Researcher studies how ground effects influence climate

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The EcoSpec reflectance sensors in position among young soybean plants at the beginning of the 2015 growing season. Credit: Yuki Hamada

Climate change can often seem concerned mainly with carbon dioxide and other greenhouse gases far above the Earth—but researchers also want to know what role things on the ground play.

Yuki Hamada, a biophysical remote sensing scientist in the Environmental Science division at the U.S. Department of Energy's (DOE's) Argonne National Laboratory, studies the realities of climate change right on the Earth's surface. Instead of peering far into the troposphere, she measures how the atmosphere near ground is interacting with plant life and soil. And Hamada is hoping that the soybean plants she studies could be windows into how the climate is changing, how those shifts might affect Earth's other ecosystems and how ecosystem function feeds back on climate patterns.

"With climate, we tend to talk all about the atmosphere, but actually the atmosphere, land and ocean are all connected," she said. "We're going to have to have a comprehensive understanding of how each piece interacts with each other—this is very important for more reliable forecasts of future climate change."

Hamada and her research team helped launch the EcoSpec project at Argonne in 2014 to accomplish this goal. The aim is to develop and validate instruments and protocols that can take the pulse of plant life and the soil without having to directly sample those materials.

"Currently, we have very sophisticated capabilities for measuring the atmosphere, but we have very poor measurement capabilities for land surfaces," Hamada said. "In EcoSpec, we rely on so-called passive remote sensing, which uses the energy source of the sun, and we are measuring the photons or energy reflected by plants and soils."

To measure the solar energy bouncing off soybean fields planted about 30 miles from Argonne, within the Fermi National Laboratory property, Hamada uses a so-called "hyperspectral" reflectance sensor, which measures sunlight reflected by the plants and soils from blue light to shortwave infrared wavelengths, mounted on 10-foot towers.

The hope is to correlate these measurements with plant health and activities by dissecting the relationships between the spectral data she collects and aspects of plant chemistry and physiology—such as moisture, nitrogen content and carbon flux—that other researchers are concurrently measuring.

"We are hoping to discover the set of wavelengths and determine statistical patterns that can indicate ecosystem function—specifically photosynthesis and plant respiration, which directly relate to the carbon cycle and water cycles," she said. "Then an ecologist can take those measurements to build models of how plants grow and how they respond to climate changes."

Because the biosphere and the atmosphere are locked in a constant feedback loop, refining such models may not only help predict how ecosystems might respond to a changing climate, but how plant life may contribute to atmospheric shifts.

Other Argonne researchers are managing "flux towers" that stand beside the EcoSpec tower at Fermilab and measure the variables—carbon dioxide flux, temperature, precipitation, etc.—that Hamada wants to correlate to reflectance.

Although the EcoSpec project is aimed at soybean fields now, the methodologies and instrumentation that it will develop will likely be applied to other ecosystems, according to University of Alberta plant ecophysiologist John Gamon.

About 10 years ago Gamon helped launch SpecNet (Spectral Network), a non-profit data-sharing effort that seeks to link researchers like Hamada who are collecting spectral data at sites spread across the globe. He said that he hopes Hamada's work on a new type of hyperspectral sensor will contribute significantly to both the dataset under the SpecNet umbrella and the tools that other investigators in the network will be able to use.

With EcoSpec, he said, "we get a deeper understanding of the underlying processes. And then having that as part of a network, we can say, 'Well, do these things hold across all ecosystems? Is there a universal truth here? Or is it just unique to crops or to certain kinds of ecosystems?'"

Hamada's sensor system, which was largely designed and built by both herself and her research team at Argonne, started recoding data from the Fermi soybean plots last spring and collected measurements through the growing season and into October.

As more data pours in from the sensors, Hamada plans to collaborate with the Mathematics and Computer Science division and Argonne Leadership Computing Facility to help analyze it, using Argonne's massively parallel computing systems. "It's going to need computation and big-data analytics," Hamada said.

To that end, Hamada recently initiated exploratory work with a collaborator at the computing facility to develop visualization techniques that will help discover currently unknown or difficult-to-identify associations between spectral reflectance data and environmental measurements. "We are hoping insights gained from new visualization of hyper-dimensional data will help us formulate interesting hypotheses," she said.

The insights they're able to glean could reach into unknown aspects of the interaction between the biosphere and the atmosphere, says Argonne meteorologist Nicki Hickmon, who manages the Atmospheric Radiation Measurement (ARM) Climate Research Facility's Southern Great Plains observational site."

"With higher resolution understanding of the processes that are happening at that plant and the light around it, you're going to probably come up with things you haven't seen before," she said.

As this kind of sensing matures with the help of projects like EcoSpec, those measurements may be incorporated into large-scale climate models, which are used to inform policy decisions on a global scale.

"Our findings will provide the fundamental understanding that can be used for satellite measurements," Hamada said, and mentioned that NASA has been developing next-generation satellite sensors to measure larger areas of terrestrial ecosystems. "We would love to be able to provide some insights to that effort as well."

Hyperspectral reflectance sensors

Hyperspectral reflectance sensors are relatively recent innovations on the optical sensor landscape. Typical cameras, like the kind we all use to capture pictures of family and friends, have internal light meters that are designed to "see" only visible light—from violet wavelengths (380-450 nanometers long) to red wavelengths (620-750 nanometers long).

The types of sensors that the U.S. Geological Survey and NASA sends up on Earth-orbiting satellites to capture imagery through its Landsat program typically record light from a broader segment of the spectrum—visible light wavelengths, near infrared (750-950 nm), two shortwave infrared wavelengths (1400-3000 nm), and thermal infrared energy (AKA heat)—but with only moderate resolution.

Hyperspectral sensors, like the ones that Hamada is developing and using as part of the EcoSpec program, capture visible, near and shortwave infrared energy, while providing unprecedented resolution. This means that her sensors can gather detailed information about the light bouncing off of soybean or other plants and record intricate information about the nature of that energy, with the hopes of eventually using that data as a proxy for plant biochemistry, physiology and growth. The sensors "create layers of information," as Hamada puts it.

Provided by Argonne National Laboratory

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