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Grasping for Air

Nighttime breezes may be key to mountain forests

Under a blue sky in mid-March, an Oregon State University research team left Corvallis to collect data in a valley deep in Oregon's western Cascades. The two-hour ride to the H.J. Andrews Experimental Forest gave the technicians and graduate students time to catch up before arriving at the facility's headquarters near Blue River. They would need their energy for what lay ahead.

by Nick Houtman

Their destination was a place known on the Andrews map as watershed 1. Its 60-degree slopes reach almost 1,500 feet from valley floor to ridge. Equipped with lunches, laptops and emergency radios, computer modeler Dave Conklin, technician and graduate student Adam Kennedy and other members of the team drove to the top of the watershed and descended into the forest through dark thickets of ferns, downed wood and moss covered rocks. Once they found the six temperature sensors (known as "HOBOs") that had been set in a line down the mountain, they checked each HOBO's battery and downloaded three months worth of data. At lower elevations, graduate student Claire Phillips collected data in soil plots that had been wired and plumbed to monitor temperature, moisture, root growth and CO_2 production. Despite the cool temperatures, this was sweaty science, a cycle of rigorous bushwacking followed by meticulous routine.

It was a typical day at the office for Andrews Forest researchers. Over the years, scientists here have hoisted themselves with climbing ropes high into the tree canopy, launched tons of soil and rock down a "debris flow flume" and spent sleepless nights observing boulder-tossing floods and recording wildlife behavior. Their results (described in the OSU Press book, *The Hidden Forest*, by Jon Luoma) have recast the national debate over old-growth forests, northern spotted owls, storm-generated erosion and other aspects of forest management. In watershed 1, they hope to create a new way to monitor mountain forests, which play a poorly understood but important role in the carbon cycle and climate system.

Since 2003, with support from a National Science Foundation grant, OSU scientists have been sampling the air in this watershed and in a neighboring valley. The latter is home to 450-year-old stands of Douglas fir and hemlock. In contrast, watershed 1 was clearcut in the mid-1960s to test the long-term effects of tree removal on ecosystem processes. Its young fir, hemlock and red alder already reach 80 to 120 feet high.

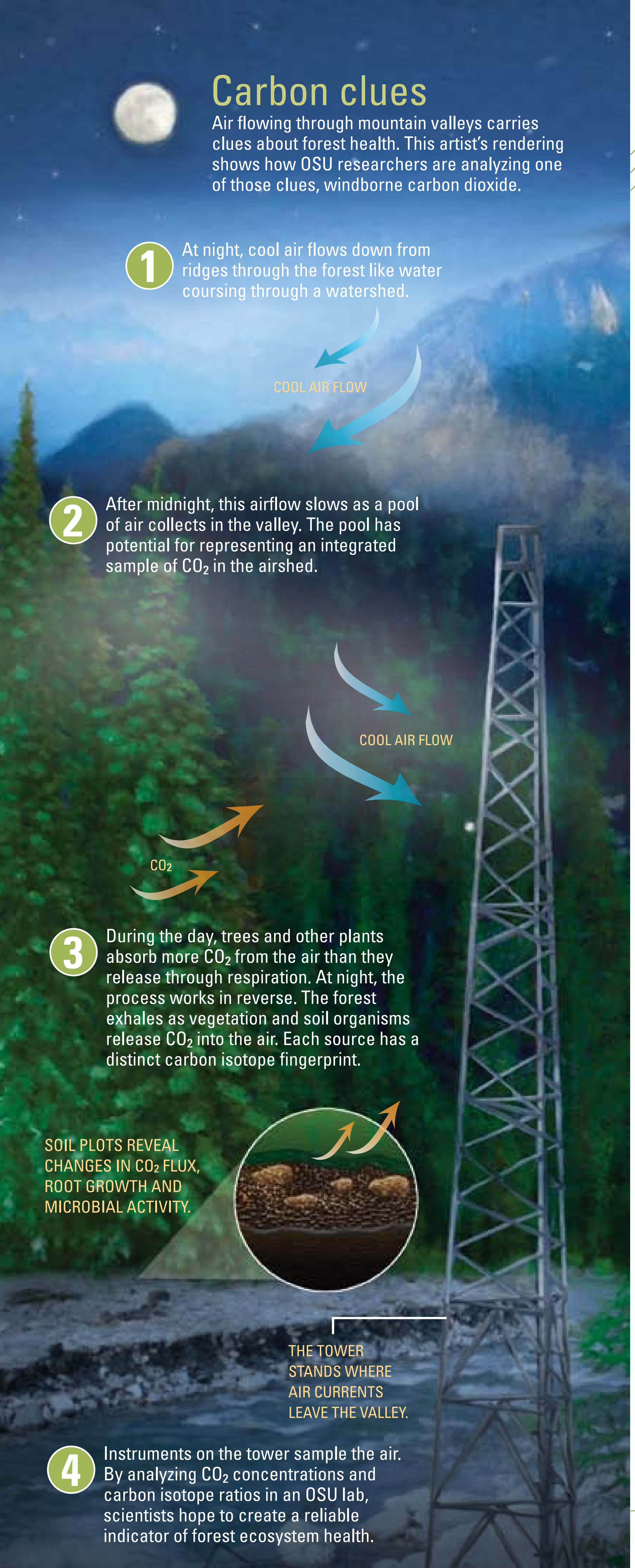
Cyber Forest

Watershed 1 is where these researchers have focused their most intense efforts. They have erected towers at the top and bottom of the watershed and equipped them to monitor the flow and chemistry of the air around the clock. (They even named their samplers "Fiona" and "Shrek," after a technician remarked that they are "big, green and ugly.") They have released tracers to track air streams that slide down the valley with nearly every setting sun. They have driven probes into the soil from ridge to ridge and have run monitoring cables up the streambed. And this fall, engineers plan to deploy a prototype ultra-low-power sensor system that could deliver even more data, turning up the information volume in what OSU forest scientist Barbara Bond and electrical engineer Terri Fiez call a "cyber forest" (see sidebar).

All this activity stems from a problem that forest scientists and climate researchers have tended to avoid until recently. In short, it's all about the mountains. Research on how forests interact with the atmosphere — how carbon flows from the air into trees and soil and back out again, how a changing climate will affect growth rates, water use and forest health — has been done largely in flat terrain. That's because mountains add complexity to systems that, in any landscape, turn on an array of factors: moisture levels, tree species, soil types, fire patterns and rates of photosynthesis and respiration, to name a few.

Reducing complexity is a common objective in science, and researchers have thus focused on wide-open landscapes that offer a single, common orientation to sun, wind and water. Mike Unsworth, an OSU environmental physicist and member of the Andrews research team, has been studying such processes since the 1970s. Then, he says, scientists regarded mountains as an "impediment" to such research.

Nevertheless, since mountains (what scientists call "complex terrain") account for about 20 percent of the planet, they loom as a gap in our understanding of how



> "We are measuring the isotopes in CO_2 that are exhaled from the trees and soils to understand the inside workings of the forest." -Barbara Bond

forests affect the carbon cycle. "Forests in mountainous terrain may respond to environmental change, such as global climate change, in completely different ways from forests growing in level terrain," says Bond, director of OSU's Andrews Forest program and a principal investigator in the watershed 1 work. "Everything that's important to tree growth, including precipitation patterns and water movement in the soil, distribution of sunlight, air temperature, fire paths and storm fronts, is shaped by mountains."

So Bond and a team of soil scientists, engineers and geoscientists are now looking for the signals that could provide a reliable, efficient way to monitor these forests. And for this purpose they have transferred the idea of a watershed, long a common concept in hydrology, to the air.

A Window Opens

Nearly every evening, as many hikers know, a steady breeze blows down through mountain valleys. As it does, it carries the exhaled byproducts of the forest, the CO_2 given off by every living organism from trees to soil microbes. By monitoring this "airshed," scientists hope to determine how much CO_2 the watershed exhales every night, and just as importantly, what this air reveals about forest health. The trick lies in distinguishing one CO_2 source (soils, trees, air entering the valley) from another and linking measurements to changing forest conditions. "Like a doctor who measures a patient's breath to learn about the inside workings of the body, we are measuring the isotopes in CO_2 that are exhaled from the trees and soils to understand the inside workings of the forest," Bond explains.

It's no surprise to OSU geochemist Alan Mix that isotopes (atoms of the same element that vary by atomic weight) provide those signals. Only half jokingly, he says that "the answer to any question, properly asked, is 'stable (non-radioactive) isotopes.'" For biologists and Earth scientists, measurements of isotopic ratios hold important clues about environmental health. The Andrews team is focusing on ratios of carbon-13 (rare carbon with an extra neutron) and carbon-12 (the most typical form) and concentrations of CO_2. The isotopes effectively provide a return-address label on the CO_2 in the air, allowing scientists to tell how much CO_2 came from trees and how much from soils.

In watershed 1, isotopes are thus key to analyzing nightly airflows and monitoring the forest. In a paper by Tom Pypker (former OSU post-doctoral researcher now at Michigan Technological University) and OSU colleagues due to be published in the journal *Agricultural and Forest Meteorology*, the OSU team reports that long after the sun sets, the breeze slows, and a pool of cool, well-mixed air settles in the valley like water behind a dam. At that time, the isotopic composition of CO_2 in that pool is a well- mixed representation of the entire watershed from ridge to ridge. The question is, what is the source of the CO_2 in that pool? Carbon isotopes give the answer and open a nightly window on forest health. The researchers caution that they need to confirm this observation through additional research.

"The project is helping us understand how the trees within a watershed alter their own environment," says Bond. "As a group they may 'behave' differently than they would on flat ground. For example, the air around these trees has different patterns of temperature, humidity and CO_2 concentrations than you'd expect in a forest on level terrain."

Another surprise stems from the soil. Research in a range of ecosystems, from prairies and farm fields to hardwood forests, has concluded that soils contribute about 70 percent of respired CO_2 from all systems on average on a yearly basis. Unconfirmed results from the Andrews suggest a less prominent role for soils in this system, perhaps as low as 20 percent in some seasons, says OSU soil scientist Elizabeth Sulzman. This may reflect the watershed's volcanic soils, steep slopes and thick coniferous forests, she adds. "We've got this unique combination of factors. We have the opportunity to figure some things out here that might teach us what's different about this system."

Sulzman's own goal is to get at the root of what drives carbon cycling in soils, the processes that cause carbon storage or release. It's not a minor concern. Globally, there is about twice as much carbon in soils and plant debris as there is in the atmosphere. But like ecosystem research, soil science grew out of work in flat land. As Sulzman and other Andrews Forest researchers know, the sheer difficulty of working in mountainous terrain stands in the way of answering today's pressing questions.

"I've been an athlete my whole life," she says. "I run marathons. I did my half of my Ph.D. work at 12,000 feet in the Rocky Mountains. The field work we're doing in the Andrews is the most physically challenging work I've ever tried to do." terra

Seeing the air Learn more about the airshed project in the Andrews Forest at *feel.forestry.oregonstate.edu/airshed/default.aspx*

(Illustration: Christina Ullman, Ullman Design)

Researchers Adam Kennedy, left, and Dave Conklin climbed 60 feet down a steep slope to download data from this "HOBO" (at right) in watershed 1. It is one of six temperature sensors stretching in a line more than 200 feet below a ridge in the H. J. Andrews Experimental Forest. (Photo: Nick Houtman)

Sensing the Forest

OSU electrical engineers would like to make it easier to collect information in harsh environments like the H. J. Andrews Experimental Forest. For good measure, they want to minimize maintenance and energy needs.

So with National Science Foundation support, Terri Fiez, the director of OSU's School of Electrical Engineering and Computer Science (EECS), has teamed up with Professor Karti Mayaram and four EECS Ph.D. students to create a prototype low-power sensor. Student members include Triet Le and James Ayers of Oregon, Thomas Brown of Florida and Napong Panitantum of Thailand.

The device contains an antenna and an integrated circuit that "harvests" RF — or radio-frequency — energy from a central hub. The power is used to record and transmit temperature data. Low-frequency RF energy, long used for radio and television, is the basis for wireless network systems, identification tags and other devices.

To date, laboratory and outdoor tests have achieved RF sensitivities three to four times higher than those reported in the literature, says Fiez.

This summer, the prototype 1-square-millimeter-sized chip will be deployed for a trial run at the Andrews Forest.

Future applications could extend to other environmental monitoring purposes, health care and wireless communication systems.

Researcher Profile

Alan Mix is a professor in the OSU College of Oceanic and Atmospheric Sciences, where he arrived in 1984 and directs the Stable Isotope Laboratory, a facility dedicated to the analysis of isotope ratios in environmental samples. University and private researchers throughout the world use the lab's four gas-source mass spectrometers. Mix's research focuses on understanding past climate changes through analysis of geochemical tracers and isotopes of oxygen, carbon, nitrogen and hydrogen in geologic archives such as sediments in the ocean and cave deposits on land. An author on more than 134 articles in peer-reviewed science journals, Mix collaborates with scientists at universities in Europe, Canada, and throughout the U.S. as well as at OSU. He has served as associate dean of COAS, on the Board of Scientific Advisors for the Universities of Kiel and Bremen in Germany, as secretary of the American Geophysical Union, and as a distinguished lecturer and co-chief scientist in the Ocean Drilling Program, an international program that studies the history of ocean basins. His research has received support from the National Science Foundation, the Department of Energy and the US Science Support Program.

Michael Unsworth is a professor and environmental physicist in the OSU College of Oceanic and Atmospheric Sciences. His research focuses on interactions between vegetation and the atmosphere, carbon-dioxide exchange in forest ecosystems and ecohydrology. He has conducted projects through the H. J. Andrews Experimental Forest program, the Terrestrial Ecosystems Research & Regional Analysis — Pacific Northwest program (both in the OSU College of Forestry), and the Wind River Canopy Crane Research Facility in Carson, Washington. His collaborators include scientists in Europe and the U.S. He has received support for his research from the National Science Foundation, the National Oceanic and Atmospheric Administration, U.S. Department of Energy and NASA.

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