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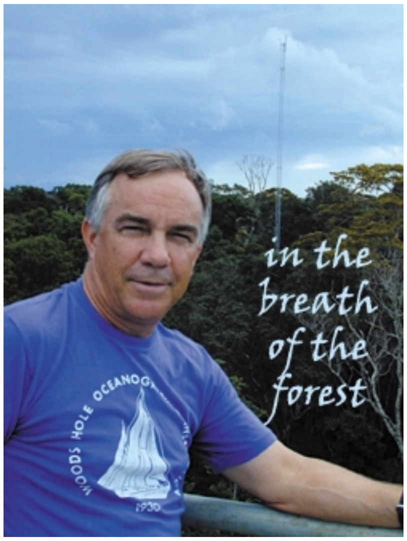

Chris Martens in Brazil.

In the Breath of the Forest

Deep in Brazil, a team takes the measure of rainforest respiration.

by Neil Caudle

When Chris Martens has climbed to the top of the tower, more than 200 feet in the air, having hugged the rough Zs of its metal so tight that his arms are now scratched up and raw, he can stop and gaze down on the deep, pillowed green of the forest. He can watch the macaws, bright as feathered candy, cruising the moist, rising air.

For a marine scientist who grew up with boats, whose preferred elevation is sea level or below, whose wife introduces him as the “mud man” because he spends so much time down and dirty in coastal sediments, this is an unthinkable height. What is he doing here, aloft in the wilds of Brazil, with only a smattering of Portuguese, with some gadgets wired inside of cooking pots like homemade bombs? He has come here to measure the breath of the forest.

What the rain forest breathes is a matter of interest because the fate of the Amazonian rain forest may be entwined with the fate of the Earth. Do rain forests protect us from global warming by producing oxygen and consuming greenhouse gases such as methane and carbon dioxide? Or does a rain forest's decaying litter actually produce more greenhouse gas than the forest consumes?

No one knows. So as pressure mounts on rain forest nations to protect and preserve the "lungs of the Earth," those nations are in the political bind of trying to limit mainstays of their economies—logging and ranching—without hard evidence that restrictions will do any good.

To try and resolve the scientific uncertainties, Brazilian and U.S. scientists in the mid-1990s proposed a comprehensive study of Amazonia, including greenhouse-gas exchange and the effects of land-use changes in the rain forest. The response was a multinational project known as the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA), led by Brazil, with U.S. participation, and funded by NASA.

When word of this project reached Christopher Martens, professor of marine sciences, his first thought was radon. Yes, this was odd. Radon is not a factor in the greenhouse effect or global warming. It is a short-lived radioactive gas that can escape from the soil and build up to risky levels in basements and crawl spaces.

But Martens knew that radon had a useful side, as well. At sites in Quebec, Alaska, and North Carolina, Martens and his students had for years used radon as a "tracer." While gases such as carbon dioxide and methane mix and merge with the elements around them, radon retains its identity—a reliable marker that goes with the flow.

“Radon has no chemistry or biology,” Martens explains. “Only physical processes affect it. When it comes in from a source, it either decays away, radioactively, or it leaves, physically, and so it’s a perfect tracer for studying the physics of gas exchange.”

Think of the rain forest as a kind of box, with the canopy as its ventilated lid. Air moves in and out at varying rates, carrying gases. Martens knew that if he could determine the ventilation rate for radon, then he could determine the ventilation rate for any other gas, including greenhouse gases such as methane and carbon dioxide.

So Martens, who had never worked in South America, who had never sampled radon or any other gas in a rain forest, sat down and began to craft a proposal that, by conventional wisdom, should have stood a snowball’s chance in, well, Amazonia.

“We had never worked in Brazil,” he says. “We were strictly Northern Hemisphere. People doubted our proposal could survive.”

But survive it did, because Martens had something nobody else could offer: the most sensitive radon-detecting instruments in the world and experience using them out of doors.

The instruments are deceptively domestic. Kitchenware is involved.

“We have to be clever,” Martens says, “because nobody wants to fund what it really costs to invent these things.”

The portable version of the team’s “fluxometer,” used to measure radon coming out of the soil, is housed in a metal crock pot. The larger version is a Presto pressure cooker with a metal probe in its belly and a plastic box full of circuitry bolted to its lid.

"Presto gives us a discount," Martens says.

The wizard behind the electronics is Steve Woodward, a design engineer who has retired from the university but who has some trouble resisting an interesting project. About eight years ago, Woodward, Martens, and Howard Mendlovitz, a chemical engineer, began tinkering with designs for a new kind of radon detector, the details of which Martens won't reveal until the patent is granted. After testing a series of prototypes, the team arrived at "a real winner," Martens says. The instrument proved itself in Duke Forest, where Martens and his students have been studying gas exchange for a project funded by the Department of Energy.

For the work in Brazil, Martens wanted to track the effects of land use on atmospheric gas exchange. South of Santarém, NASA scientists had already staked out the two sites he needed—one scheduled for selective logging, the other along the Tapajos River in a national forest that would remain undisturbed. At each site, the LBA project erected a 220-foot tower. The Martens team would place tubing at eight elevations on each of the towers, piping air from the tubes into an array of detectors housed in shelters on the ground. Laptop computers would control the detectors and compile the data.

"Radon in the air produces daughters," Martens explains, "and the science of counting the daughters involves a bunch of analytical chemistry. We've been doing it for years, and we can actually measure radon on the fly. So we're able to operate the detectors continuously, except when we're doing intercalibration exercises, when we take the air from one altitude and make sure the detectors can see the same number."

But pots and pans full of nifty electronics aren't enough, when you go to the rain forest. You need an experienced team. In addition to Mendlovitz, an indispensable research partner, Martens has found two Brazilian collaborators—

Osvaldo Moraes of the Universidade Federal de Santa Maria and Reynaldo Victoria of the Universidade de São Paulo. Patrick Crill of the University of New Hampshire, one of Martens' former students, also brings experience to the team. But the job of handling the fieldwork called for a rare type, a pioneer sturdy enough and resourceful enough to camp in the jungle for weeks at a time, endure the heat and rain and snakes and bugs, keep the instruments tuned up and running, supervise a pair of Brazilian students, and *stay alive*.

Martens found her. She was Mary Menton, an impressive six footer and recent Phi Beta Kappa graduate in environmental science from the School of Public Health. Menton wanted an adventure before she headed off to graduate school at Oxford University, and she'd been through the Portuguese-language program at Carolina, which Martens calls "the best in the country."

So the core of the team was complete. And one day last April, Martens, Menton, and company drove an hour south from Santarém, turned off the hard surface, slogged their truck along a logging trail more waterway than road, hiked into the forest, and arrived at the foot of a tower so tall that it punctured a cloud. The team would have to attach eight gas-sampling tubes to that tower, at intervals all the way to the top. Brazilian trainers would show them how to use the safety gear—climbing harness, guide wire, and rope. But the climbing itself would be up to the team.

At this point, the term *team leader* lost a certain amount of appeal. Martens, a sea-level sort of guy by nature and profession, wasn't wild about heights. Yes, he had climbed other towers but nothing like this. And now, someone had to raise the pulley.

Basically, it's a radio-antenna tower made of rods held together with Z-shaped, quarter-inch metal braces," he says. "And the weather is hot—one hundred degrees in the canopy, ninety-nine percent relative humidity. So you're soaking wet. And you start climbing this tower, and by fifty feet you're wondering why you didn't just stay home watching TV or, better yet, go for a swim in Key Largo.

"Then at a hundred feet you're still below the forest canopy, but you're up there with the climbing vines and the bird noises, and it's still hot, and you're dripping and you're thirsty, and your arms are tired. And the metal is dimpled and rough, so when you need to rest your hands you are hugging the Zs and the metal nicks and scrapes your arms. So you have to make this decision. And in my case, the decision was, 'I'm the group leader, and if I don't do this now, I might not ever do this.'

"So I did. And then, when I got to a hundred and fifty feet, all of a sudden I felt a cool breeze, and I popped up to the top of that tower. I stayed for three-and-a-half hours and got sunburned. I could see the Tapajos River, fifteen kilometers away. There was no sound, no jet contrails. I had macaws flying around me. Once you're above them, they don't notice you any more. So they fly along below you, chattering away."

He is back in Chapel Hill now, but Christopher Martens still hasn't really come down from that perch in the clouds. As he describes the spectacular rivers and animals and trees, describes his fearless team and their adventures in Amazonia, you can feel the rain forest spreading steamy and green all around him. And, to make things just perfect, more perfect than he'd ever dared to hope, *the instruments work*. Every 15 minutes, 24 hours a day, the data come boiling out of those pressure cookers and align themselves into beautiful, meaningful valleys and peaks.

On the door of his office, Martens has taped a sample printout—a series of colored lines, each color corresponding to an altitude. "What you see," Martens says, tracing lines with his finger, "is a buildup in radon that begins during the nighttime, when everything is more still than usual—unless there's a storm, of course. So there's an inversion layer that forms over the canopy—it's called a nocturnal inversion—and it basically caps the forest and makes everything quiet. The air becomes stagnant. The radon doesn't escape. So it builds up until morning, when the sun comes up and starts heating the top of the canopy. At first you see the radon drop at the upper elevations because the heat has to work its way down. And then, all of a sudden as the sun reaches down in the forest, there's a flushing. Ventilation starts, and the radon drops."

Martens had known to expect this pattern of nighttime buildup and daytime venting. But during the late afternoon, the levels were building again. That was a surprise.

"What we've learned," he says, "is that on most days there's a second really stagnant-air period in these tropical rain forests that I don't think has been fully understood. We believe that it happens at the end of hot, steamy days when the hot canopy begins giving heat back to the cooling atmosphere. It's hot, but the air is stagnant, so there's a lack of turbulence, and you'll sometimes see a radon level higher than the nocturnal ones. This is the first time, to my knowledge, that this has ever been measured this way."

Ultimately, the goal of the radon work is what Martens calls a "gas exchange coefficient," a factor that could be multiplied by the concentration of any gas to yield the exchange rate of that gas. Having such a coefficient would be a fundamental step toward learning how rain forests affect greenhouse gases.

In the meanwhile, the project's first step—to set up an accurate, reliable system for continuously measuring radon in air as it moves through the rain forest—has been a resounding success. So Martens and his team are celebrating, but just a little. They know that the technical issues will grow more complex as they begin working with other scientists to factor the radon data into numerical models. "Once you meet your initial goals people get all excited," Martens says, smiling. "They want you to become more sophisticated."

One research group in the LBA project wants him to take his instruments to higher altitudes, using airplanes to collect the samples. Other groups would like to use the radon data to corroborate their studies of how gases travel and mix in random eddies of air sampling of various gases. These groups are taking "eddy correlation flux measurements," which employ the rapid sampling of gas concentrations and a numerical model to estimate rates of exchange.

"We can cross-check and corroborate those kinds of measurements because we use a totally different approach," Martens says. "So if a big jet of air that's low in radon comes in from outside and flushes the canopy with low-radon air, we'll see it. Because we're independent of the other models."

For Martens, though, the next logical level of sophistication involves sorting out what happens at ground zero—on the rain forest floor. Having spent a good portion of his career studying "biogeochemical cycling," which, among other things, involves learning how gases enter the atmosphere from decaying organic matter in coastal sediments and muds, Martens is at home on soggy ground. Using several of the "fluxometers," the crock-potted radon detector invented at Carolina, the team will measure the rate at which radon escapes the soil and how that rate varies with such things as rainfall and soil hydrology. Martens' plans for Brazil also include a study of methane, perhaps the most pernicious of greenhouse gases. By detecting the isotopic signatures of methane produced by rapidly decaying organic matter, Martens hopes to help calculate how much methane the rain forest yields.

And so, as he outlines this work from his office in Venable Hall, constantly harking back to something he's learned on the coast of North Carolina or the tundra of Alaska or the slopes of northern Quebec, it seems as though Martens has seized his career by its various roots and planted it right in the heart of Brazil. The radon is the same, the methane is the same, and the physics are the same. But now there are jaguars and bushmaster snakes. There are harpy eagles that swoop down and pick off monkeys from the canopy's top.

He knows that Mary Menton can take care of herself, so he won't say he's worried about her. But he can't help thinking his way through the checklist of hazards. The nearest hospital is hours away, so she will just have to watch out for 10-foot bushmaster snakes, one of which has already crossed her path. And when her truck goes up to its headlights in muddy water, so deep that the engine needs a snorkel to suck air into its carburetor, she will just have to find the right gear and drive on. She will have to learn how to go back to sleep, at four in the morning, when the howler monkey troops come prowling through the forest, loud as a raucous political rally.

Yes, there is help with the work. Two Brazilian students are already on-site, and one of them has a new driver's license. The quarters are decent, and there's a reasonably liveable outpost a few miles away. So the basics are covered. The team is in place. And the hardware is pulling some mighty fine numbers right out of the air.

And Chris Martens will be there as soon as he can.

Neil Caudle was the editor of Endeavors *for fifteen years*.

Learn more:

- LBA Ecology Project
- Chris Martens

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