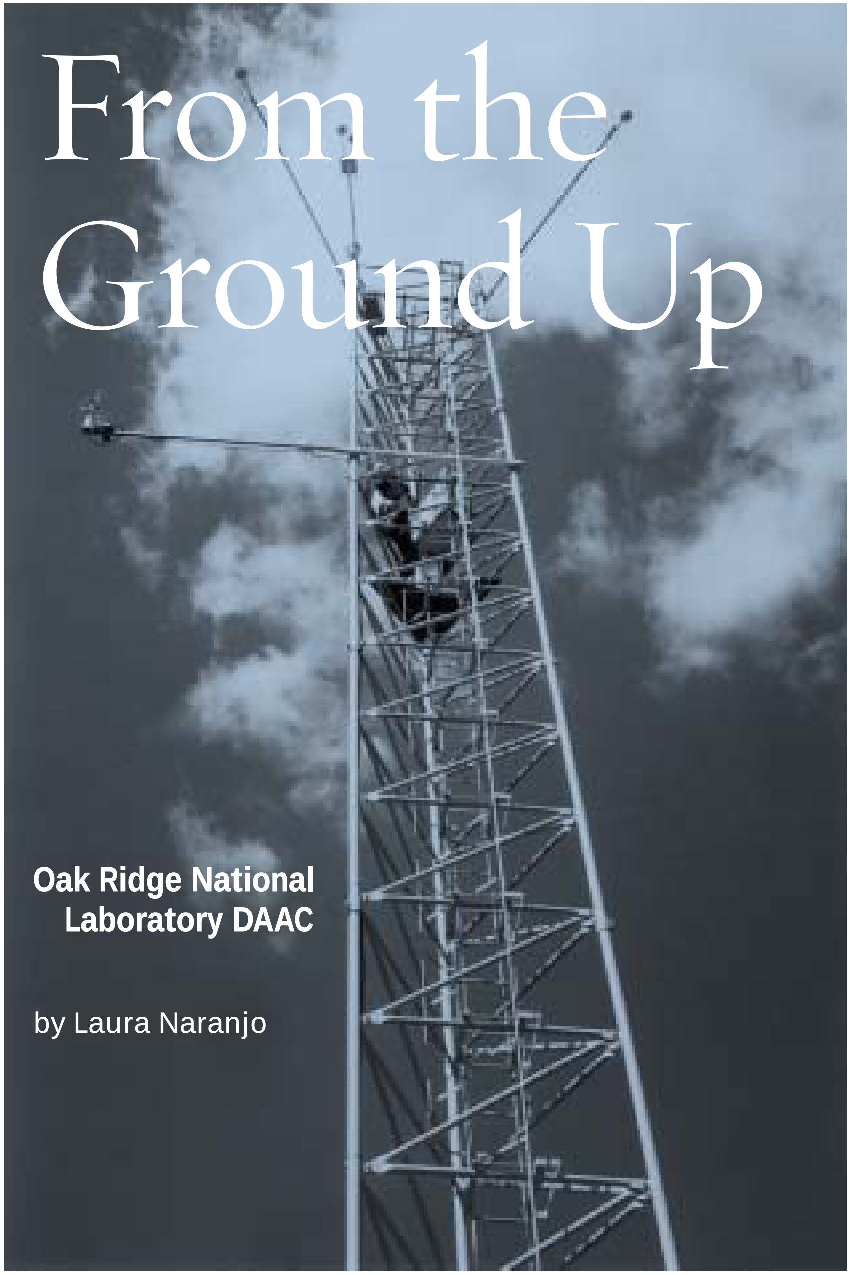


> *"When users request MODIS data, we like to give them the validation status so that they understand the quality and uncertainty of the data and have an appreciation for its limitations."*

South Africa's Kruger National Park, a subtropical savanna speckled with acacia and baobab trees, is providing scientists with a look at the Earth's metabolism. All over the world, in fact, scientists are exploring a variety of ecological communities to understand how each one exchanges water, sunlight, and carbon between the land surface and the atmosphere.

Because the Earth supports a variety of different communities, such as savannas, deserts, tropical forests, and wetlands, making sense of these complex relationships is no small task. To measure the land-atmosphere exchanges for each ecological community, or biome, scientists are turning to satellite remote sensing. Satellite data provide a reliable, long-term way to measure land-atmosphere exchanges on a global basis. But satellites monitor these processes from hundreds of kilometers above the Earth's surface. How do scientists know that what they're seeing is an accurate snapshot of what's happening on the ground?

Oddly enough, the best way scientists can determine the accuracy of what the satellite shows them is by validating the data with information collected on the ground.

Validation confirms the accuracy of satellite data by comparing them to independent reference data collected via stationary instruments, field campaigns, and even other satellites. Validation differs from data quality assurance, which involves identifying specific sensor malfunctions or problems with certain data products that the satellite generates.

Scientists working with NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) sensors onboard the Terra and Aqua satellites have formed teams to validate MODIS land cover data. Although validation is a work in progress, it has already improved MODIS data quality, incorporated more data sources, and made data more accessible to remote sensing investigators and field researchers.

Because validation is costly and involves an extensive network of measurements, it requires long-term collaboration. "We don't have the resources to travel throughout the network, so we're trying to interact with other people doing field work in different

The Skukuza FLUXNET tower in Kruger National Park, South Africa, houses a variety of instruments that measure atmospheric chemistry, humidity, air temperature, soil temperature, and soil water content. (Image courtesy of Bob Cook, Oak Ridge National Laboratory) parts of the world," said Jeff Morisette, validation coordinator for the MODIS Land Team, or MODLAND. Morisette serves as science lead and primary contact for the team, facilitating communication between the validation groups and maintaining the land validation web site. Obtaining a continuous and reliable stream of ground-based measurements, however, is a challenge. Much of the validation effort relies on FLUXNET, a worldwide network of sites centered on flux towers, such as the one in South Africa, that record the exchanges of carbon dioxide, water vapor, and solar energy between land and the atmosphere. This network allows scientists to compare MODIS data to a variety of ground-based measurements taken from different biomes around the globe.

In 2001, FLUXNET included 140 long-term sites, but by 2003, that number had jumped to 252. By integrating U.S. meteorological networks with others in Europe, Canada, Asia, Australia, and Brazil, FLUXNET gave the MODLAND team a broader sample of biomes for validating satellite data. "The flux towers are probably the single most valuable and most globally distributed validation network we have," said Steve Running, ecology professor in the school of forestry at the University of Montana.

In addition to providing more extensive meteorological data, the proliferation of flux towers has also fostered collaboration between ground teams and satellite data providers. Sharing resources and exchanging data with ground teams provides more opportunities to validate MODIS products. "Validation tends to be expensive because you need people on the ground," said Crystal Schaaf, associate professor in the department of geography and the Center for Remote Sensing at Boston University. "We try to arrange a reciprocal agreement where we provide satellite imagery in exchange for ground data. In turn, we hope they can do some validation work for us."

However, because most ground teams don't include remote sensing staff, members are often unfamiliar with using satellite data. "We needed to make MODIS data simple and easy for flux tower ground teams to use," said Running. The MODLAND team members coordinated with the validation community to generate "subsets" of data. Making subsets involved cutting out a portion of data imagery located directly over flux towers and other field sites and providing the data in ASCII (plain text), which is a more accessible format for ground teams.

Site-specific 7 x 7-kilometer ASCII subsets of MODIS data are available from the Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC). The Land Processes Distributed Active Archive Center (LP DAAC) distributes larger 200 x 200-kilometer subsets that provide regional data coverage for each tower.

"Providing subsets encourages some of our users. Now they can just download a small collection of data in ASCII format that's relevant to their needs," said Schaaf. For instance, ground teams looking at the Kruger National Park site in South Africa can download a text

This image is a south view from the Skukuza FLUXNET tower in South Africa's Kruger National Park. The tower straddles two distinct savanna types to collect information about land-atmosphere interactions. (Image courtesy of Bob Cook, Oak Ridge National Laboratory) file of MODIS data pertaining to their site, or look at files specific to other similar savanna sites around the world.

To improve data accessibility, the ORNL DAAC also released an online browse tool in August 2004. "We're providing a couple of different ways to visualize the data so that ground teams can compare the MODIS products very easily with results from their field studies," said Bob Cook, a research scientist at the ORNL DAAC. Ground teams can now view the 7 x 7-kilometer data subsets as a time series in graphical format. Field campaigns, such as the current Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA), also contribute valuable reference data for validation, allowing scientists to obtain more detailed data. According to Nikolay Shabanov, a post-doctoral research associate in the department of geography at Boston University, taking ground measurements of vegetation density from several different biomes helps scientists develop samples of specific biomes against which to compare satellite data.

However, according to Shabanov, "A broadleaf forest in North America is somewhat different from a broadleaf forest in Amazonia, so we sample both areas to provide more accurate validation." Shabanov and his colleagues at Boston University sampled Harvard Forest in North America and used LBA data to compare the same biomes on different continents.

"We also developed a sampling strategy to scale from field measurements to fine-resolution data," said Shabanov. Because field campaigns gather fine-resolution data, his team needed to scale the data through a series of steps so they could more accurately compare field data with lower-resolution MODIS data.

Morisette credits the MODIS investigators for many of the data improvements. "They're looking at independent reference data to see how their product is doing and using that information to improve it," he said. To incorporate new software fixes, update algorithms, or fill in missing data, investigators periodically reprocess the validation data. The most recent reprocessing, called Collection 4, was completed in 2003. Releasing periodic updates helps scientists and other data users apply the improvements to their current studies. MODIS validation is divided into three stages, with each successive stage indicating an increased level of accuracy. "When users request MODIS data, we like to give them the validation status so that they understand the quality and uncertainty of the data and have an appreciation for its limitations," said Cook. By December 2003, all of the land products had achieved Stage 1 validation.

According to Morisette, achieving Stage 2 validation will require more extensive international collaboration. Morisette, who chairs the land product validation subgroup for the Committee on Earth Observation Satellites (CEOS), hopes to cultivate more international participation for future MODIS validation.

Reliable, validated satellite data are vital for studying the Earth's broad range of unique biomes. By measuring and quantifying land-atmosphere interactions, scientists can better study individual biomes, as well as understand how the Earth's communities collectively interact with the atmosphere on a larger scale.

For more information, visit the following web sites:

Oak Ridge National Laboratory Distributed Active Archive Center
http://daac.ornl.gov/

MODIS Land Team Validation Web Site
http://landval.gsfc.nasa.gov/MODIS/index.php

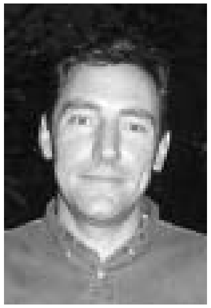
MODIS ASCII Subsets
http://public.ornl.gov/fluxnet/modis.cfm

References:

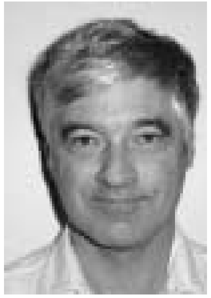
FLUXNET. Accessed February 10, 2004.
http://daccl.esd.ornl.gov/FLUXNET/

MODIS Land Team Validation. Accessed February 10, 2004.
http://landval.gsfc.nasa.gov/MODIS/

Robert Cook is a research scientist in the Environmental Sciences Division at the Oak Ridge National Laboratory. His research interests include biogeochemistry, global change, aqueous geochemistry, transport and fate of contaminants in aquatic ecosystems, and water resources management. Cook received his PhD in geochemistry from Columbia University.



Jeffrey Morisette is validation coordinator for the MODIS Land Team validation activities. His current research focuses on the application of multi-resolution and time series satellite imagery to the validation of global land products and ecological studies. Morisette holds a PhD from North Carolina State University, where he focused on geostatistics, accuracy assessment, and satellite-based change detection.



Steve Running is a professor in the school of forestry and director of the Numerical Terradynamic Simulation Group at the University of Montana. He currently serves as the principal investigator for MODIS Net Primary Production products. Running earned a PhD in forest ecophysiology from Colorado State University.

Crystal Schaaf is a research professor in the department of geography and the Center for Remote Sensing at Boston University. As a MODLAND associate team member, she is currently working to develop operational products for MODIS. Her research interests include modeling reflectance and albedo, and using remote sensing data to reconstruct reflectance characteristics of land surfaces. Schaaf earned a PhD in geography from Boston University.