just a function of moisture in the soil and salt in the oceans. To ensure that data from the mission are correctly converted into units of moisture and salinity, many other effects that influence the signal received by the satellite need to be carefully accounted for.

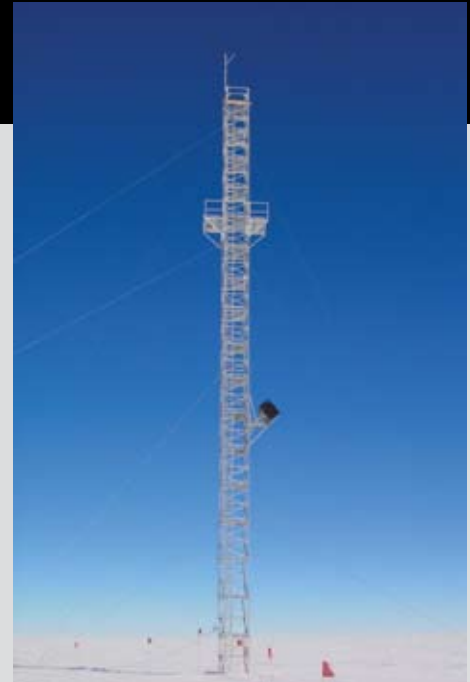
For instance, changes occurring in the ionosphere and atmosphere while the signal travels from the ground to the satellite need to be considered. On the surface of Earth, geophysical variables such as vegetation and seasonal variability, soil type, surface roughness, dew and frost all influence the measurement signal. Temperature variations of the land and sea surface also have an impact, as do the effects of waves and foam in the ocean.

Consequently, the full 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 to ensure that the soil moisture and ocean salinity data are as accurate as possible. This means that various studies accompanied by dedicated campaign activities, which involve taking many measurements on the ground and from aircraft, are carried out to simulate and evaluate the data products.

For example, extensive fieldwork has been carried out from a drilling platform in the Mediterranean Sea to examine the relationship between radiation emitted from the sea surface at L-band (frequency 1.4 GHz/wavelength 21 cm) and how it changes under varying sea-state conditions as a consequence



The 'Skyvan' aircraft, which belongs to the Helsinki University of Technology from Finland, carries the Danish Technical University's EMIRAD L-band radiometer. The aircraft is being used in several campaigns carried out over Germany and Spain for soil moisture validation.



courtesy G. Macelloni, IFAC, CNR

Long-term observations of the ice-sheet surface have been conducted at Concordia station in Antarctica since 2005. The ice sheet in this area is very stable at 1.4 GHz, as proven by tower radiometer measurements during DOMEX-1 and the current DOMEX-2 experiment. This area will, therefore, be exploited for external calibration and monitoring the performance of MIRAS.

of different wind speeds, different wave types and varying foam coverage. In a number of campaigns, several instruments have been operated from aircraft, measurement towers and research platforms. Measurements have been taken over a range of targets such as forests, agricultural fields, mountains and ocean to retrieve soil moisture and ocean salinity information. In order to analyse the impact of wind on the retrieval of the microwave signal over oceans, a dedicated experiment flew a radiometer over the North Sea. Campaign activities have also been carried out on the polar plateau in eastern Antarctica, which has proven to be a very stable environment for calibrating and monitoring the SMOS instrument.

Many detailed results are obtained from these and other activities and are vital for fine-tuning the retrieval concept. This ensures that SMOS will provide the best data possible for soil-moisture and ocean-salinity retrieval. About 40 scientific teams around the world are contributing to the validation of SMOS data products.

→ SMOS OVERVIEW

SMOS will make global observations of soil moisture over Earth's landmasses and salinity over the oceans. The data will result in a better understanding of the water cycle and, in particular, the exchange processes between Earth's surfaces and the atmosphere. Data from SMOS will help improve weather and climate models, and also have practical applications in areas such as agriculture and water resource management.

Mission Details

Launch: 2009

Duration: Nominally three years (including a six-month commissioning phase) with an optional two-year extension

Mission Objectives

- Soil moisture
Accuracy of 4% volumetric soil moisture, spatial resolution of 35–50 km and revisit time of 1–3 days
- Ocean salinity
Accuracy of 0.5–1.5 practical salinity units (psu) for a single observation/0.1 psu for a 30-day average for an area of 200×200 km

Mission Orbit

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

Mean altitude: 758 km

Inclination: 98.44°

Payload

- 2D Microwave Imaging Radiometer with Aperture Synthesis (MIRAS) at L-band (1.4 GHz/21 cm)
- 69 receivers arranged along a Y-shaped deployable antenna array

Configuration

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

Mass

Total 658 kg, comprising:

- Proteus platform 303 kg (including 28 kg hydrazine fuel)
- MIRAS payload 355 kg

Power

- Maximum available for satellite: 1065 W
- Maximum consumption for MIRAS payload: 511 W
- Proteus platform battery: 78 Ah Li-ion

Satellite Attitude and Orbit Control

- 3-axis stabilised, 32.5° forward tilt in flight direction, local normal pointing and yaw steering
- Startrackers, gyros, magnetometers, GPS, Sun sensors
- Reaction wheels, magnetotorquers, 4 × 1-N 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

Onboard Storage

- 1 solid-state recorder, capacity 2 × 20 Gbits
- Payload data generated on board: 15.4 Gbits/day (full polarimetric mode)
- Payload data downlink via X-band in nominal mode – commanded from ground by mission planning system, in backup mode – autonomous, using onboard GPS information for ground station visibility

Communication links

- X-band downlink for science data to ESA's European Space Astronomy Centre (ESAC) in Villafranca, Spain, complemented by an X-band station in Svalbard, Norway, for acquisition of near-realtime data products;
- S-band uplink (4 kbps) and downlink (722 kbps) to Kiruna, Sweden, for satellite telemetry and telecommand (generic Proteus ground station)

Launch Vehicle

Rocket (converted SS-19) with Breeze-KM upper stage. Launch from Plesetsk Cosmodrome, Russia.

Flight Operations

Mission control from the CNES Proteus Control and Command Centre (CCC) in Toulouse, France via the CNES S-band ground station network – Kiruna in Sweden, Aussaguel in France and Kourou in French Guiana. Payload operations prepared by the Payload Operations Programming Centre (ESA) and executed via the CCC.

Data Processing

Data Processing Centre at ESAC, long-term archive at Kiruna, and User Services via ESA's Centre for Earth Observation ESRIN in Frascati, Italy

Payload Prime Contractor

EADS CASA Espacio (Spain)

Platform

Provided by CNES (France) through Thales Alenia Space (France)



Illustrations: AOES Medialab





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