cleanenergy

No. 2 • 2013

NEWSLETTER OF *Oak Ridge National Laboratory's Energy and Environmental Sciences Directorate*

Environmental Intelligence

Answering big questions about environmental change begins with many small measurements

Researchers with the Next-Generation Ecosystem Experiments in the Arctic (NGEE-Arctic) project, including a team from ORNL, are quantifying the physical, chemical, and biological behavior of terrestrial ecosystems in Alaska. Image credit: NGEE-Artic

Environmental intelligence is the wealth of information on the physical, biological, and chemical processes that drive Earth's ecosystems (its organisms, soil, air, and water) and the impact humans have on these ecosystems through our practices and developments. Such intelligence is often gathered though small, precise efforts to monitor complex environmental processes with sensing and measurement systems. By collecting new or more detailed observational data from a greater number of locations across the globe, researchers can improve scientific analysis through increasingly accurate computer models.

At the Department of Energy's (DOE's) Oak Ridge National Laboratory (ORNL), scientists and engineers in the Energy and Environmental Sciences Directorate (EESD) depend on environmental intelligence to broaden our understanding of how our

(continued on next page)

Center for Transportation Analysis
Sits down for a discussion with energy policy expert David Greene

Environmental and Biosciences Divisions
Study Arctic vegetation in order to build better climate models

Electrical and Electronics Systems Research Division
Designs sensors that monitor soil chemistry and microbial activity at new depths

Buildings Technologies Research and Integration Center
Unleashes simulated weather on building materials in new air and moisture chambers

National Transportation Research Center
Ramps up wireless power transfer technology for powering vehicles on the go

Energy and Environmental Sciences Directorate
Takes home honors in scientific research, outreach, and more at UT-Battelle Awards Night

OAK RIDGE National Laboratory

in the spotlight

Renae Speck, new manager of research relationships

Renae Speck named Manager of Research Relationships

Over the last few years, EESD has increasingly committed its expertise to large, multipartner initiatives such as the BioEnergy Science Center (BESC) and Critical Materials Institute (CMI), which were established to expedite research and development in high-priority areas. To effectively coordinate these expansive, timely relationships across disciplines and institutions, former Technology Transfer Division Senior Commercialization Manager Renae Speck began a new position as directorate Manager of Research Relationships on September 1. The position serves in roles similar to those of a project manager, proposal coordinator, and external partner liaison, as needed.

"What we're learning as we enter these large, multipartner collaborations that call on expertise across disciplines—and even across directorates, laboratories, and other partners—is that there is a larger burden of communication and coordination that is crucial to keeping the objectives of the project moving forward and succeeding," Speck said.

When DOE introduced CMI, an Energy Innovation Hub led by Ames Laboratory that focuses on finding science and technology solutions to the energy challenges posed by critical material scarcity and expense, Speck coordinated ORNL's efforts, which involved EESD; the Physical Sciences Directorate; and 18 partners from academia, industry, and other DOE national laboratories. Speck will continue work with CMI and BESC, while working with directorate management to capture and strategize future cross discipline, multipartner projects.

"EESD has a lot of signature strength that spans many clean energy areas, and we want to be a part of the hubs, institutes, and centers in those areas," Speck said. "So EESD wanted someone who had been a part of the early development of these newer model projects like CMI—someone who could mentor staff and management on the proposal process, the launch, and the maintenance of these large projects."

In her time with the Technology Transfer Division, Speck worked closely with research management and partners to negotiate agreements, often advising on contractual issues, intellectual property, and licensing. She also informed research staff on the processes required to achieve commercialization of their inventions. Likewise, Speck is a knowledgeable resource who can facilitate strategic collaborations and partnerships for EESD staff.

Before coming to ORNL in 2008, Speck served as a proposal development coordinator at Western Kentucky University and a program manager for the Vanderbilt Meharry Center for AIDS Research. She received her bachelor of science in recombinant genetics and chemistry from Western Kentucky and her doctorate in pharmacology from Johns Hopkins University, where she first developed an interest in technology transfer through exposure to the public health industry and research in HIV pharmacotherapy.

(continued from cover)

energy use affects environmental conditions in the long and short term. Researchers with the Next-Generation Ecosystem Experiments in the Arctic are investigating carbon storage and release in permafrost (where large stores of soil carbon may be susceptible to climate change) by monitoring soil composition and structure and nitrogen availability and by developing more precise classification methods for plant and root types for climate modeling (see p. 4). Furthermore, a team of researchers across EESD divisions is developing a multimeasurement probe outfitted with a range of sensors for measuring chemicals and microorganisms in soil layers up to 2 meters below ground (see p. 6).

Along with the directorate's continual advancements in energy-efficient vehicle, manufacturing, and building technologies, sensors and other instrumentation to gather environmental intelligence are answering crucial questions about what clean energy technologies must accomplish and how EESD research and development can get us there.

cleanenergy

Produced by Creative Media at Oak Ridge National Laboratory for the Energy and Environmental Sciences Directorate

Team Leader
Suzy Fowler

Publication Director
Katie Elyce Jones

Editors
Wendy Hames,
Priscilla Henson,
and Charlie Horak

Graphic Designer
LeJean Hardin

Newsletter Committee and Contributing Writers
Meghan Drake, Lori Frye, Penny Humphreys, Katie Elyce Jones, Jennifer Palmer, Tamara Rogers, and Sara Shoemaker

Photographers
Curtis Boles, Genevieve Martin, and Jason Richards

Additional Images
iStockphoto

Sustainability Summit engages record number of attendees in energy efficiency talks and demonstrations

ORNL's 3rd Annual Southeast Sustainability Summit convened August 21–22 in downtown Knoxville. The summit to advance a culture of sustainability and implement energy efficiency, renewable energy, and energy management projects has grown over the last 3 years, and this was the first year it was held off-campus in partnership with the state of Tennessee's Department of Environment and Conservation and the city of Knoxville.

Presentations by regional and national experts and 16 business vendor displays of clean energy technologies offered more than 250 government, business, industry, and academic stakeholders ideas for promoting energy-efficient designs and practices.

"The summit is an opportunity for key stakeholders who are trying to make sustainable decisions about their facilities or operations to learn about existing tools and technologies and what's coming down the pipeline," said Melissa Lapsa, whole-building and community integration group leader and summit cohost with Teresa Nichols.

Attendees also toured sustainable development activities taking place in Knoxville, including the LEED Silver Certified Convention Center and Transit Center, the University of Tennessee's (UT's) campus E-bike program, and solar-assisted electric vehicle charging stations on the UT campus and at the Knoxville Coliseum.

From ORNL, Laboratory Director Thom Mason announced the lab's role in establishing a new nonprofit organization, the Southeast Sustainability Group (SSG). With a goal of reducing energy cost and leaving a smaller environmental footprint in the Southeast, SSG will be focused on energy efficiency, sustainable transportation, low-carbon power generation, and waste reduction.

Martin Keller, associate laboratory director for energy and environmental sciences, shared EESD's efforts in developing clean energy technologies in the areas of transportation, buildings, and advanced manufacturing. In particular Keller discussed directorate research and development achievements in high-efficiency appliances, wireless power transfer technologies, and sensors and controls for optimizing buildings and manufacturing efficiency.

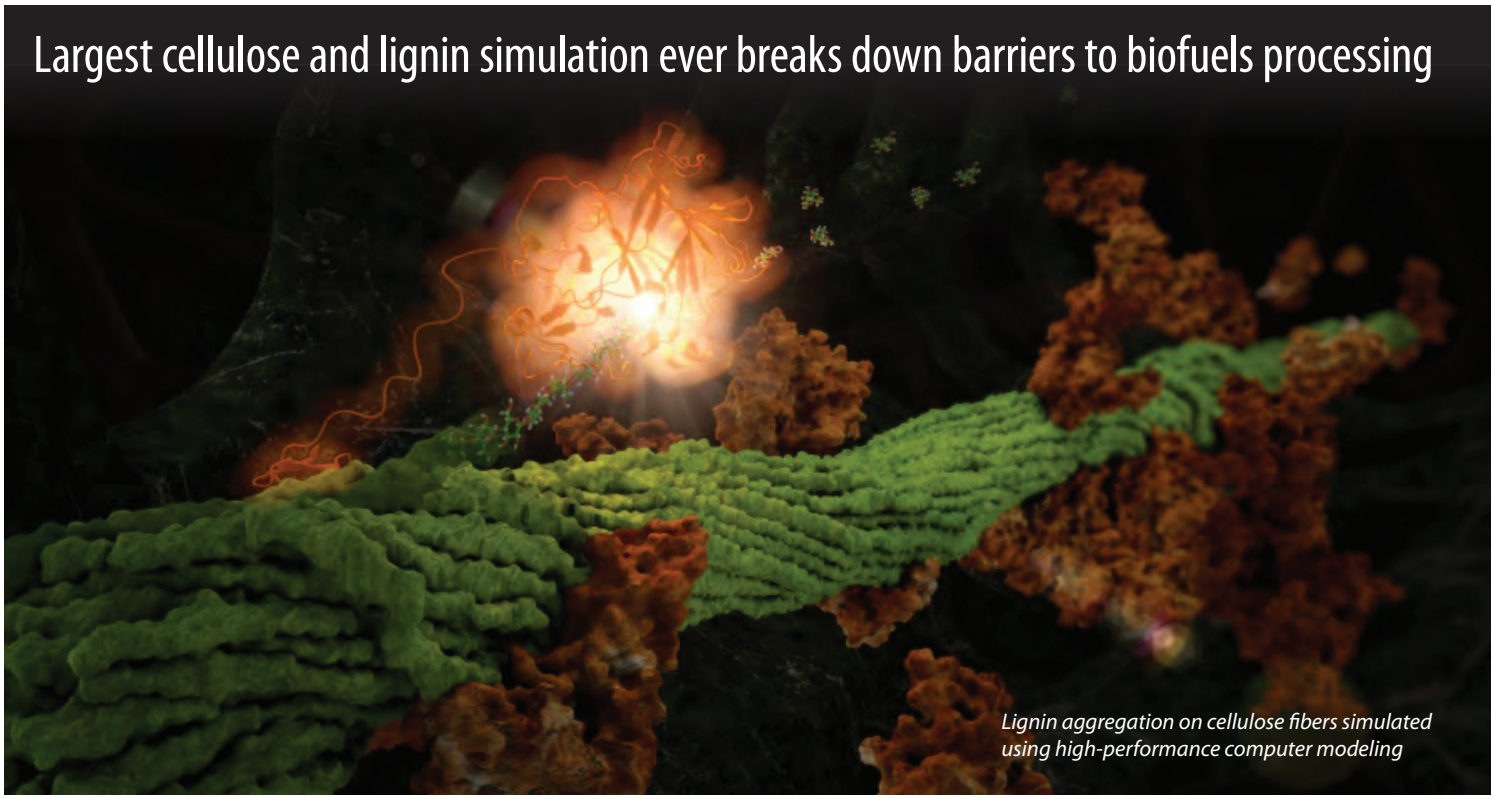
Lapsa presented ORNL's Sustainable Campus Initiative, which has implemented efficiency measures in lab facilities and provided regular information and incentives for more than 4,000 employees to reduce energy waste and improve sustainability, including campus initiatives such as a bike sharing and wellness programs.

"We've hosted the Sustainability Summit once a year, but through the Sustainable Campus Initiative we provide employees with ways to save energy at work year-round by integrating our research expertise and our own facilities," Lapsa said. "The summit is a chance to share what we've learned and to see what other organizations are doing as well."

Other ORNL speakers included Herb Debban, Scott Curran, John Shonder, Julia Kelley, and Roderick Jackson. In addition to ORNL, SSG board members include the Black Bear Solar Institute, Clark-Atlanta University, Indian River State College, Nissan North America, the Tennessee Valley Authority, and UT.

Sustainability Summit attendees visited vendor exhibits for information on energy-efficient technologies and products, such as the Rhoades Car, a pedal-powered quadracycle.

Largest cellulose and lignin simulation ever breaks down barriers to biofuels processing



Lignin aggregation on cellulose fibers simulated using high-performance computer modeling

(continued on next page)

David Greene retires, leaving long legacy of energy and transportation research

After an illustrious 36-year career, energy policy research analyst David Greene retired from ORNL at the end of September. Greene's expertise has made him a frequently sought authority when energy is in the news. His observations, which often point to market forces' effects on oil prices, have invariably proven accurate in the long term.

In addition to generating a lengthy list of publications and honors as a corporate fellow and senior research staff member at ORNL's Center for Transportation Analysis, Greene has worked extensively with government, industry, and academia, including on the National Research Council's Transportation Research Board as an emeritus member of its energy and alternative fuels committees.

He was also the ORNL team lead for the development of FuelEconomy.gov, one of the US government's most visited websites. Developed by DOE and the Environmental Protection Agency, the site hosts 48 million user sessions annually and is estimated to have helped the US reduce petroleum consumption by more than 928 million gallons in 2012.

Greene is a lifetime National Associate of the National Academies and was recognized as a contributor to the 2007 Intergovernmental Panel on Climate Change report, which won a Nobel Peace Prize.

He continues to share a wealth of fuel-economy and energy-policy knowledge through his work at the Howard H. Baker Center for Public Policy as the senior fellow for energy and the environment and as a professor in the University of Tennessee's economics department.

During an interview with Bill Cabage of ORNL media relations, Greene offers his vision for the future of the nation's sustainable transportation architecture.

CABAGE: What's changed in 36 years—1977 to 2013?

GREENE: In 1977 people weren't thinking about climate change and greenhouse gases as an urgent problem. Since then there has been a realization and understanding that we need to completely change the energy basis of our transportation systems over the next 40 to 50 years. Unfortunately, while our understanding may have changed, our practice hasn't, and history tells us that's going to be a challenge.

CABAGE: Why is it so hard?

GREENE: It's not so much about the automobile but the energy. The internal combustion engine has become extremely sophisticated over the years, and we have a fuel supply system to support that.

Changing that petroleum energy infrastructure is going to be very difficult because of what systems analysts call "technology lock-in," or the difficulty of introducing novel technologies like fuel cells or battery electric vehicles.

CABAGE: What are the difficulties with new technologies?

GREENE: It could take the industry 10 to 20 years to make a viable transition for several reasons: technology lock-in, the upfront expense of electric and hybrid cars, and the inconvenience of their shorter travel range before charging. All the while, companies that are selling cleaner, new technologies are losing money.

The good news is that if the estimates are right, you're going to receive roughly 10 times the cost in benefits over the long run. The benefits to the environment, the climate, and energy security are probably going to save a significant amount of money

(continued on next page)

(continued from previous page)

To investigate atomic interactions in plant cell walls that cause recalcitrance, or the resistance to molecular breakdown for biofuels processing, University of Tennessee (UT)/ORNL Center for Molecular Biophysics researchers conducted the most detailed high-performance computing simulation of cellulosic biomass to date.

Lignin, a polymer in plant cell walls, gives woody plants their rigidity. However, lignin's aggregation and strong adhesiveness to cellulose blocks enzymes from breaking down cellulose fibers into sugar, adding significant cost and time to biofuel production.

To better understand the physical mechanisms at play in lignin aggregation to cellulose, researchers, including Benjamin Lindner, Loukas Petridis, Roland Schulz, and Jeremy Smith, simulated millions of cellulose and lignin atoms on ORNL's petascale Jaguar supercomputer. The results, published in *Biomacromolecules*, offer new insights into how cellulosic ethanol for biofuels could be more effectively processed.

"We wanted to know what drives lignin to aggregate," Smith said. "It was the biggest biomass simulation ever performed, and it showed lignin aggregating on two different cellulose forms, crystalline and noncrystalline."

Although biofuels researchers have long known that plants have crystalline, highly structured cellulose regions, as well as less structured, noncrystalline cellulose regions, how cellulose crystallinity affects lignin adhesion had not been confirmed.

The UT/ORNL team modeled three simulations (two of crystalline and one of noncrystalline cellulose), each with 52 lignin molecules surrounding the cellulose fibrils in water. Three quantities were calculated to describe lignin aggregation: contact between atoms (lignin-to-lignin and lignin-to-cellulose atoms), the energy of intermolecular interaction, and the surface area accessible to water.

"Our findings support previous observations that two of the main factors contributing to the recalcitrance of plants—the ordered structure of crystalline cellulose and the adhesion of lignin that blocks enzymes from reaching the cellulose—are interdependent," Petridis said.

Because noncrystalline cellulose regions are more hydrophilic (have a greater affinity for water), they are less likely to adhere to lignin molecules in favor of bonding to water, which promotes hydrolysis, or the separation of bonds due to a reaction with water.

"This understanding of the molecular interactions between cellulose and lignin and the influence of hydration suggests we could make the pretreatment process more effective by manipulating cellulose crystallinity," Lindner said.

These results indicate scientists could introduce more disorder into crystalline cellulose regions when processing biofuels, giving enzymes the opportunity to break through lignin barriers and more efficiently release sugar compounds.

David Greene… (continued from previous page)

on energy. It's going to be cheaper to operate these vehicles.

CABAGE: What are the benefits?

GREENE: Obviously one benefit is the potential to reduce greenhouse gases. If you want to get to near-zero or 80% reduction in greenhouse gases [as proposed in a March 2013 National Research Council report], you can't do that by burning petroleum, even if we make the vehicles as efficient as possible. Another is reducing petroleum dependence to increase our energy security. This is a hard problem for our political system because there's a certain amount of pain up front.

We are doing well with improving energy efficiency—what I've spent my career on. About 30 years ago I realized that fuel economy standards were the most important thing in transportation and energy. Right now the standards are in good shape. The Environmental Protection Agency (EPA) just set appropriately strict standards that, more or less, call for doubling the efficiency of cars and light trucks by 2025.

CABAGE: Will those standards be met through engine technologies, lightweight materials, going to electric vehicles, or hybrids?

GREENE: All of the above. It will be mostly engine transmission and body technologies—like aerodynamics, rolling resistance, and engine efficiency and transmission improvements. But, I think they're still going to need some degree of lightweight materials, and there will be more hybridization than EPA and the Department of Transportation have predicted.

Manufacturers spend hundreds of billions of dollars making improvements to these vehicles, and consumers save hundreds of billions of dollars every year. So even though we're still roughly 95% dependent on petroleum, we're using it more efficiently now, and we will continue doing so in the future.

David Greene shares insight on nation's fuel economy future.

Researchers of plants, roots, and soil shed light on Arctic ecosystem

To gain a better understanding of the importance of Arctic vegetation in climate models, a team of researchers from ORNL's Climate Change Science Institute is taking a closer look at the intricacies of the Arctic's plant communities, research that has huge implications for global climate models. Because plants are instrumental in terrestrial carbon, water, and energy exchange, the team's work will reveal the complex relationships that, woven together, create Earth's climate. They shared their work August 5 in Minnesota during talks at the annual meeting of the Ecological Society of America.

Using the environs of Barrow, Alaska, as their laboratory, ORNL researchers Stan Wullschleger, Richard Norby, Colleen Iversen, Joanne Childs, and Victoria Sloan study different portions of the Arctic plant ecosystem that, while seemingly separate, are all intricately connected. They are participants in the Next-Generation Ecosystem Experiments in the Arctic (NGEE-Arctic) project of DOE's Office of Science. NGEE-Arctic seeks to increase confidence in climate projections by quantifying the physical, chemical, and biological behavior of terrestrial ecosystems in Alaska. The results will likely inform research in the greater Arctic, which is warming twice as fast as the rest of the planet.

If climate models are to continue to evolve, a better understanding of the Arctic is necessary. The NGEE-Arctic project will entail 3 years of integrated modeling and experiment at the Barrow Environmental Observatory, followed by a decade of extending the approach across Alaska. Data will be used to reduce uncertainty in climate models and help predict the effects of global warming over the next century.

Plants of a feather

Even with the most powerful computers in the world, climate scientists are forced to make numerous approximations and classifications to simplify their models. For example, plant functional types (PFTs) are categories researchers use to classify plants according to certain characteristics (i.e., deciduous versus evergreen trees or trees versus grasses). Scientists need a database of where the various categories are located on the globe.

Despite this need, the Community Land Model, a portion of the popular Community Earth System Model used to model global climate change, treats all of the Arctic's diverse plant types as a grass. A better, more precise classification system is needed to further our understanding of the larger Arctic ecosystem and its effects on Earth's climate. Enter Stan Wullschleger, and the team of ORNL plant ecologists who are attempting to better classify Arctic plants by type and function, giving climate modelers one more level of precision in their quest to more accurately predict the years ahead.

"The challenge likely to be encountered in moving forward with modeling vegetation dynamics lies in evaluating the trade-offs between simplicity in our classification of PFTs while capturing sufficient complexity in describing differences among PFTs for major ecosystem properties and processes," Wullschleger said.

If climate models are to continue to increase in accuracy, a more nuanced and thorough classification of PFTs is critical.

After the thaw

Wullschleger's teammates Richard Norby and Victoria Sloan are digging a little deeper—literally. By exploring the effects of soil nitrogen on the Arctic's vegetation, Norby is learning more about the role of climate change in reorganizing plant communities. Researchers expect that as climate change escalates, the Arctic's thawing permafrost will release nitrogen stored in the soil for eons.

The released nitrogen will almost certainly escalate plant growth, but different plant types will respond differently. By studying the relationship between leaf area

Polygon formations in Alaska provide researchers with a unique natural laboratory in which to study the Arctic and, by extension, the Earth's climate. Image credit: NGEE-Arctic

and nitrogen availability in polygonal land structures around Barrow, Norby hopes to make accurate estimates of the effects of nitrogen on Arctic plant life.

Specifically, Norby's project tracks nitrogen availability with depth as the active permafrost layer thaws during the growing season; seasonal variation in plant nitrogen; spectral signatures of plant communities that will correlate with nitrogen content; and the link between plant and soil characteristics, with root characteristics controlling nitrogen uptake.

The root of it all

The final piece in the team's research involves the classification of root systems. Just as Wullschleger is attempting a finer categorization of plant types and function, his colleague Colleen Iversen hopes to accomplish the same with the Arctic's root systems.

Surprisingly, belowground plant characteristics are not represented in most large-scale climate models. And in environments such as the tundra that are typified by extreme conditions, surveys indicate that roots and belowground stems can contain as much as six times the mass of aboveground plant parts. The plant species that call the tundra home have a variety of unique adaptations that enable them to survive in harsh Arctic conditions. These unique, integral systems are begging to be classified and, ultimately, associated with PFTs for a more complete representation in models of the processes that govern the Arctic ecosystem.

The symbiotic nature of the team's various research interests serves one purpose: to give climate modelers a better picture of the Arctic, a heretofore mysterious region that is not accurately represented in modern models, yet plays critical roles in the global climate system.

Susan Hubbard (Lawrence Berkeley National Laboratory), left, and Stan Wullschleger (ORNL) measure thaw depth and temperature near Barrow Environmental Observatory. Image credit: NGEE-Arctic

NGEE-Arctic project director receives double honors for climate research, communication

Next-Generation Ecosystem Experiments in the Arctic (NGEE-Arctic) project director Stan Wullschleger has been named a 2013 UT-Battelle Corporate Fellow. Wullschleger also received the UT-Battelle Science Communicator Award, which was presented on November 15 at ORNL's Awards Night celebration.

Since joining ORNL's Environmental Sciences Division in 1990 as an Alexander Hollaender Distinguished Postdoctoral Fellow, Wullschleger has performed pioneering research in climate change, the genetic basis for bioenergy crops, carbon-water cycles, and molecular ecology.

He has published 144 peer-reviewed articles with 8500 citations, organized international conferences, and given more than 200 invited talks. Throughout his career Wullschleger has demonstrated exceptional breadth and depth in his science. The rank of corporate fellow is among the lab's highest honors and recognizes his accomplishments and continuing leadership in his field.

As recipient of the Science Communicator Award, Wullschleger was lauded for sustained communications efforts to educate the public—as well as the broader scientific community—about climate change research, thereby sharing the excitement and value to society of ORNL's and DOE's scientific research programs. As part of his outreach to the public, he manages a blog at http://ngee-arctic.blogspot.com/, where he has posted more than 125 entries and photographs of the NGEE-Arctic project in action.

Probe uses multiple sensors to measure soil characteristics crucial to carbon cycle

Researchers extract a 2-meter soil sample from a Minnesota peat bog for assessing a new probe that monitors biological and chemical processes in soil.

Energy and environmental research often calls scientists to places and depths they can't physically go—beneath ice shelves or inside volcanoes and nuclear reactors. Even the soil beneath our feet presents many unknowns to scientists studying climate and the carbon cycle.

Researchers estimate that 50% of the world's carbon is stored in soil and vegetation. In this way, soil affects the course of climate change, not to mention it's the stuff that houses roots, microbes, and other crucial components of Earth's complex terrestrial ecosystem. However, scientists need to monitor multiple layers below ground to study the biogeochemical processes taking place and how those processes are impacted by environmental changes.

Rapid developments in sensor technology are granting researchers the remote access they need to study such extreme or inaccessible environments.

A Laboratory Directed Research and Development project led by the Electrical and Electronics Systems Research (EESR) Division is developing new measurement technology for characterizing fundamental carbon-cycle processes in the subsurface environment. Principal investigator Peter Fuhr and coinvestigators Roger Kisner, Timothy McIntyre, Jeffrey Warren, Paul Hanson, and Christopher Schadt, who work across the EESR, Environmental Sciences, and Biosciences Divisions, just completed their first year of the project and are into their second.

The multimeasurement probe under development will measure microbial activity, gases, temperature, and other variables 2 meters below ground—without digging or disturbing the natural environment. The probe will also be outfitted with a wireless communication module so researchers can access it from their offices, which can accelerate analysis, allow real-time observation of environmental response to changing conditions, and enable researchers to monitor many sites at once.

A better understanding of how microbial activity and chemical composition contribute to carbon storage and release will help improve climate models that rely on real-world, observational data to test their accuracy—and the more data, the better.

The probe design consists of a cluster of optical fibers and electronic sensors, including a unique ORNL sensor design that integrates electrical wires and optical fibers ("wibers"). The sensors, capable of collecting data across the stratum of the subsurface environment, measure temperature and water level and offer a range of measurement techniques, including optical absorption spectroscopy, optical fluorescence spectroscopy, and electric impedance spectroscopy.

The probe is also equipped to extract small, aqueous samples. The sensors

(continued on next page)

Advanced manufacturing R&D is "rolling" out printed sensors for range of devices

ORNL's printed sensor research is focused on the integration of functional sensors and devices onto low-cost, flexible substrates and within complex 3D structures. The sensors have the potential for a wide variety of applications, including multiparameter sensing and detection, data processing, wireless communication, and energy harvesting. Advancements in printed electronics by direct writing techniques could be used on thin film transistors, organic light-emitting diodes, solar cells, radio-frequency identification devices, antennas, inductors, capacitors, interconnects, sensors, and displays, among other devices.

While printed electronics are a relatively mature technology, the emerging capabilities of large-area thermal processing and low-cost printed electronics are bringing about new opportunities for using sensors on unconventional substrates. The benefits of printing devices on flexible substrates include their potential to be lightweight, foldable, thin, and manufactured by continuous, roll-to-roll processes.

Diverse materials and process technologies are being assessed to develop a novel, multifunctional sensor platform that will evolve with advances in materials technology; low-cost printing techniques; and integration of monitoring, control, and communication circuitry. Smart sensor systems combined with microsensor technology also enable the ability to make units that are small, smart, and multifunctional.

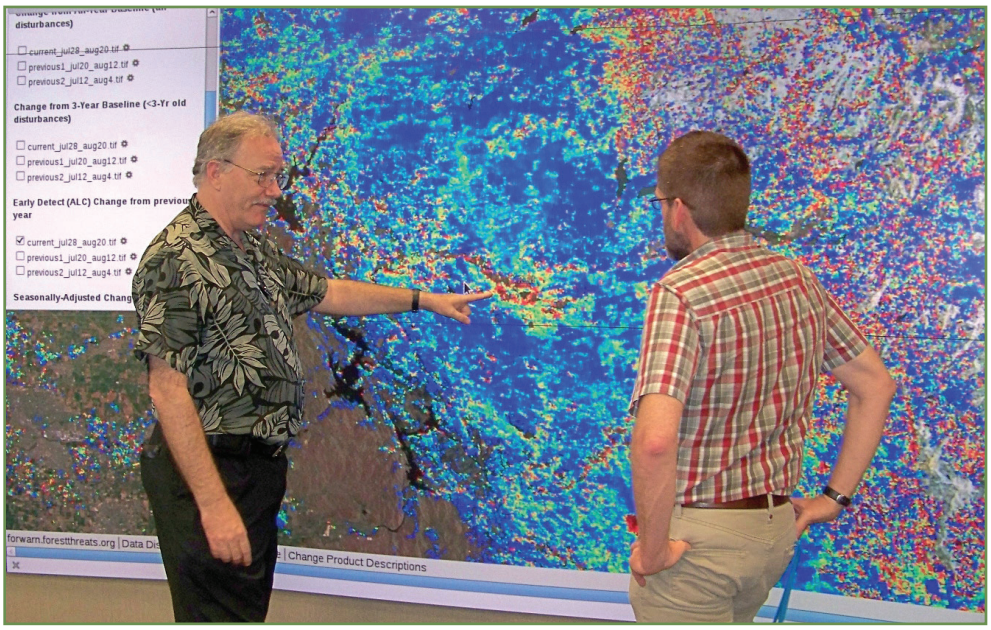
(continued from previous page)

communicate a suite of measurements on temperature, gas (such as carbon dioxide and methane) concentrations, dissolved organic matter (which can be a food supplement for microbes and, therefore, an indicator of microbial activity), and the presence of nitrogen compounds, all at incremental depths from 5 to 200 centimeters within a soil column.

One uncertainty at greater depth is the concentration of soil gas (pockets of air containing oxygen), which influences plant growth and microbial activity. To overcome this lack of information, ORNL researchers included a fluorescent oxygen-sensing probe that measures a chemical composition that changes fluorescence with the level of oxygen concentrations. Although measuring oxygen in situ is normally difficult, the optical fibers can signal when fluorescence is high or low, indicating how much oxygen is present.

In its first year, the research team designed the probe with optical sensors and constructed a column to hold a sample of peat bog. The peat bog column was extracted from the area in northern Minnesota studied by ORNL's Spruce and Peatland Responses Under Climatic and Environmental Change (SPRUCE) project, an experiment to assess the response of peatland ecosystems to increases in temperature and elevated atmospheric carbon dioxide concentrations. The column was brought back to ORNL for calibrating and testing of the probe. More SPRUCE columns are expected to arrive as the team continues to assess the probe's sensors.

The team will also install probes in the field closer to home. Before the end of the year, it expects to begin wirelessly connecting inground sensors deployed at Walker Branch on the ORNL reservation to a set of computers on ORNL's main campus. This step will allow researchers to develop and refine the probe's remote access data visualization wireless communication module.



At ORNL's EVEREST visualization facility, Forest Service research ecologist Bill Hargrove, left, and ORNL research scientist Forrest Hoffman use a ForWarn map to examine growing impacts of the Yosemite Rim Fire.

ForWarn researchers get EVEREST-sized look at woodland disturbances

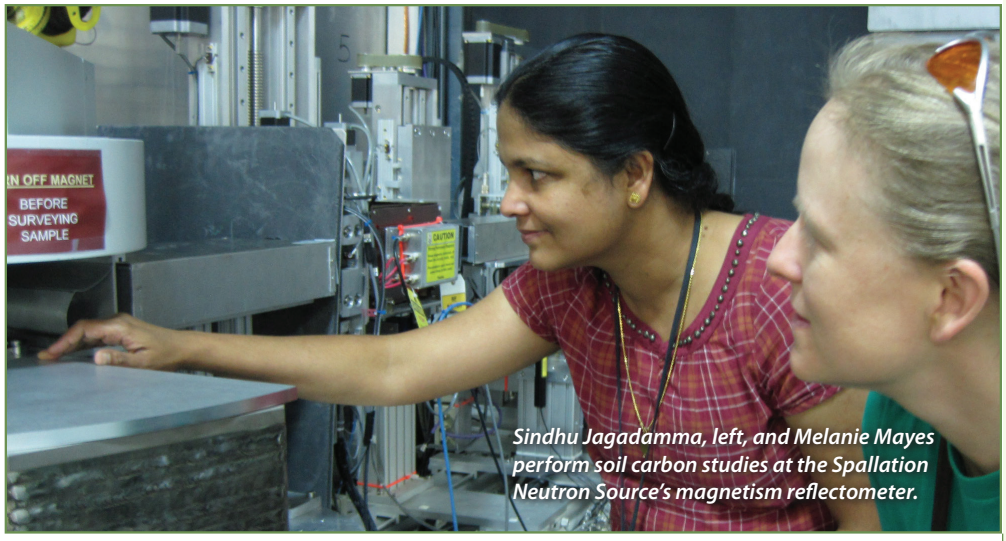
An exploratory visualization facility at ORNL has provided researchers with the US Department of Agriculture Forest Service's Eastern Forest Environmental Threat Assessment Center and its partners a unique view of maps used for detecting and tracking unexpected forest changes and disturbances.

The researchers are part of a large team that developed the first near-real-time forest threat early warning system in the contiguous United States. Called ForWarn, the satellite-based system delivers maps that provide information about forest greenness from coast to coast every 8 days. The maps compare current vegetation greenness levels to those from 1, 3, and 10 years ago to highlight potential disturbances and postdisturbance recovery. ForWarn provides tools to help attribute disturbances to insects, disease, wildfire, extreme weather, and human development.

On August 23, Forest Service research ecologists Bill Hargrove and Steve Norman came to ORNL to meet with Forrest Hoffman and Jitendra Kumar, experts in data analytics algorithms at ORNL's Climate Change Science Institute. To turn data into insight, they viewed recent ForWarn maps at ORNL's EVEREST (Exploratory Visualization Environment for Research in Science and Technology) visualization facility. Operated by ORNL's Oak Ridge Leadership Computing Facility staff, EVEREST creates depth in detailed images for a 3D effect using 18 individual display monitors, each with 1920-by-1080-pixel resolution. The monitors are arranged in a 6-by-3 configuration to create a 37-megapixel wall.

When the Forest Service researchers came to ORNL to analyze big data regarding a number of forest disturbances, they were at the right place at the right time to view effects of past wildfires in the West and give the massive Rim Fire burning in California near Yosemite National Park a closer look. The ForWarn "Early Detect" map showing the Yosemite wildfire had just been processed and made available that day.

ForWarn researchers say that the tool's capability to provide information about the fitness of forests over time may improve predictions about the number of years required for vegetation to recover to its prefire level of greenness. Through close examination of vegetation impacts, the collaborators may be able to help resource managers track recovery from increasingly frequent and intense blazes, including the Rim Fire—now California's third-largest wildfire.



Sindhu Jagadamma, left, and Melanie Mayes perform soil carbon studies at the Spallation Neutron Source's magnetism reflectometer.

ORNL researchers use neutron analysis to understand soil carbon cycling

Researchers at ORNL are using neutron beams to shed light on the chemical mechanisms that influence soil carbon stability and its impact on future climate change. Sindhu Jagadamma, a postdoc in the Environmental Science Division and Climate Change Science Institute, is collaborating with the laboratory's Neutron Sciences Directorate to conduct a novel study to understand the interaction of organic carbon with soil minerals at the nanometer scale.

Why is soil carbon stability important to climate modeling?

JAGADAMMA: Soil represents the largest active pool of carbon on land, but we've never had the most appropriate technology to investigate how it interacts with minerals. It's mostly been viewed as a "black box."

Because soil carbon is a significant component of the global carbon cycle, its stability is very important. We want to know how long carbon can be stored in the soil. The goal of our paper that was published in Geoderma this year was to determine how different carbon compounds become arranged on soil minerals and whether compounds are stacked on top of one another to increase carbon storage in soils. Once we understand this concept, we'll be able to better represent soil carbon dynamics in computer models.

Recently you and your Neutron Science colleagues, Haile Ambaye and Valeria Lauter, have used neutrons to study the architecture of organic carbon on minerals for the first time. Why is this study significant?

JAGADAMMA: Researchers have used other techniques like microscopy and spectroscopy to study soil carbon chemistry and pore structure, but the resolution and sensitivity of those techniques are not fine enough to capture the layering of different carbon compounds on soil minerals. We used the intense neutron beam of ORNL's Spallation Neutron Source to fill this gap by performing experiments on the magnetism reflectometer.

Neutrons are uncharged particles that can rapidly penetrate the electron clouds of atoms, allowing them direct interaction with the nucleus of light elements like carbon. By using neutron beams, we have confirmed that there are specific preferences in the layering of carbon compounds on minerals, bringing us one step closer to revealing the mystery of the soil carbon black box.

How will your research improve climate modeling?

JAGADAMMA: With the help of neutrons, we've learned that different carbon compounds can be arranged in a layered profile on minerals. We suppose that microbes degrade compounds at different rates depending on their position within the layered structural framework, but we don't know that yet. We are planning to conduct further studies to determine whether this is true. Understanding controls on the stability of carbon could improve predictions of the rates of decomposition in climate models.

The project was funded by the ORNL Laboratory Directed Research and Development program.

Chamber simulates indoor and outdoor environmental conditions to study durability of wall assemblies

The air-and-moisture-penetration chamber that simulates the exposure of walls to weather and indoor conditions was installed in the Maximum Energy Efficiency Building Research Laboratory (MAXLAB) at the end of July. The chamber is an essential research facility for characterizing the air-sealing and moisture-durability performance of wall assemblies and understanding the interaction of their components: interior/exterior cladding, vapor retarder, air barrier, structural framing, and insulation. The facility is composed of an indoor and an outdoor room that regulate temperature, relative humidity, and pressure. The outdoor room is additionally capable of simulating solar radiation, rain, and wind pressure—allowing researchers to replicate the effects of Florida's coastal summers or North Dakota's blustery winters.

Three removable wall frames are available to be outfitted with a wall assembly, then rolled and sealed between the two rooms, separating the indoor and outdoor spaces. ORNL researchers and industrial partners can make performance characterizations on an accelerated basis, in the sense that there is no need to wait for weather to happen. Researchers know the most challenging weather for the performance attributes being measured and can impose those same weather conditions on a series of alternative new or retrofitted wall assemblies. An accelerated test might involve, for example, stressing the assemblies with wind loads and then implementing moisture soaks to test performance over cycles of rain and high winds.

"Things get complicated when you put all the wall components together," said Diana Hun of the Building Envelope Research Group. "There are many tests for investigating the performance of insulations, sealants, and other building materials in isolation, but the chamber allows researchers to study an entire assembly at once without having to wait for weather to happen."

(continued on next page)

Visitors tour the air-and-moisture-penetration chamber installed at the Maximum Energy Efficiency Building Research Laboratory (MAXLAB) in July.

(continued from previous page)

Throughout air and moisture cycles, researchers can examine durability by installing sensors within the test walls to measure temperature, relative humidity, moisture content, airflow and pressure, which will serve as indicators of moisture buildup, heat transfer, and airtightness. Hun said the chamber will also help researchers determine a performance baseline by comparing advanced wall assemblies to baseline walls representative of what exists in many of our buildings—which could help manufacturers, designers, and contractors make decisions about when and how to upgrade buildings, as well as what materials will be most cost- and energy-efficient.

"There are a large number of building materials and wall assembly options out there, and designers and manufacturers want to be able to recommend cost effective, energy-efficient new wall designs and existing wall retrofits for various climates," Hun said.

In the near future, Hun and Building Technologies Research and Integration Center staff will use the chambers in research projects funded by DOE's Building America program, as well as the US-China Clean Energy Research Center for Building Energy Efficiency (CERC BEE), a collaboration between the United States and China to reduce the carbon footprint of residential and commercial buildings in both countries.

"For the CERC BEE collaboration, I'm working with Dow Chemical and 3M to characterize the performance of technologies they have under development for sealing gaps around windows and other penetrations through walls," Hun said. "The emerging products are expected to speed up the installation process and improve the performance of the air barrier system, which decreases air conditioning and heating loads."

The chamber might also be used to identify potential wall retrofits for the research buildings currently installed on MAXLAB's flexible research platforms or FRPs. The FRPs are permanent foundations and skeletal structures around which research buildings are installed and monitored. Essentially any feature that would influence the energy use of the research buildings can be changed, making them ideal test beds for emerging building energy efficiency technologies.

Researchers address environmental and industrial interests in new hydropower models

Three government agencies are collaborating to meet the nation's goals for reliable, affordable, and environmentally sustainable hydropower. Under the Memorandum of Understanding for Hydropower, DOE, the Department of the Interior, and the Department of the Army are advancing the science of maximizing hydropower production while ensuring the water quality of rivers and reservoirs will sustain healthy ecosystems.

Hydropower converts the potential energy of stored water into electrical energy using turbine generators. However, reservoirs that store water for hydropower production can form deep layers of cold, oxygen-deficient water that are harmful to aquatic life downstream. Aquatic life is also sensitive to the timing of flow releases from reservoirs.

"These impacts are especially noticeable where flow varies significantly and can adversely impact downstream aquatic ecosystems that depend on particular flow patterns," said Boualem Hadjerioua, ORNL's principal investigator for hydropower quality research.

Apart from predicting precipitation and runoff into streams and rivers, optimization of reservoir flow releases for hydropower generation alone is straightforward with modern computer systems. Yet most facilities do not have daily decision-making tools that model both the best means of generating power and the water quality needs of the local environment.

"A well-optimized hydropower system requires a fully integrated approach with the goal to achieve energy production and environmental quality simultaneously," Hadjerioua said.

Many decision-support systems currently available to hydropower facilities predict variables, such as inflow and reservoir storage and spill releases for excess water, focused on maximizing power generation, while separate models provide information on water quality, such as the amount of dissolved oxygen and water temperature—indicators essential to assessing the health of aquatic life.

The integration of power and environmental considerations is challenging because what is known about relationships between healthy ecosystems, water quality, and flow releases is mathematically complex.

To improve water quality and hydrodynamic models, the Water Power Program team, funded by DOE's Office of Energy Efficiency and Renewable Energy (EERE), is

(continued on next page)

hydropower models…*(continued from previous page)*

developing state-of-the-art mathematical modeling tools that can be embedded in current decision-support systems used by hydropower facilities nationwide.

Researchers first examined the operational challenges and current processes used to manage hydropower operations. Then they used an existing high-fidelity hydrodynamic and water quality model (known as CE-QUAL-W2) to develop detailed simulations of water flow, temperature, and dissolved oxygen throughout demonstration reservoirs.

Ongoing work is aimed at integrating these complex simulations into daily decision-making models. Collaborators are working on models of the Columbia River in the Pacific Northwest to address total dissolved gas limits for fish and the Cumberland River in the Southeast to address temperature and dissolved oxygen needs. The Cumberland River prototype will optimize hydropower generation while maintaining water quality in the Cordell Hull and Old Hickory Reservoirs, which are bound by Wolf Creek and Cheatham Dams.

"The tools can be integrated within multiple models such as those used to operate the Columbia or Cumberland River systems on a real-time basis or for long-term planning," Hadjerioua said.

Self-cleaning solar panel coating lets in the light

Soiling—the accumulation of dust and sand—on solar power reflectors and photovoltaic cells is one of the main efficiency drags for solar power plants, capable of reducing reflectivity up to 50% in 14 days. Though plants can perform manual cleaning and brushing with deionized water and detergent, this labor-intensive routine significantly raises operating and maintenance (O&M) costs, which is reflected in the cost of solar energy for consumers. Under the sponsorship of DOE's Energy Efficiency and Renewable Energy SunShot Concentrating Solar Power Program, ORNL is developing a low-cost, transparent, antisoiling (or self-cleaning) coating for solar reflectors to optimize energy efficiency while lowering O&M costs and avoiding negative environmental impacts.

The coating—which is being designed by members of the Energy and Transportation Science Division, including Scott Hunter, Bart Smith, George Polyzos, and Daniel Schaeffer—is based on a superhydrophobic coating technology developed at ORNL that has been shown to effectively repel water, viscous liquids, and most solid particles. Unlike other superhydrophobic approaches that employ high-cost vacuum deposition and chemical etching to nano-engineer desired surfaces, ORNL's coatings are deposited by conventional painting and spraying methods using a mixture of organics and particles. In addition to being low-cost, these methods can be easily deployed in the field during repairs and retrofitting.

There are, however, challenges to the successful development of such a transparent, antisoiling coating. First, the coating must be very superhydrophobic to minimize the need for occasional cleaning, and it must have little (or even zero) effect on the transmission and scattering of solar radiation between the wavelengths of 250 to 3,000 nanometers. To meet these requirements, the coating must be no more than a few hundred nanometers thick, and the embedded particles must be considerably smaller. The extremely thin coating must also be durable under environmental exposure, including UV radiation and sand erosion, and be compliant with the US Environmental Protection Agency Clean Air Act emission standards, which limit the selection and combination of particles and organics that can be effectively used.

During the first year of this project, researchers experimented with a variety of organics and silica particles compliant with the Clean Air Act. They arrived at a particular formulation combining organic compounds with silica particles, which are dispersed in two sizes to enhance area coverage of particles within the coating.

The antisoiling coating exhibited excellent superhydrophobic properties, losing less than 0.3% of transparency over the entire solar radiation wavelength range. When exposed to several hundred hours of accelerated UV radiation and 100 hours of salt fog exposure, the coating exhibited no degradation in superhydrophobic or optical transmission properties. Also, when glass slides with the antisoiling coating were exposed to sand and dust in a custom-made wind tunnel, the particles did not adhere to the coated surface of the slides—showing great potential for its use in harsh environmental conditions.

In addition to antisoiling coating for solar applications, ORNL researchers are using their superhydrophobicity expertise to develop antisoiling cool-roof coatings, as well as anti-icing and anticondensation coatings for air conditioning and evaporative cooling applications, respectively. Going into 2014, the project will optimize the coating, perform accelerated exposure tests, begin development on a scalable coating technique, and perform small-scale field testing.

ORNL supercharges wireless power transfer technology for electric vehicles

ORNL researchers are dropping the cord in battery charging for electric vehicles (EVs) and plug-in hybrid models in favor of wireless power transfer (WPT) technology that has proven to be safer, more convenient, and more efficient than the standard plug-in model.

Using a proprietary design created at ORNL's National Transportation Research Center (NTRC), John Miller, principal investigator with the Power Electronics and Electric Machinery (PEEM) lab, and his team have developed a hands-free, magnetic coupling coil system that wirelessly transfers electricity to a vehicle with an onboard battery pack while it's parked over a floor-embedded charging sensor.

The project's multiphase approach includes testing stationary charging of multiple vehicles in real-world situations, such as cars and buses in parking lots and garages. A longer-term objective involves further developing dynamic in-motion charging in which the vehicle's battery pack is replenished as it is driven over sensors installed along roadways. As part of a 2-year, Laboratory Directed Research and Development project that concluded in September, the ORNL team successfully demonstrated in-motion wireless charging of a small EV that was charged while driving across a series of six roadway coils.

"This is the ultimate in convenience. Without having to use a cord to plug in the charger to the vehicle, wireless technology takes the charging burden completely off the driver, making it autonomous and safer for people to use," Miller said.

ORNL has focused on WPT for onboard vehicle battery charging since 2008. During the past year, the lab has made significant strides in modified coil and power inverter technologies, as well as system controls that effectively and efficiently handle both in-motion and stationary charging. Test results from the lab show that using ORNL's wireless coils as a charging source can bring an EV's battery pack to full charge with 90% efficiency, which is comparable to the current plug-in method and is the highest charge rate among competing WPT technologies for EVs. The efficiency goal is to match that of conductive chargers for which wall-plug-to-vehicle-battery efficiency must be 85% or higher. This value includes functionality to maintain grid power quality and electrical safety isolation. The ORNL WPT technology incorporates all these features and employs a wide bandgap SiC semiconductor-based power factor corrector that achieves a power factor greater than 98%, ensuring an efficient delivery of power to the vehicle

Wireless power transfer technology enables in-motion charging of onboard vehicle batteries. Electric vehicle owners could one day use wireless charging as they drive over embedded sensors such as those picture here.

The ORNL-led project team includes Evatran, General Motors, Toyota, and Clemson University, with support from Duke Energy and International Rectifier. This team's impressive gains in wireless charging research, coupled with a strong focus on user safety, led to an $8 million award from DOE to fund further development and demonstration of the grid-connected, ground-based coil units. With DOE's support ORNL plans to install its latest wireless charging coil design at an existing EV charging station as part of the lab's Sustainable Campus Initiative. It will be tested with a Toyota Prius parked over an 18- to 20-inch square of charging coils designed for 7 to 10 kilowatts of electrical charge.

Miller explained that during the next 2 years, his team will continue development of the stationary charging functionality of the wireless system; take the technology into the production-intent phase as it moves toward commercialization; and present the system to DOE for further testing, data collection, and validation at Idaho National Laboratory.

In the future, Miller said, moving from stationary to in-motion wireless charging of onboard vehicle batteries may require installation of inground direct current cabling along American highways. Setting up EV charging stations, which could resemble and function like toll roads, could be done in tandem with scheduled road construction and repair, and EV owners could use the equivalent of an electronic fast-pass system to pay for wireless charging as they drive over embedded sensors.

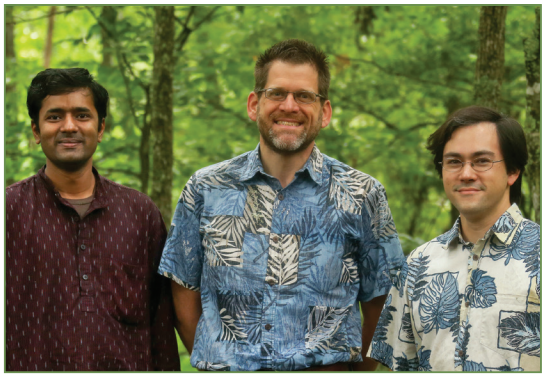
employee excellence

Pradeep Bansal, Energy and Transportation Science Division (ETSD), was appointed associate editor of *Heating, Ventilating, Air-Conditioning, and Refrigerating Research*, a journal published by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), the world's leading organization in heating, ventilating, air-conditioning, and refrigerating (HVAC&R) technology.

Kenneth Tobin, Electrical and Electronics System Research Division, was honored by the Institute of Electrical and Electronics Engineers (IEEE) Instrumentation and Measurement (I&M) Board of Directors as an IEEE I&M Society Fellow "for contributions to computer vision technology for instrumentation and measurement." This award is presented to a person with an extraordinary record of accomplishments in any of the IEEE fields of interest.

Stuart Daw, ETSD, has been elected fellow of the American Institute of Chemical Engineers (AIChE). AIChE recognized Daw for "numerous technical contributions in the fields of coal conversion, fluidization, reaction engineering, combustion, and engineering applications of nonlinear dynamics." Daw, who is a UT-Battelle Corporate Fellow and an adjunct faculty member at the University of Tennessee, holds 15 patents and has more than 200 published papers. He is a director of the local AIChE chapter.

John Shonder, ETSD, was named to ASHRAE's Research Administration Committee, which conducts and coordinates the society's research and technical studies in the HVAC&R fields.



For their contributions to ForWarn (see p. 7), an early warning system for identifying threats to forest health using remote sensing data, ESD's **Jitendra Kumar**, **Forrest Hoffman**, and **Richard T. Mills** were corecipients of five honors:

- The National Federal Laboratory Consortium (FLC) for Technology Transfer 2013 Interagency Partnership Award
- The Southeast Regional FLC 2012 Partnership Award
- The United States Department of Agriculture Forest Service Southern Research Station Director's Science Delivery Award
- The National Aeronautics and Space Administration Group Achievement Award
- The ORNL-Computer Science and Mathematics Division 2012 Most Distinguished Scientific or Technical Contribution Award

Esther Parish and **Virginia Dale**, Environmental Sciences Division (ESD), were interviewed in June about bioenergy sustainability by Bruce Burkhardt of the new Public Broadcasting Station series "This American Land." The interview segments may appear on an episode about biofuels expected to air in fall 2013.

EESD employees earn high praise at Awards Night

UT-Battelle presented its annual Awards Night honors to outstanding employees on November 15. Seventeen EESD employees were recognized for their scientific, administrative, or outreach achievements.

Liyuan Liang, Mircea Podar, Craig Brandt, Steven Brown, Dwayne Elias, Baohua Gu, Alexander Johs, Carrie Miller, Jerry Parks, Jeremy Smith, Scott Brooks, and **Xiangping Yin** were honored with the **Scientific Research** award for their groundbreaking research in biotic and abiotic mechanisms of mercury methylation in the environment, leading to high-impact publications in *Science* and *Nature Geoscience*.

Honored with **Excellence in Operations**, **David Fowler** was lauded for recent accomplishments that exceeded normal performance expectations and positively advanced ORNL's mission.

Kathleen Gambrell received the **Administrative Support** award for her exceptional contributions to administration and budgetary management of ORNL's DOE Vehicle Technologies Office subprogram in advanced power electronics and electric motors, exemplary contributions to the yearly Annual Operating Plan process, and completion of the *U.S. DRIVE Electrical and Electronics Technical Team roadmap* update.

For his exceptional efforts and dedication in mentoring and developing the next generation of leaders through Boy Scouts of America, specifically in the area of science, technology, engineering, and math education, **Trent Nichols** was honored with the **Community Outreach by a Team award**, along with **April McMillan** of the Computing and Computational Sciences Directorate.

Stan Wullschleger received the **Science Communicator** award for his sustained efforts to educate the public—as well as the broader scientific community—about climate research (see p. 5).

Oak Ridge National Laboratory
Energy and Environmental Sciences Directorate
P.O. Box 2008
Oak Ridge, TN 37831

Oak Ridge National Laboratory is operated by UT-Battelle for the US Department of Energy under contract DE-AC05-00OR22725.

Researchers with the Next-Generation Ecosystem Experiments (NGEE-Arctic) project collect permafrost cores in Alaska.
Image credit: NGEE