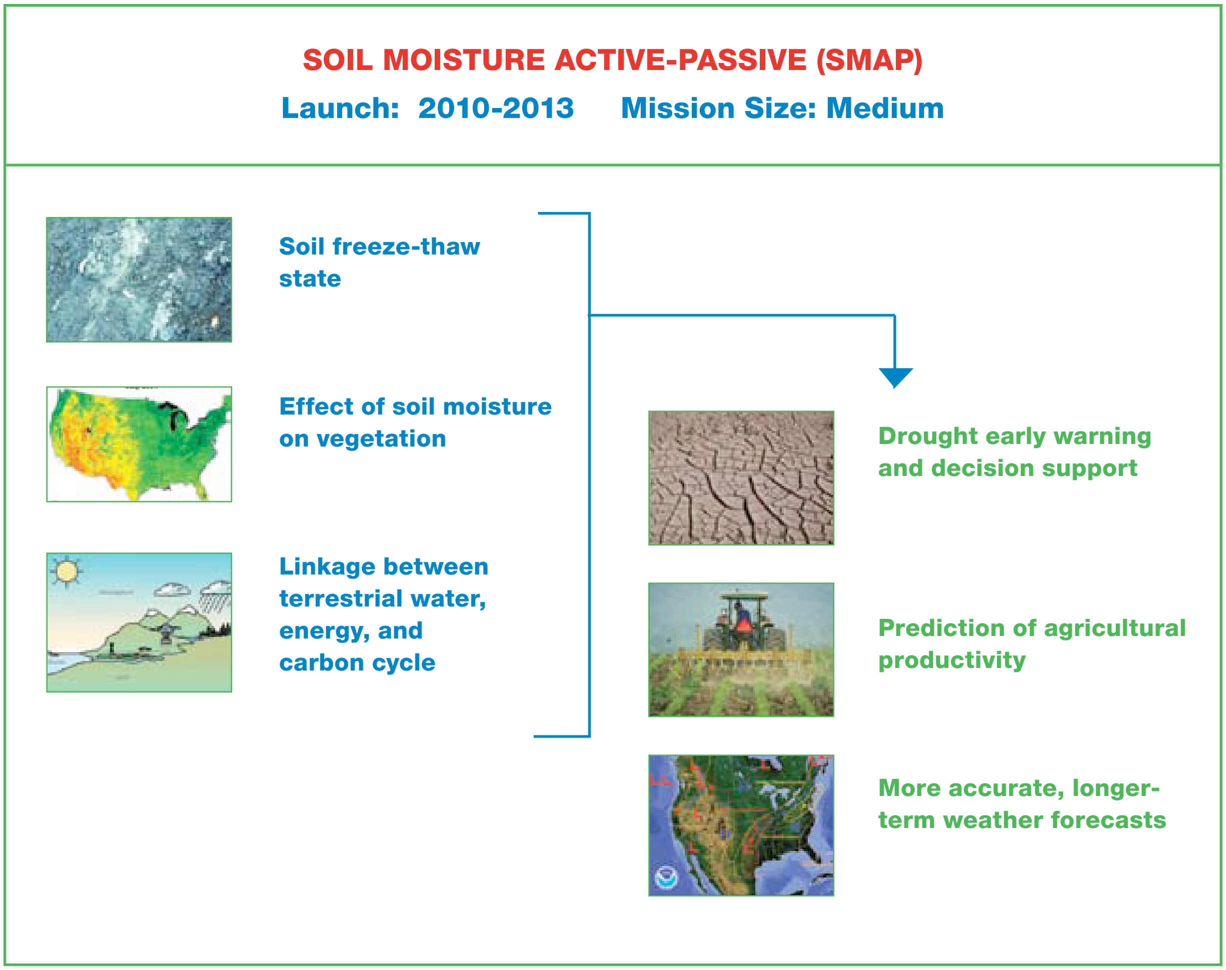

SOIL MOISTURE ACTIVE-PASSIVE (SMAP) MISSION

Soil moisture is a key control on evaporation and transpiration at the land-atmosphere boundary. Large amounts of energy are required to vaporize water, and so soil control on evaporation and transpiration also influences surface energy fluxes. Hence, variations in soil moisture affect the evolution of weather and climate over continental regions. Initialization of numerical weather prediction (NWP) models and seasonal climate models with correct information on soil moisture enhances their prediction skill and extends their lead times. Soil moisture strongly affects plant growth and therefore agricultural productivity, especially during conditions of water shortage, the most severe of which is drought. There is no global in situ network for measuring soil moisture, and global estimates of soil moisture, and, in turn, plant water stress, must be derived from models. The model predictions (and hence drought monitoring) could be greatly enhanced through assimilation of soil-moisture observations. Soil moisture and its freeze-thaw state are also key determinants of the global carbon cycle. Carbon uptake and release in boreal landscapes are a major source of uncertainty in assessing the carbon budget of the Earth system (the so-called missing carbon sink). Soil moisture also is a key variable in water-related natural hazards, such as floods and landslides. High-resolution observations of soil moisture would help to improve flood forecasts, especially for intermediate to large watersheds, where most flood damage occurs, and thus improve the capability to protect downstream resources. Soil moisture in mountainous areas is one of the most important determinants of landslides, a hazard that could be better predicted with consistent observations, which are currently lacking.

Background: Global mapping of soil moisture and its freeze-thaw state at high resolution has long been of interest because these variables link the terrestrial water, energy, and carbon cycle. Such measurements also have important applications in predicting natural hazards, such as severe rainfall, floods, and droughts. The spatial variations in soil-moisture fields are determined by precipitation and radiation forcing, vegetation distribution, soil-texture heterogeneity, and topographic redistribution processes. The spatial variations lead to the need for high-resolution soil-moisture mapping (Entekhabi et al., 1999). Numerous airborne and tower-based field experiments have shown that low-frequency L-band microwave measurements are reliable indicators of soil-moisture changes across the landscape. Only by combining high-resolution active radar and high-accuracy passive radiometer L-band measurements is it possible to produce data that meet the science and application requirements. The proposed SMAP mission builds on the risk-reduction performed for the AO-3 ESSP called the Hydrosphere State (Hydros) mission (Entekhabi et al., 2004). The SMAP radar makes overlapping measurements, which can be processed to yield resolution enhancement and 1- to 3-km resolution mapped data. The SMAP radar and radiometer share a large deployable lightweight mesh reflector that is spun to make conical scans across a wide (1,000-km) swath. This measurement approach allows global mapping at 3- to 10-km resolution with 2- to 3-day revisit.

Science Objectives: Soil moisture and its freeze-thaw state are primary controls on the exchange fluxes of water, energy and carbon at the land-atmosphere interface. More important, those variables are what link the water, energy, and carbon cycles over land. The availability of soil-moisture data will remove existing stovepiping in the water, energy, and biogeochemistry communities by directly characterizing the link between the cycles over land regions. The data will also enable the Earth system science community to address the question of how perturbations in one cycle (radiative forcing) affect the rates of the other cycles. The spatial variability that is due to the influences of intermittent precipitation, patchy cloudiness, soil and vegetation heterogeneity, and topographic factors leads to the requirement for high-resolution mapping of soil moisture and its freeze-thaw state. Currently there are no in situ networks to support the data needs of Earth system scientists. Forthcoming satellite missions do not have the active-sensor and passive-sensor combination needed to meet the resolution requirements to characterize the heterogeneous fields.

Soil moisture serves as the memory at the land surface in the same way as sea-surface temperature does at the ocean surface. The use of sea-surface temperature observations to initialize and constrain coupled ocean-atmosphere models has led to important advances in long-range weather and seasonal prediction. In the same way, high-resolution soil-moisture mapping will have transformative effects on Earth system science and applications (Entekhabi et al., 1999; Leese et al., 2001). As the ocean and atmosphere community synergies have led to substantial advances in Earth system understanding and improved prediction services, the availability of high-resolution mapping of surface soil moisture will be the link between the hydrology and atmospheric communities that share interest in the land interface. The availability of such observations will enable the emergence of a new generation of hydrologic models for applications in Earth system understanding and operational severe-weather and flood forecasting.

Mission and Payload: The SMAP mission, based on one flight system in a low-Earth, Sun-synchronous orbit, includes a capability for active radar and passive radiometer measurements. The two sensors share a single feedhorn and mesh reflector to form a beam offset from nadir with the surface of 39°. This beam is rotated conically about the nadir axis to make a wide-swath measurement. The reflector is composed of lightweight mesh material that can be stowed for launch. The feed and reflector components shared between the two sensors lead to cost savings. The SMAP hardware is derived from the Hydros design and has therefore been subject to substantial study and risk reduction. Similarly, the spacecraft dynamics, ground data system, and science algorithms have been tested to a great extent. Field experiments have been used to validate the science algorithms, and scale models have been constructed to test the antenna performance. As a result of the Hydros risk-reduction investments and activities, all the components of the proposed SMAP are at technology readiness level 7 and higher.

Cost: About $300 million.

Schedule: As a pathfinder, SMAP is conceptualized as being built on the foundations of the earlier AO-3 concept (Hydros) that has undergone risk reduction marked by rigorous reviews. As a result, SMAP is ready to move on a fast-track toward launch as early as 2012, when there are few scheduled Earth missions. SMAP's readiness also gives a capability for gap-filling observations to meet key NPOESS community needs; soil moisture is the key parameter (see Section 4.1.6.1.6 in Joint Requirements Oversight Council, 2002). In addition, SMAP will yield continuity measurements for the Aquarius mission community.

Further Discussion: See in Chapter 11 the section "Soil Moisture and Freeze-Thaw State."

Related Responses to Committee's RFI: Similar to those of the Hydros mission proposed for ESSP.

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