How Wet's Our Planet?

Scientists want to be able to measure soil moisture everywhere, every day!


STEPHEN AUSMUS (K10756-1)

Hydrologist Tom Jackson and several of the Alabama SMEX03 (Soil Moisture Experiment 2003) ground crew collect an array of ground observations at a permanent NRCS Soil Climate Analysis Network site.

Tom Jackson has his eye on 2010. That's when the National Aeronautics and Space Administration (NASA) will use the Hydros satellite, scheduled for launch that year, exclusively to monitor daily soil moisture change around the globe—for the first time in history.

Daily soil moisture monitoring of Earth from space has long been the goal of hydrologist Jackson and his colleagues in the Agricultural Research Service (ARS) and many other agencies. They're working closely with NASA to verify soil moisture data from several of its satellites in hopes that this information will one day feed into the models on which today's daily weather forecasts are already based.

Jackson, who is with the ARS Hydrology and Remote Sensing Laboratory in Beltsville, Maryland, explains that soil moisture change is part of the global water cycle and is the result of rain, evaporation, or snowmelt. This soil surface–atmosphere interaction is similar to the better-known ocean surface–atmosphere interactions that cause the El Niño and La Niña weather phenomena.

"We want soil moisture monitoring to become routine for regional and world weather forecasting," Jackson says. "That information would be good for agriculture because farmers could use it to make decisions on everything from planting and fertilizing to irrigating. Municipalities could use it to manage reservoirs and flooding. It could also tell homeowners when to water lawns and gardens."

NASA's experimental, climate-monitoring Aqua satellite is exploring weather-related forecasting based on daily, global, soil moisture monitoring. Until its untimely demise in October 2003, Japan's ADEOS-II satellite was doing the same. Both satellites were launched in 2002.

In a major field experiment last year—called SMEX03 (for Soil Moisture Experiment 2003)—Jackson and colleagues took ground-level readings to verify daily reports mainly from Aqua's soil moisture-monitoring sensors. But they also checked equipment on ADEOS-II and two other satellites—

Coriolis, a prototype of the next generation of U.S. weather satellites, and Europe's Envisat. They tested the sensors' ability to "see" through vegetation, including forests in Alabama, Georgia, Oklahoma, and Brazil.

To See Beneath the Trees

"Blinding" by dense vegetation is the last obstacle to soil moisture monitoring of the globe.

"As satellites move from bare land to grassland to cropland to forest, it gets harder and harder for them to sense soil moisture, and then it becomes impossible," says Jackson. "But before that point is reached, soil moisture can be estimated accurately—if adjustments are made to measuring techniques and interpretation."

For more than a decade, ARS, NASA, and other agencies have been doing these on-ground verification campaigns periodically in Oklahoma. They started with the area easiest to monitor for soil moisture from space: land that is bare in spring and summer and has cover of grass or wheat in winter. "We've shown that the sensors are really accurate for this type of land area, matching the ground-collected data very closely," Jackson says.

Jackson and colleagues began the annual SMEX experiments in 2002. Those focused on corn and soybean fields in Iowa, where plant cover was a little harder to see through. But again, sensor results closely matched ground-level results.

In 2003, the SMEX tests in the United States were completed in 23 days and used one or two airplanes along with the satellites. The campaign in Alabama, for example, involved NASA's P-3B Orion airplane, while the Oklahoma campaign used NASA's DC-8 as well as the P-3B.

Sampling by Satellite, Plane, and Ground Crew

The Aqua satellite makes its measurements at 1:30 a.m. and 1:30 p.m., while ADEOS-II gave readings at 10:30 a.m. and 10:30 p.m. They both carried different versions of Advanced Microwave Scanning Radiometer sensors that

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The NASA P-3B aircraft in flight over the Alabama study region during SMEX03.

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On board the NASA P-3B aircraft, Marian Klein (foreground), a contractor with the National Oceanic and Atmospheric Administration, and hydrologist Tom Jackson examine data collected by a microwave sensor.

STEPHEN AUSMUS (K10759-1)

Soil moisture samples are processed in the SMEX03 Alabama laboratory by Alabama A&M students Susan Bodner and Mustafa Yousif.

measure soil moisture indirectly, using microwave signals emitted from soil.

The sensors require an antenna that looks like an umbrella or a satellite dish. It functions as a mirror, constantly reflecting radiation emitted from Earth onto sensors that measure the strength of the radiation. Currently, the device is as big as can be shipped into space in one piece—6 feet in diameter. Jackson says diameter is the limiting factor for the sensors, which could measure longer wavelengths and be more accurate with larger dishes.

"Better soil moisture products might require a dish 18 to 36 feet or more in diameter," he says. "The only way that could be done would be to construct it as a mesh umbrella that could be shipped into space closed and then unfurled," Jackson says. The Hydros satellite will use this technology. Success should bring larger and larger dishes on successive generations of weather satellites. Jackson hopes the Hydros soil moisture-monitoring mission would demonstrate the value of such single-use satellites to military and civilian weather forecasters.

Moisture sensors aboard airplanes have higher resolution than those on satellites. The airplanes are also used to test new ideas for sensors.

A ground crew of about 40 sampled plants and soil in Alabama and 20 flew aboard the P-3B plane—fairly typical-size crews for the SMEX campaigns. The ground crew checked moisture in crop and pasture-plant leaves and soil. They analyzed the samples at Alabama A&M University labs and at the nearby National Space Science and Technology Center. The center is a venture of NASA and the State of Alabama through the Space Science and Technology Alliance—a group of six research universities: Alabama A&M, Auburn, Tuskegee, Alabama-Tuscaloosa, Alabama-Birmingham, and South Alabama.

"The moisture measurements of plants and soil were part of the ground 'truth' readings we used to gauge—and calibrate—the accuracy of the air- and space-based sensors," Jackson says.

In Alabama, the ground crew faced a dense, oak-pine forest around the NASA Marshall Space Flight Center in Huntsville. They also did tests around the campus of Alabama A&M University and on cotton, corn, and soybean fields. Their farm/forest study area formed a 31- by 62-mile area mostly in Alabama, but with a portion in Tennessee. Alabama A&M students and faculty worked with the federal scientists.

STEPHEN AUSMUS (K10762-9)

Using a dielectric probe, hydrologist Charles Laymon and Alabama A&M student Parmecia Jones collect soil moisture data for comparison with satellite data to determine whether a satellite can "see" through a forest canopy to accurately measure soil moisture.

USDA's Natural Resources Conservation Service set up seven monitoring towers at the University of Alabama as part of the Soil Climate Analysis Network, which currently has over 70 permanent towers around the country to monitor soil moisture and temperature and weather data.

"Soil moisture readings from the towers closely matched satellite and airplane sensor readings for the farm areas. But tower readings really began deviating from air and space readings in the densest parts of the forested land," Jackson says.

"We've found that we can see through forest—though much of the signal is diminished after passing through all that vegetation. Now we need to figure out what in the vegetation is causing the signal weakening. Then we plan to see whether we can remove those obstacles so we can read soil moisture accurately."

Jackson and colleagues worked with the ARS Southeast Watershed Laboratory in Tifton, Georgia, and the ARS Grazinglands Research Laboratory in El Reno, Oklahoma. This year, Jackson and crew will set up again in America's Southwest—surveying a land mass that includes much of Arizona and Mexico—in a National Oceanic and Atmospheric Administration project focusing on understanding North American "monsoons." The atmospheric disturbance caused by rapid evaporation from these sudden, heavy rainstorms over a large land mass has a major effect on water supply forecasts in the West.

Once soil moisture predictions and measurements are part of daily weather forecasts, Jackson explains, "it will help predict certain storms, because sudden changes in soil moisture over vast areas in America's West—and similar climates worldwide—can be important determinants of whether it rains or not. They drive the atmospheric circulation that spawns storms."—By **Don Comis,** ARS.

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Thomas J. Jackson is with the USDA-ARS Hydrology and Remote Sensing Laboratory, Bldg. 007, 10300 Baltimore Ave., Beltsville, MD 20705-2350; phone (301) 504-8511, fax (301) 504-8931, e-mail tjackson@hydrolab.arsusda.gov. ★