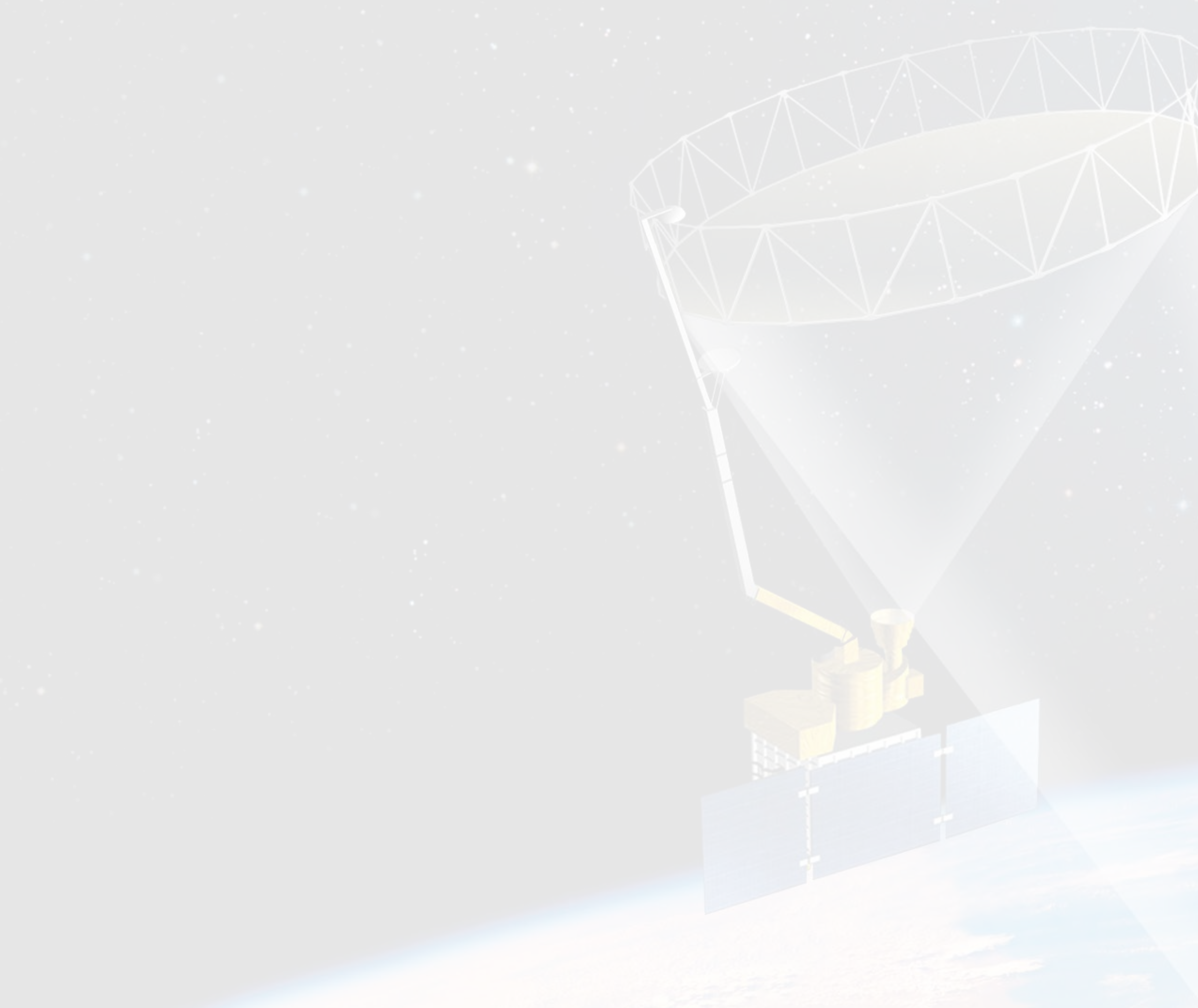
National Aeronautics and Space Administration

SMAP

Soil Moisture Active Passive

Mapping Soil Moisture and Freeze/Thaw State from Space



Acknowledgments

Soil Moisture Active Passive
smap.jpl.nasa.gov

Special thanks to all who have worked so hard on the Soil Moisture Active Passive (SMAP) mission for making this publication possible.

Content: Heather Hanson, Brian Campbell
Design: Kevin Miller

Cover image: Artist’s conception of the SMAP observatory in Earth orbit. SMAP’s two instruments, an L-band radiometer and an L-band radar, share a single 6-m rotating mesh reflector to produce conically-scanned data at a constant incidence angle of 40°. The SMAP configuration enables global maps of soil moisture to be obtained every 2-3 days.

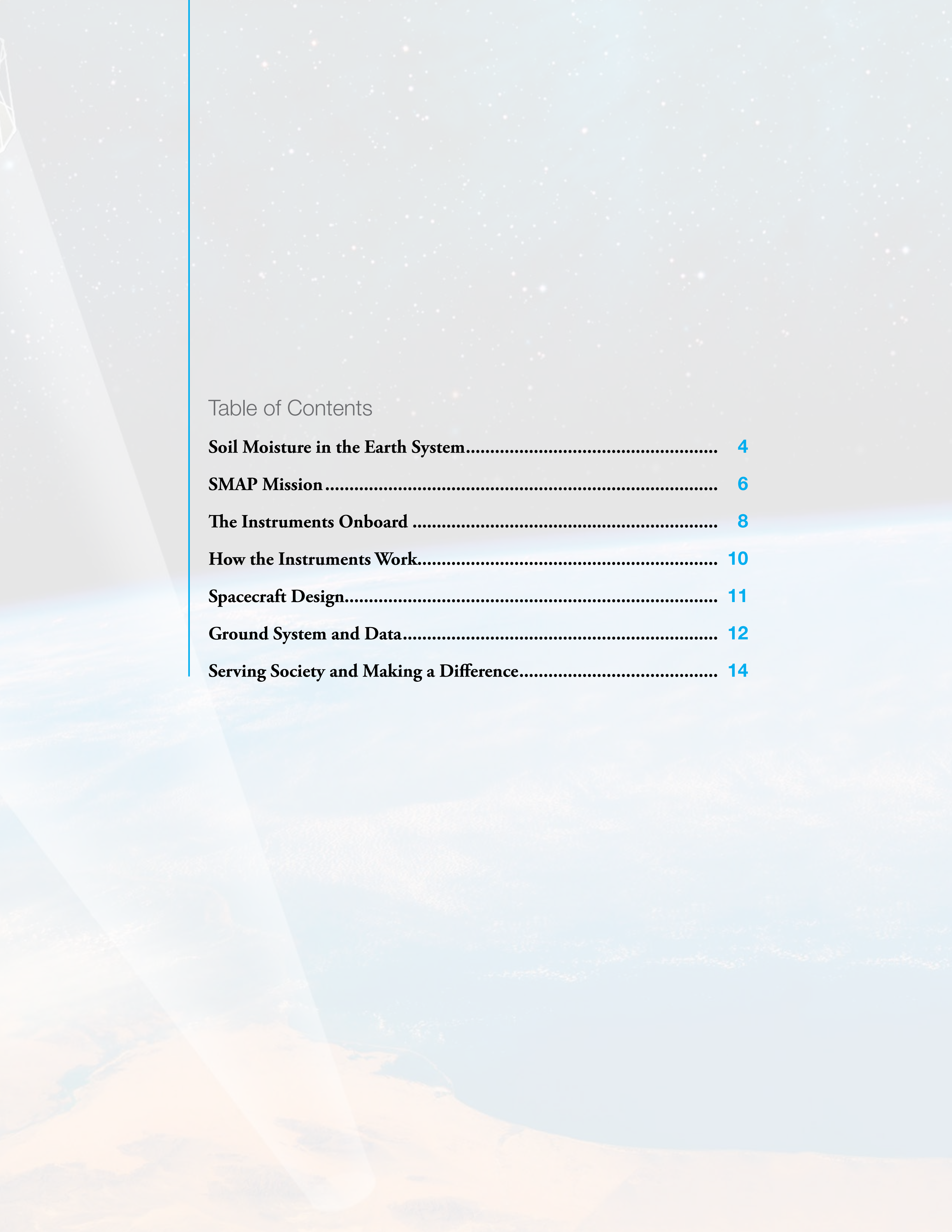


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Photo credit: Ronnie

Soil Moisture in the Earth System

Photo credit: Pat Dumas

Soil. It is one of our planet's most useful natural resources. Important processes occur in soil that help sustain life on Earth such as the absorption, infiltration, storage, and release of water. In addition, soil provides a haven for organic nutrients; a place for plants to grow; habitats for animals; and a medium for gas exchange (e.g., carbon dioxide, methane, and water vapor) between the land and atmosphere.

Water is one of the most important components of soil, but the volume of water contained within a given volume of soil—or *soil moisture*—can fluctuate annually, seasonally, daily, and even hourly, due to changes in water availability from precipitation, irrigation, and evaporation from the soil and plants. To better understand changes in the amount of water stored and released between the land and atmosphere, scientists study soil moisture conditions as well as whether or not the water contained within the soil is frozen or thawed—called its *freeze/thaw state*.

Soil moisture and its freeze/thaw state are key components to understanding Earth's water, energy, and carbon cycles, and also impact weather

Image credit: stellets

Variations in soil moisture influence weather by affecting the availability of moisture to form clouds and rain, which subsequently impacts a region's flood or drought potential.

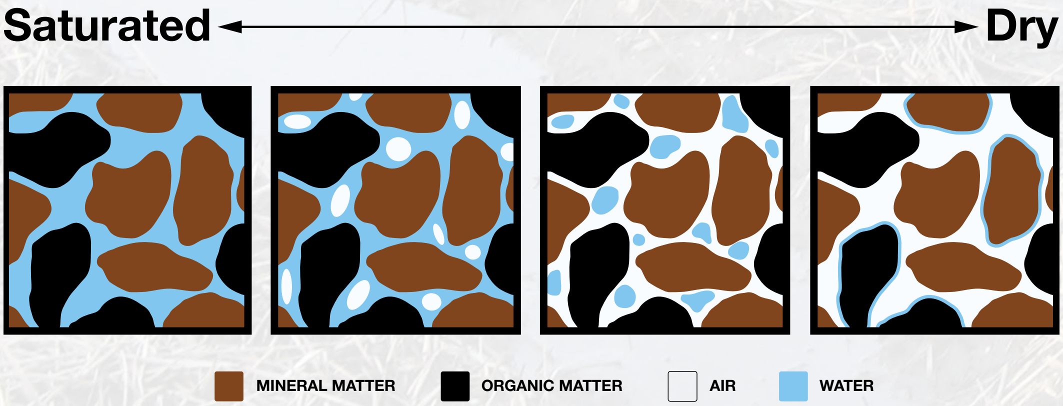


Image credit: NASA

Soil is made up of four main components: mineral matter, organic (carbon-based) material, air, and water. This graphic depicts relative soil moisture conditions from saturated to dry. Note that even in the driest of soils there remains a very small amount of water in the pores—so tightly bound to individual soil particles that it is unavailable to plants.

and climate. Large amounts of energy are required to evaporate water from Earth's surfaces; therefore, soil moisture influences the global energy cycle and has significant impacts on surface energy fluxes. Similarly, soil moisture and its freeze/thaw state are key determinants of the global carbon cycle. For example, carbon uptake by forests in boreal regions in the Northern Hemisphere is influenced by the length of the active vegetation growing season between the spring thaw and winter freeze transitions. Variations in soil moisture also affect the evolution of weather and climate phenomena, particularly over continental regions, and contribute immensely to a region's flood or drought potential, which impacts agricultural productivity.

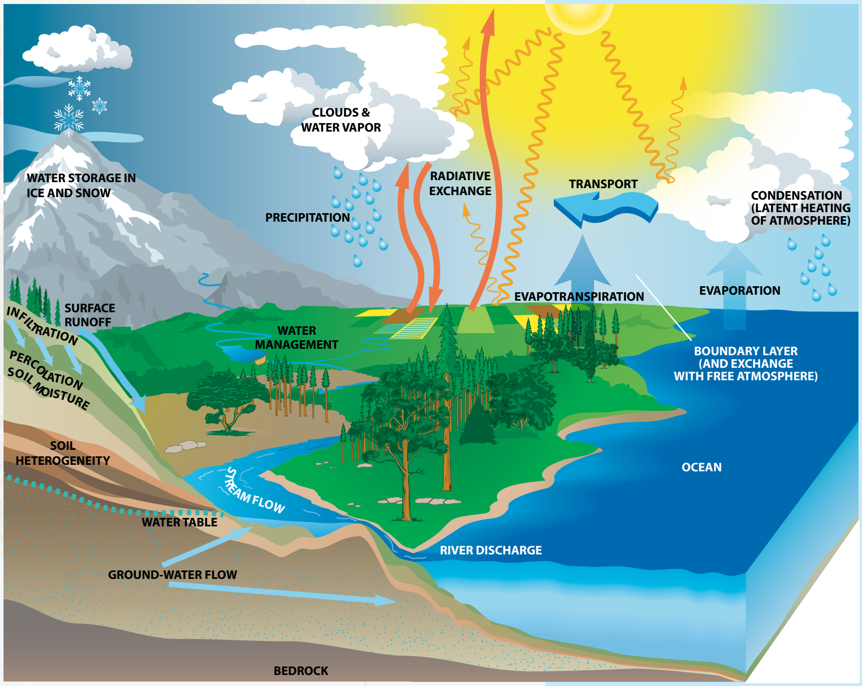


Image credit: NASA

The water cycle describes how water evaporates from the Earth's surface, rises into the atmosphere, cools, condenses to form clouds, and falls again to the surface as precipitation. About 75% of the energy (or heat) in the global atmosphere is transferred through the evaporation of water from the Earth's surface. On land, water evaporates from the ground, mainly from soils, plants (i.e., transpiration), lakes, and streams. In fact, approximately 15% of the water entering the atmosphere is from evaporation from Earth's land surfaces and evapotranspiration from plants. Such evaporation cools the Earth's surface, cools the lower atmosphere, and provides water to the atmosphere to form clouds.

While ground-based instruments can be used to obtain reliable measurements of soil moisture at specific locations, there are large gaps between instrument sites. Therefore they cannot be used to make measurements across large areas. Satellite observations from space, however, can cover broad areas and provide frequent measurements detailed enough to allow scientists to determine the amount of water contained within soil, as well as distinguish between frozen and non-frozen soil.

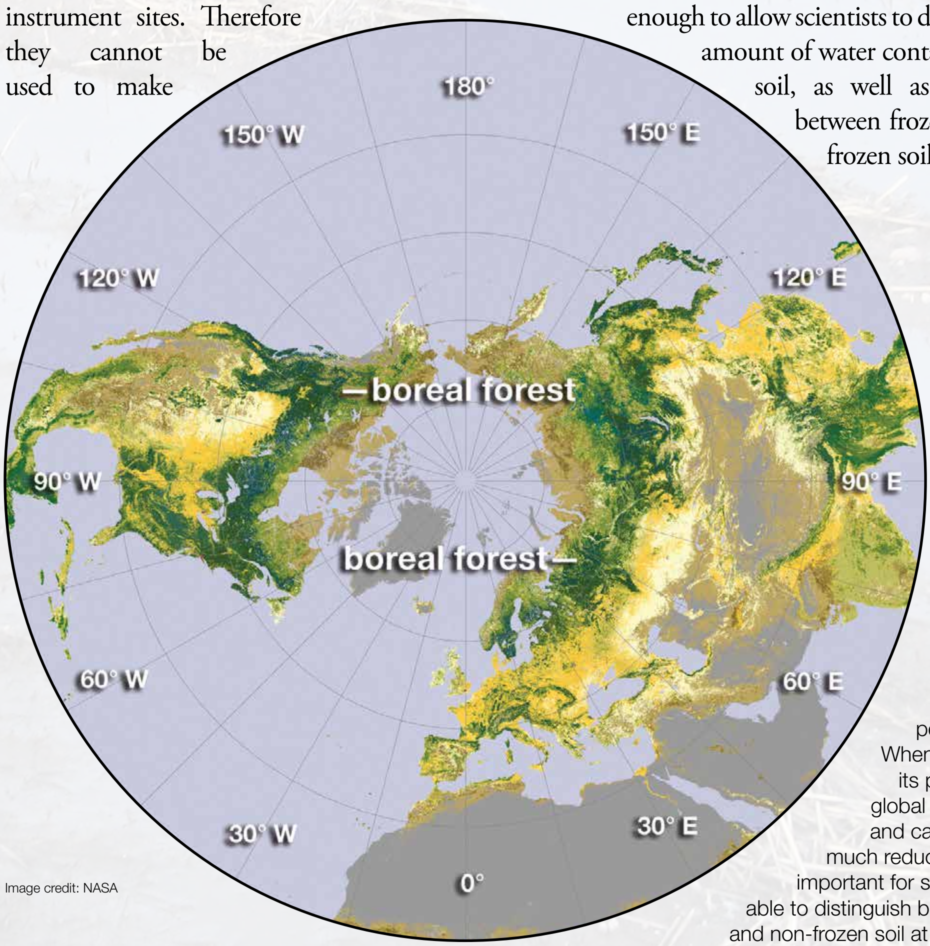


Image credit: NASA

This map highlights the location of the world's boreal forests in dark green. It is not uncommon for soil in these regions to become frozen for extended periods of time. When soil is frozen, its participation in global water, energy, and carbon cycles is much reduced. Thus, it is important for scientists to be able to distinguish between frozen and non-frozen soil at global scales.

SMAP Mission


Photo credit: Mike Beauregard

In addition to measuring soil moisture, SMAP will provide data on whether the water contained within the soil is frozen or thawed, focusing on the boreal zone at latitudes higher than 45° North latitude. Such data will help scientists home in on interannual shifts in the timing of soil freeze/thaw transitions.

SMAP Characteristics

Orbit	Near-polar, sun-synchronous
Altitude	685 kilometers (~425 miles)
Equatorial Crossing Time	18:00 hrs [6:00 AM (descending note) and 6:00 PM (ascending node)]
Inclination	98.12°
Orbit Duration	98.5 minutes
Repeat Cycle	8 days (exact orbit repeat)
Revisit	2-3 days

The Soil Moisture Active Passive, or SMAP, mission is NASA's first Earth-observing satellite mission designed to collect continuous global observations of surface soil moisture and freeze/thaw state every 2-3 days at 3 to 40 kilometer (~2 to 25 mile) spatial resolution. As suggested by the name "Active Passive," SMAP will carry an *active* microwave radar and a *passive* microwave radiometer that will measure across a 1000-kilometer (~621-mile) wide swath.

The ability to measure global soil moisture and its freeze/thaw state from space with unprecedented accuracy and spatial resolution will allow scientists to better understand the processes that link the Earth's water, energy, and carbon cycles, as well as enhance the predictive skills of weather and climate models. In addition, scientists can use these data to develop improved flood prediction and drought monitoring capabilities. Societal benefits include improved water-resource management, agricultural productivity, and wildfire and landslide predictions.

Data from SMAP are also expected to allow seasonal and interannual variations of soil moisture and freeze/thaw state to be more accurately predicted. These data will help quantify the nature, extent, timing, and duration of landscape seasonal freeze/thaw state transitions that are key to determining the length of the growing season and the resulting impact of a longer growing season on global water, energy, and carbon cycles, as well as other aspects of society. The ability to detect variations in the timing of spring thaw and the subsequent length of the growing season will also allow scientists to determine how much carbon plants absorb from the atmosphere each year, which is used to estimate terrestrial carbon sources and sinks and quantify net carbon flux. In addition, SMAP freeze/thaw state measurements will contribute to understanding how ecosystems respond to and affect global environmental change (i.e., climate change), improving regional mapping and prediction of ecosystem processes, particularly in boreal regions.

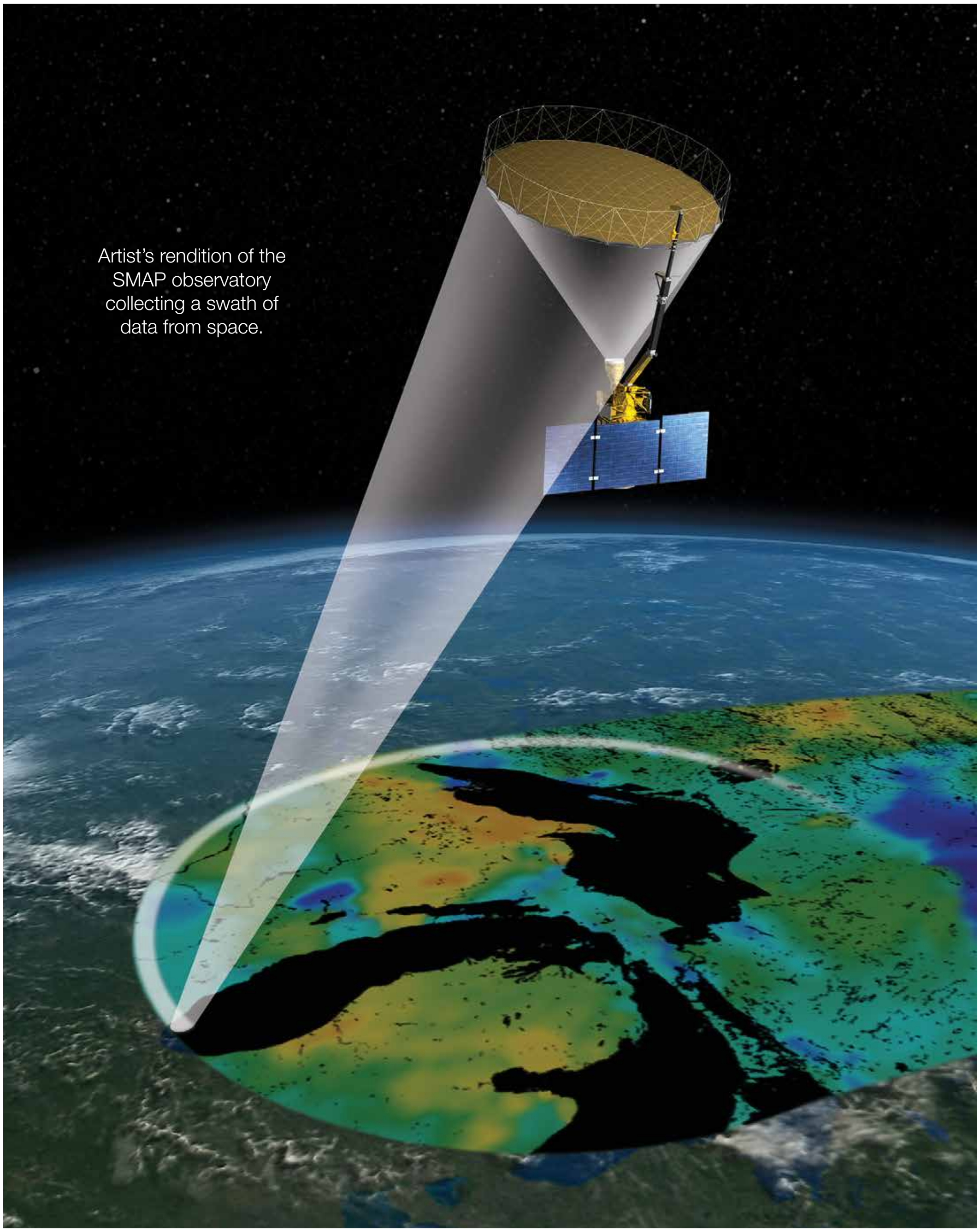
Implemented within the NASA Earth Systematic Mission Program, the SMAP project is managed by NASA's Jet Propulsion Laboratory (JPL) with participation from Goddard Space Flight Center (GSFC). JPL is responsible for project management, system engineering, and instrument management,


The SMAP observatory is scheduled to launch from Vandenberg Air Force Base near Lompoc, CA aboard a United Launch Alliance Delta II *7320-10C* in November 2014.

Image credit: United Launch Alliance

and will oversee mission operations and the ground data system. JPL also designed the radar instrument, and is responsible for science data processing and delivery of science data products to a designated archive for public distribution. Likewise, GSFC designed the radiometer instrument, and is responsible for science data processing of higher-level products.

The SMAP spacecraft is scheduled to launch from Vandenberg Air Force Base near Lompoc, CA aboard a United Launch Alliance Delta II *7320-10C* in November 2014. The spacecraft will be placed in a near-polar, sun-synchronous orbit 685 kilometers (~425 miles) above Earth, crossing the equator at both 6:00 AM (descending node) and 6:00 PM (ascending node).



Artist's rendition of the SMAP observatory collecting a swath of data from space.

Photo credit: NASA

SMAP Helps Fill a Critical Need for Information

The SMAP mission is one of four Tier-One missions recommended by the National Research Council's Committee on Earth Science and Applications from Space in 2007. Measurements from SMAP will provide high-resolution, frequent-revisit global mapping of soil moisture and freeze/thaw state that will enable science and applications users to:

Understand processes that link the terrestrial water, energy, and carbon cycles

•

Estimate global water and energy fluxes at the land surface

•

Quantify net carbon flux in boreal landscapes

•

Enhance weather and climate forecast capability

•

Develop improved flood prediction and drought monitoring capability

Photo credit: NASA

The Instruments Onboard

The instruments onboard SMAP consist of a passive L-band radiometer and active L-band radar, both with multiple polarizations. The L-band frequency enables observations of soil moisture through clouds and moderate vegetation cover both during the day and at night. Multiple polarizations allow for accurate soil moisture estimates to be made with corrections for vegetation, surface roughness, Faraday rotation (i.e., interactions between electromagnetic radiation and Earth's magnetic field), and other perturbing factors. Both instruments have also been designed to mitigate radio frequency interference, which comes from ground-based radars and microwave transmissions that can contaminate the L-band measurements.

The 1.41 GHz radiometer will measure the intensity of microwave radiation emitted from the Earth's surface (i.e., brightness temperature) to provide estimates of soil moisture at a spatial resolution of approximately 40 kilometers (~25 miles). Specifically, the radiometer will acquire measurements in four channels [vertical (V) and horizontal (H) polarization, and third and fourth Stokes parameters—parameters which represent the polarization state of electromagnetic radiation] with an antenna temperature precision better than 0.5 Kelvin.

The 1.26 GHz radar will transmit microwave radiation in two linear polarizations and measure the scene backscatter in multiple polarimetric channels to provide estimates of both soil moisture and freeze/ thaw state. Specifically, the radar employs *synthetic-aperture* as well as *real-aperture* radar processing, which will result in high-resolution (1-3 kilometer) and low-resolution (30 kilometer) radar data, respectively. Each channel will receive and transmit polarized radiation in different orientations: HH, VV, and HV or VH [HH stands for Horizontal Receive, Horizontal Transmit; VV stands for Vertical Receive, Vertical Transmit; HV stands for Horizontal Receive, Vertical Transmit; and VH stands for Vertical Receive, Horizontal Transmit]. The first two are referred to as co-polarized; the third and fourth are cross-polarized. Real-aperture radar measurements will be available in four channels (HH, VV, HV, VH), while synthetic aperture measurements will be available in three channels with one cross-polarized channel left out.

Observations from the radiometer will yield high soil moisture accuracy with coarse spatial resolution, while observations from the radar will yield high spatial resolution with lower soil moisture accuracy. By combining observations from the radiometer and radar, scientists will be able to provide estimates of soil moisture in the top

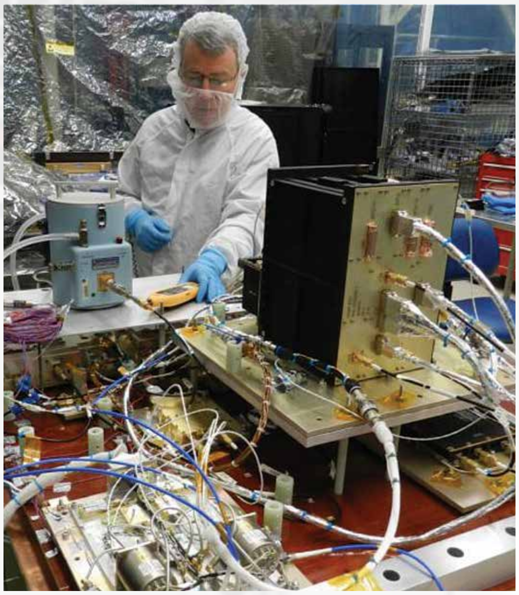


Photo credit: NASA/ Cheryl Albert

A quality assurance engineer at NASA's Goddard Space Flight Center performs instrument tests on the spacecraft's radiometer.

5 centimeters (~2 inches) of soil at 9-kilometer (~6 mile) spatial resolution in 3-day intervals—excluding regions of snow and ice, frozen ground, mountainous topography, open water, urban areas, and dense vegetation such as tropical forests (i.e., areas with vegetation water content greater than approximately 5 kilograms per meter squared).

Soil freeze/thaw state will be determined using data from the radar only at 3-kilometer spatial resolution in 2-day intervals. The high-resolution radar data are critical for accurate determination of freeze/thaw state in the heterogeneous landscapes of the boreal region north of 45° North latitude.

Photo credit: NASA/JPL-Caltech

In the cleanroom at NASA's Jet Propulsion Laboratory, NASA Administrator Charles Bolden [*left*] learns about the SMAP radar instrument assembly from a flight system engineer [*right*].

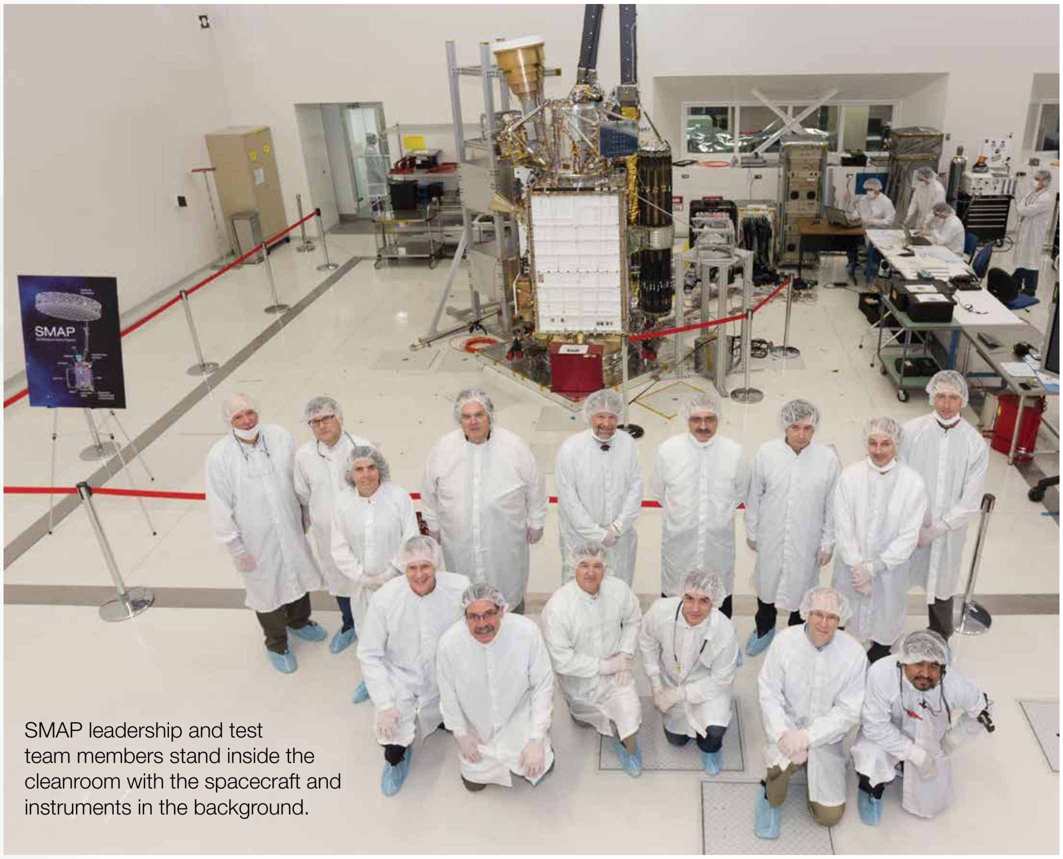


Photo credit: NASA

SMAP leadership and test team members stand inside the cleanroom with the spacecraft and instruments in the background.

Instrument Overview

Radar

Frequency

1.26 GHz
(tunable between 1.215 and 1.300 GHz)

Polarizations

VV, HH, HV or VH
(not fully polarimetric; cross-polarized channel selectable on orbit)

Relative accuracy (3 km grid)

1 dB (HH and VV),
1.5 dB (HV)

Data acquisition

- High-resolution (synthetic-aperture radar) data acquired over land
- Low-resolution data acquired globally

Radiometer

Frequency

1.41 GHz

Polarizations

H, V, 3rd & 4th Stokes

Relative accuracy (36 km grid)

1.3 K

Data acquisition

- High-rate (sub-band) data acquired over land
- Low-rate data acquired globally

How the Instruments Work

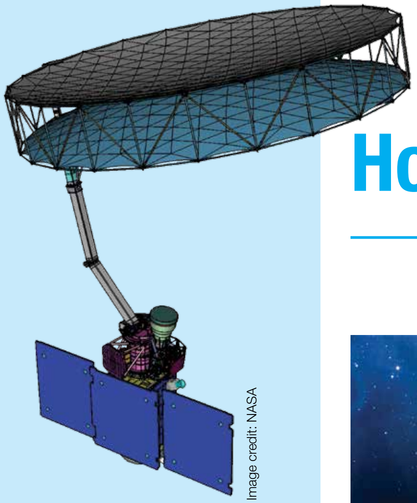


Image credit: NASA

This diagram shows the feedhorn, radar, radiometer, and spinning mesh reflector aboard the SMAP spacecraft. The radiometer is mounted on the spinning-instrument platform, while the radar is mounted to the non-spinning interior of the anti-sun spacecraft panel to reduce spin momentum.

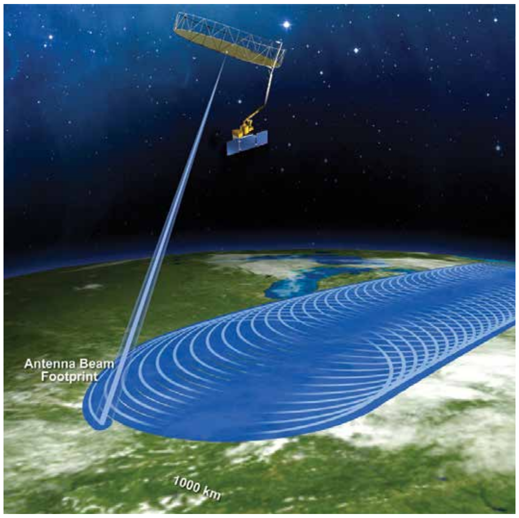
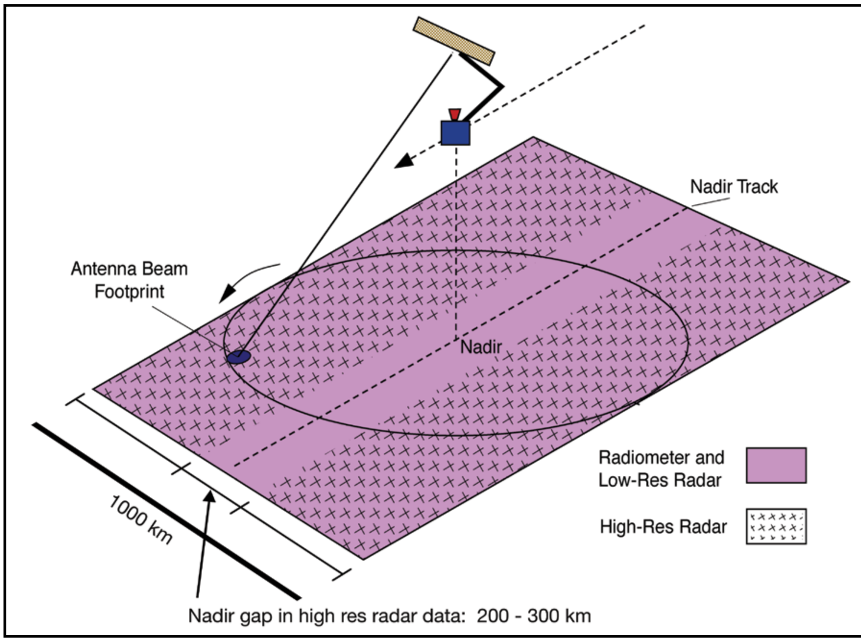


Image credit: NASA

Schematic of the SMAP conically-scanning antenna beam mapping out a swath width of 1000 kilometers at the Earth's surface. The light blue depicts the antenna bore-sight direction, while the dark blue depicts the 3 dB real aperture footprint area (characteristic of the radiometer spatial resolution).

What makes the SMAP observatory unique is the lightweight, deployable mesh reflector antenna, or *reflector boom assembly*, measuring 6 meters (~20 feet) in diameter. Both the radiometer and radar share the same feedhorn used to transmit and receive signals to/from the mesh reflector. The reflector assembly will point towards the ground at a constant incidence angle of 40° and spin at ~14 *revolutions per minute* (RPM), resulting in conically scanned data. This arrangement will allow both instruments to collect data jointly across a 1000-kilometer (~621-mile) wide swath, enabling global coverage every 2-3 days.

The reflector diameter of 6 meters will yield a radiometer footprint spatial resolution at the surface of 39 x 47 kilometers (~24 x 29 miles), and a real-aperture radar (i.e., low-resolution radar) footprint resolution of 29 x 35 kilometers (~18 x 22 miles) over the entire swath width (i.e., 1000 kilometers). Due to the reflector's unique scanning geometry, however, the synthetic-aperture (i.e., high-resolution) radar processing will provide 1 to 3 kilometer (~0.6 to 2 mile) data over the outer 70% of the swath only, i.e., not over the inner 300 kilometers (~186 miles) of the swath.



The amount of swath area covered by the radiometer and high- and low-resolution radar is shown here. The synthetic-aperture radar will provide high-resolution data over the outer 700 kilometers (~435 miles) of a given swath.

Image credit: NASA

Photo credit: NGAS

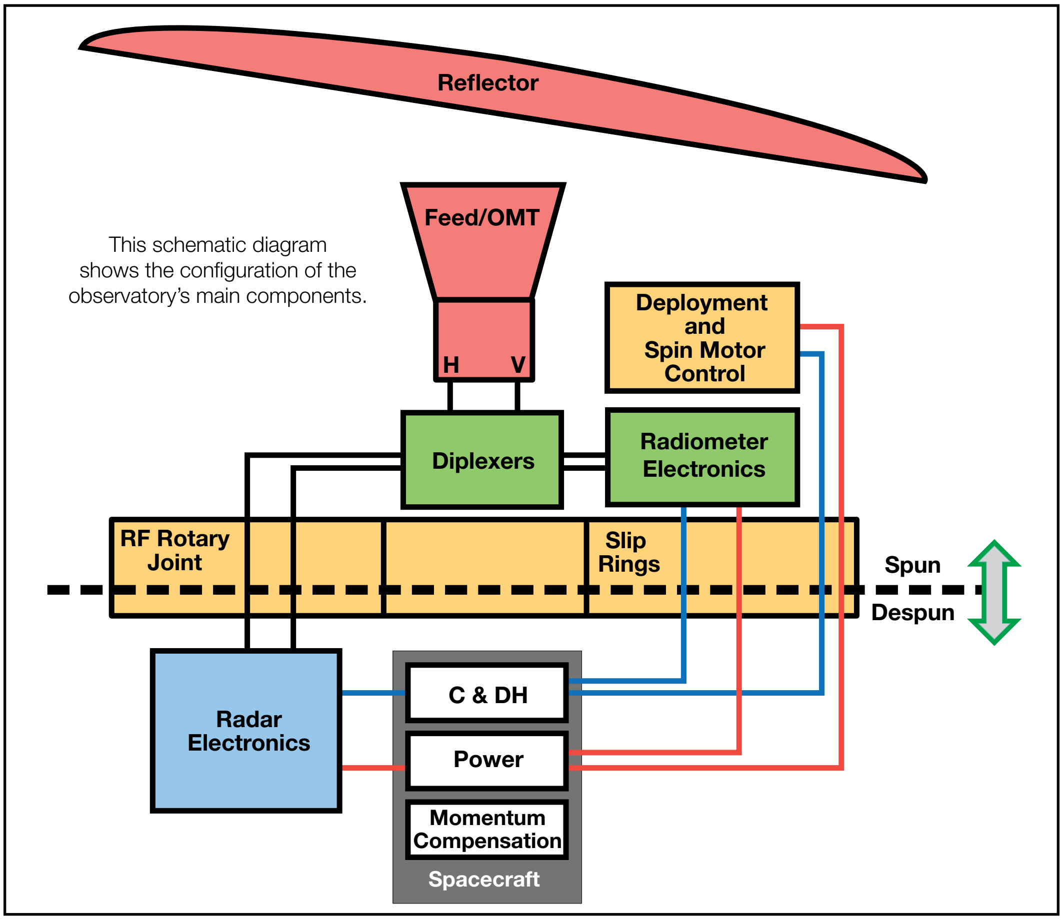
Northrop Grumman Aerospace Systems (NGAS), under contract to NASA's Jet Propulsion Laboratory, built the deployable mesh reflector pictured here.

Spacecraft Design

The SMAP spacecraft has been built at NASA's Jet Propulsion Laboratory, leveraging avionics, software, and power electronics derived from previous planetary missions. The spacecraft is designed to accommodate the unique needs of a large spinning instrument in a compact package that can fit within a small launch vehicle fairing. The spacecraft structure is made of aluminum and includes large reaction wheels that provide momentum compensation for the large, spinning 6-meter diameter mesh reflector. The spacecraft supplies power, orbit and attitude control, communications, and data storage for the radiometer and radar. A solar array with three fixed panels provides power to the observatory components.

A solid-state memory with large data storage is aboard the spacecraft, and an X-band antenna will transmit radiometer and radar data in real time or played back from the onboard memory. The spacecraft's S-band transponder will accommodate ground-based Doppler tracking for orbit determination rather than using the *global positioning system* (GPS) because the large spinning instrument antenna blocks GPS satellite visibility.

The spacecraft was built with a design life of three years, but carries sufficient fuel for more than five years of normal operation.



This schematic diagram shows the configuration of the observatory's main components.

Image credit: NASA

Photo credit: NASA/Kent Kellogg

All spacecraft components, the instruments, feedhorn, and reflector boom assembly were integrated on the observatory in the cleanroom at NASA's Jet Propulsion Laboratory.

Spacecraft Specs

Dimensions	1.5 x 0.9 x 0.9 meters (4.9 x 3 x 3 feet), spacecraft bus only
Mass	960 kilograms (~2120 pounds), including propellant and instrument
Power	1450 Watts
Downlinks	S-Band (satellite control and monitoring), X-Band (science data)
Design Life	3 years


Photo credit: Nicholas A. Tonelli

Ground System and Data

The SMAP mission ground system includes all the assets needed to command and operate the SMAP spacecraft in orbit, as well as manage and distribute data. Once the spacecraft reaches orbit and begins transmitting data, the SMAP Science Data System (SDS) will convert telemetry downlinked from the SMAP observatory into science data products provided to the science community for research and applications. Designed to process data products in a timely manner, the SDS facility includes computer hardware dedicated to operational data production as well as hardware for use by the SMAP science algorithm development team to enhance algorithm accuracy and performance.

The SDS is housed primarily at JPL, but with components at GSFC. Specifically, JPL is responsible for implementation of software to generate Level 1 instrument data products (both radar and radiometer) as well as Level 2 and Level 3 geophysical data products. GSFC is responsible for the Level 1 radiometer algorithms and for implementation of software to generate the value-added Level 4 geophysical data products produced by the GSFC Global Modeling and Assimilation Office (GMAO).

The SMAP baseline science data products will be generated within the project's SDS and made available publicly through two NASA Distributed Active Archive Centers (DAACs), the Alaska Satellite Facility (ASF) (for Level 1 radar products) and the National Snow and Ice Data Center (NSIDC) (for all other products).

The SMAP Team will coordinate the release of data product versions with the data centers and will ensure the completeness and accuracy of quality control information and validation status of the data products.

Simulated Level 2 and Level 3 Soil Moisture Products

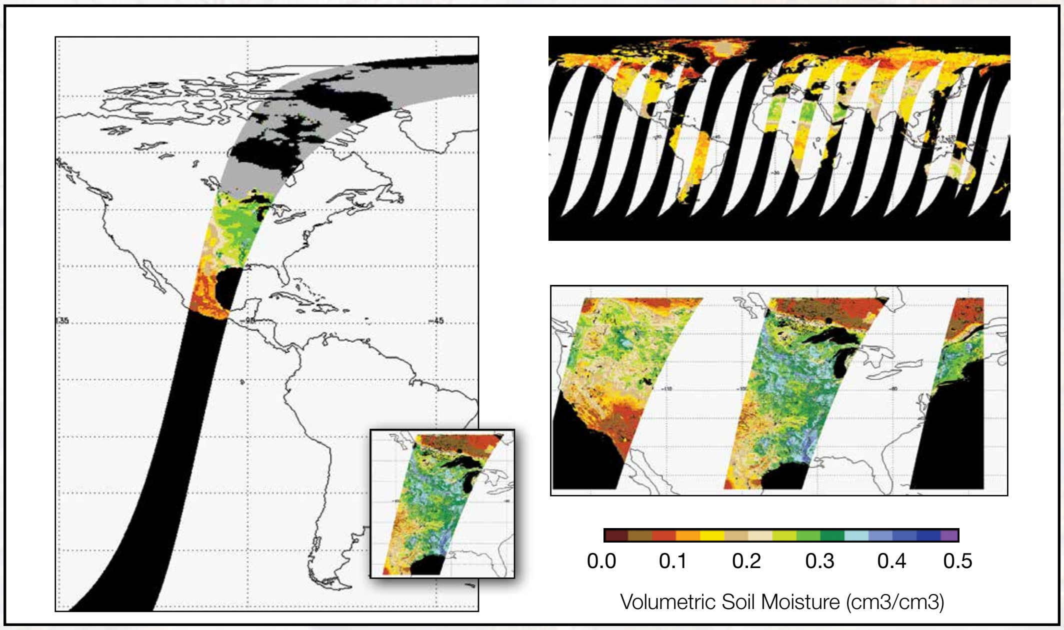


Image credit: NASA

These maps show simulated Level 2 (half-orbit) and Level 3 (daily composite) soil moisture products from SMAP. After 3 days the entire surface of the globe is mapped at least once.

Science Data System

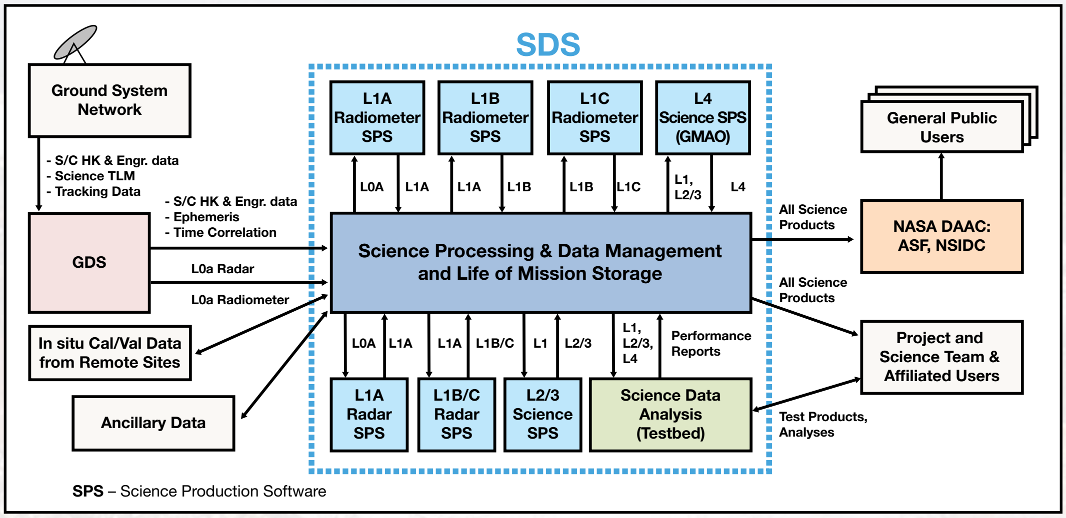


Image credit: NASA

Data from SMAP, received by the Ground System Network, will travel to the Science Data System at JPL and GSFC before being made publicly available.

SMAP Data Products

Data Product Short Name	Short Description	Gridding (Resolution)	Latency*
L1A_Radar	Radar raw data in time order	–	12 hours
L1A_Radiometer	Radiometer raw data in time order	–	12 hours
L1B_S0_LoRes	Low resolution radar σ_o in time order	(5x30 km)	12 hours
L1B_TB	Radiometer T_B in time order	(36x47 km)	12 hours
L1C_S0_HiRes	High resolution radar σ_o (half orbit, gridded)	1 km (1-3 km)**	12 hours
L1C_TB	Radiometer T_B (half orbit, gridded)	36 km	12 hours
L2_SM_A	Soil moisture (radar, half orbit)	3 km	24 hours
L2_SM_P	Soil moisture (radiometer, half orbit)	36 km	24 hours
L2_SM_AP	Soil moisture (radar/radiometer, half orbit)	9 km	24 hours
L3_FT_A	Freeze/thaw state (radar, daily composite)	3 km	50 hours
L3_SM_A	Soil moisture (radar daily composite)	3 km	50 hours
L3_SM_P	Soil moisture (radiometer, daily composite)	36 km	50 hours
L3_SM_AP	Soil moisture (radar/radiometer, daily composite)	9 km	50 hours
L4_SM	Soil moisture (surface & root zone)	9 km	7 days
L4_C	Carbon net ecosystem exchange (NEE)	9 km	14 days

* Mean latency under normal operating conditions (defined as time from data acquisition by the observatory to availability to the public data archive). The SMAP project will make a best effort to reduce these latencies.

** Over outer 70% of the swath.

Image credit: NASA

Level 1B and 1C data products are calibrated and geolocated instrument measurements of surface radar backscatter cross-section and radiometer brightness temperature. There are three Level 2 soil moisture products resulting from the radar and radiometer data streams. Level 2 products are output on a half-orbit basis. Level 3 products are daily composites of Level 2 surface soil moisture. The radiometer-only soil moisture product is derived from radiometer brightness temperature measurements and is posted at 36 km. L2_SM_AP is a combination active and passive (radar and radiometer) product that produces soil moisture estimates at 9 km resolution. The radar-only high-resolution experimental soil moisture product is based on the radar measurements and is posted at 3 km. Level 4 products are model derived value-added data products that support key SMAP applications and more directly address the driving science questions. The Level 2 to Level 4 data products are posted on an Equal Area Scalable Earth-2 (EASE2) grid that is nested consistently with the 36 km, 9 km, and 3 km grids used by other SMAP products.

Simulated Level 3 Freeze/Thaw

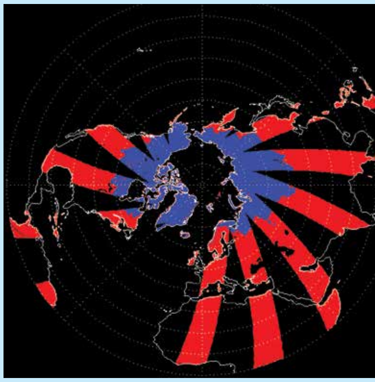
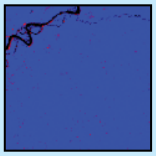


Image credit: NASA

🟦 Frozen 🟥 Thawed

Daily Freeze/Thaw State

17 February 1998



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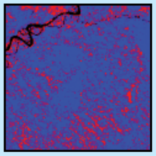

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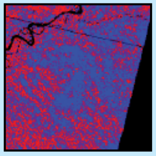

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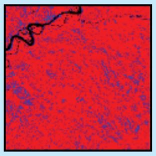

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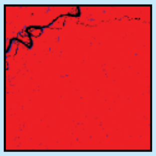

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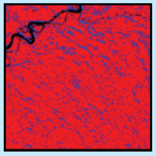

Shown here is a landscape freeze/thaw classification based on an earlier L-band radar mission (JERS-1).

Serving Society and Making a Difference

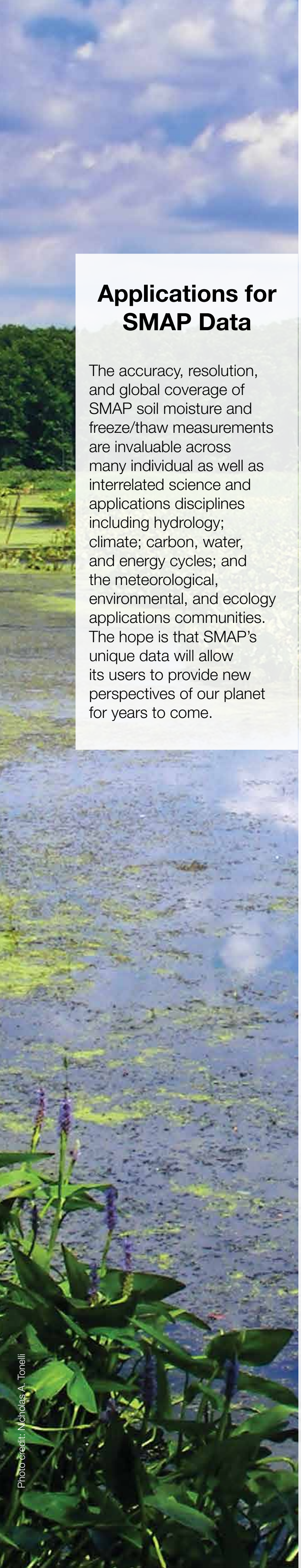
Photo credit: Nicholas A. Tonelli

Applications for SMAP Data

The accuracy, resolution, and global coverage of SMAP soil moisture and freeze/thaw measurements are invaluable across many individual as well as interrelated science and applications disciplines including hydrology; climate; carbon, water, and energy cycles; and the meteorological, environmental, and ecology applications communities. The hope is that SMAP's unique data will allow its users to provide new perspectives of our planet for years to come.

Weather and Climate Forecasting

Soil moisture variations affect the evolution of weather and climate. Initialization of numerical weather prediction and seasonal climate models with accurate soil moisture information enhances their prediction skills and extends lead times. Improved seasonal climate predictions will benefit climate sensitive socioeconomic activities, including water management, agriculture, fire, and flood and drought hazards prediction and monitoring.

Agricultural and Rangeland Productivity

SMAP will provide information on water availability for estimating plant productivity and potential yield. The availability of direct observations of soil moisture from SMAP will enable significant improvements in operational crop and rangeland productivity and information systems by providing realistic soil moisture observations as inputs for agricultural prediction models.

Drought

Soil moisture strongly affects plant growth and determines the fate of agricultural and rangeland productivity, especially during conditions of water shortage and drought. At present, there is no global *in situ* network for soil moisture monitoring. Global estimates of soil moisture and plant water stress must be derived from models. These model predictions, and therefore drought monitoring, can be greatly enhanced through assimilation of space-based soil moisture observations.

Floods and Landslides

Soil moisture is a key variable in water-related natural hazards such as floods and landslides. High-resolution observations of soil moisture will lead to improved flood forecasts, especially for intermediate to large watersheds where most flood damage occurs. The surface soil moisture state is key to partitioning of precipitation into infiltration and runoff. Soil moisture in mountainous areas is one of the most important determinants of landslides. Hydrologic forecast systems initialized with mapped high-resolution soil moisture fields will therefore open up new capabilities in operational flood forecasting.

Human Health

Improved seasonal soil moisture forecasts using SMAP data will directly benefit famine early warning systems, particularly in sub-Saharan Africa and South Asia where hunger remains a major human health factor and the population harvests its food from rain-fed agriculture in highly monsoonal (i.e., seasonal) conditions. Indirect benefits will also be realized, as SMAP data will enable better weather forecasts that lead to improved predictions of heat stress and virus spreading rates. SMAP will also benefit the emerging field of landscape epidemiology (aimed at identifying and mapping vector habitats for human diseases such as malaria) where direct observations of soil moisture can provide valuable information on vector population dynamics.

Area	Likely Mission Applications	Potential Mission Applications
Weather 	More accurate weather forecasts; prediction of severe rainfall	Regional weather prediction improvements
Natural Disasters 	Drought early warning decision support; key variable in floods and landslides; operational flood forecasts; lake and river ice breakup; desertification	Fire susceptibility; heat wave forecasting
Climate Variability and Change 	Extended climate prediction capability; linkages between terrestrial water, energy, and carbon cycles; land/atmosphere fluxes and carbon (CO_2) source/sink activity for atmospheric greenhouse gases	Long-term risk assessments
Agriculture and Forestry 	Predictions of agricultural productivity; famine early warning; monitoring agricultural drought	Crop management at the farm scale; input to fuel loading models
Human Health 	Landscape epidemiology; heat stress and drought monitoring; insect infestation; emergency response plans	Disease forecasting and risk mitigation
Ecology 	Carbon source/sink monitoring; ecosystems forecasts; improvements in monitoring of vegetation and water relationships over land	Wetlands resources and bird migration monitoring; cap-and-trade carbon inventory assessment and monitoring
Water Resources 	Regional and local water balance; more effective management	Monitoring variability of water stored in lakes, reservoirs, wetlands, and river channels
Ocean Resources 	Sea ice mapping for navigation, especially in coastal zones; temporal changes in ocean salinity	Provision of ocean wind speed and direction, related to hurricane monitoring
Insurance Sector 	More accurate forecasts of weather; prediction of severe rainfall; operational severe weather forecasts; mobility and visibility	Crop insurance programs; flood insurance programs; tourism and recreation
Coastal Inundation 	Input to sea level rise products	Maps of coastal inundation; ocean winds monitoring for hurricanes
Drought 	Early warning decision support; Drought Monitor products	Desertification identification
Flood 	Improved forecasts, especially in medium to large watersheds; flood mapping; protection of downstream resources; soil infiltration conditions; prediction of ice breakup	Prediction of the impact of tropical storms on hydrology
Ecosystem Health 	Improvements in monitoring of vegetation health and change; ecosystem dynamics	Wetlands and bird migration monitoring; Rangeland forage productivity forecasts
Wildfires 	Input into fire potential models	Improvements in fuel loading models, especially for non-heavily forested areas

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