The flux of the matter

By Sam Bishop

Above: Eugénie Euskirchen pauses on a boardwalk in the fen at her research site in the Bonanza Creek Experimental Forest southwest of Fairbanks in August 2022. The tower in the background holds instruments for recording carbon dioxide, methane and other environmental conditions. UAF photos by Eric Engman unless otherwise noted.

Eugénie Euskirchen pointed to a 30-foot metal tower rising from a forest of short black spruce trees on the Tanana River flats southwest of Fairbanks.

"You don't want to be hanging out here very much," she told two visiting college students who swatted mosquitoes while she talked.

Not that the tower was dangerous. Stabilizing guy wires extended from midway up the

structure to anchors in the mossy ground nearby.

Nor were the mosquitoes terribly dense for July 21 in Interior Alaska.

Euskirchen explains instruments at one of two bogs where her research team has set up such towers in the Bonanza Creek Experimental Forest in August 2022.

The reason Euskirchen recommended only a brief visit instead lay in the scientific instruments adorning the tower and several rods extending horizontally from it.

The tiny bulbs, cones, buckets and devices with other curious shapes gulped down environmental data as Euskirchen talked with the students — Margaret Haney of North

Carolina State University and Evan Donnachie of Brown University in Rhode Island.

Their conversation would affect the data collected by a key instrument hanging about 20 feet up the tower, Euskirchen said.

The instrument measures carbon dioxide, a gas exhaled as a product of human respiration. The device is so sensitive that a person — or a moose — merely walking past causes an uptick in its carbon dioxide readings.

Since 2010, Euskirchen has helped oversee operation of such solar-powered towers to better understand how the lowland boreal forests of Alaska may or may not make a net contribution to the atmospheric carbon that warms the Earth's climate.

'You never know'

The tower in the spruce forest delivered its first full year of data in 2011. Combined with information from similar towers in a nearby fen and two bogs, researchers have found that this roughly square kilometer in the Bonanza Creek Long-term Ecological Research site is a net contributor to atmospheric carbon.

With the array of instruments on the towers, they've been monitoring not only carbon dioxide (CO_2) but also methane (CH_4), along with numerous other environmental factors such as precipitation, temperature, humidity, wind speed and light intensity.

The goal is to find correlations that might give insights into not only how much carbon comes and goes from the land but also why. It's part of a worldwide effort to understand atmospheric carbon sources and their effects upon global warming. In northern regions such as Alaska, Euskirchen said, the measurements are particularly vital to that understanding because frozen organic soils are thawing, potentially releasing the carbon they contain.

Euskirchen planned to complete her latest paper on the Bonanza Creek site results this fall. But, in December 2021, she and colleagues summarized what they knew thus far at the American Geophysical Union meeting in New Orleans.

"Based on just over a decade of measurements, from 2011-2021, we found that these ecosystems acted as sources of CO_2 and CH_4 to the atmosphere," they noted.

However, the annual variability in the results makes conclusions about the environmental processes elusive, Euskirchen said.

The swampy land resembles nothing so much as Forrest Gump's famous box of chocolates.

"It just varies a whole lot," Euskirchen said, "and you never know what you're going to get."

Inundated with data — and water

"I don't know anyone who has fallen off," Euskirchen said as she walked along a narrow boardwalk built from two parallel planks suspended a few feet above the Bonanza Creek fen.

Top: Euskirchen crosses the fen on an elevated boardwalk at her research site in the Bonanza Creek Experimental Forest in

August 2022. Bottom: Euskirchen opens a box holding a data logger at the fen.

The fen forms a wide field, covered mostly by sedge and aquatic cinquefoil, near the foot of a bluff in the research site 25 miles southwest of Fairbanks. For most of the summer 2022, water inundated the fen and much of the vegetation, making it look more like a shallow lake. That's been the usual situation since 2014, a period that has generally seen above-average precipitation.

The boardwalks rest on crossbars mounted between two 10-foot metal pipes driven into the ground. The elevated walkway, newly completed for the fen this year by UAF's Bonanza Creek LTER staff, allows researchers to enter the site with minimal disturbance of the environment they're studying.

Another, older boardwalk also leads to the tower in the nearby black spruce forest. Another dead-ends at a bog — a spot where the ground has slumped following permafrost thaw and become wetter, killing the spruce trees but leaving the moss and some shrubs and prompting colonization by a few small, hardy larch trees.

In each habitat — fen, bog and spruce forest — Euskirchen and colleagues operate "flux" towers. Carbon flux, which can be positive or negative, is an estimate of how much carbon is

taken up in the locality by, for example, plant growth, versus the amount that is released through, for example, respiration by bacteria in the soils.

The researchers arrive at their flux numbers using the "eddy covariance" technique. It uses complex math to correlate high-frequency data about carbon dioxide and methane in the air with three-dimensional measurements of wind, or the fast-moving eddies in the atmosphere. The result is an estimate of the net atmospheric carbon produced at the different tower sites. (They also collect the information on temperature, precipitation, light intensity and humidity to understand how those factors affect the carbon fluxes.)

The sites produce a vast amount of data. The carbon dioxide readings, for example, are taken 10 times per second. The data is logged by an instrument on the tower then broadcast via cell signal to UAF.

The cell signal is new. In previous years, researchers only could receive 30-minute averages of the data, which would reveal whether the instruments worked but weren't adequate for the science.

"To calculate correctly, we have to use the 10 Hertz data," Euskirchen said. "Until last winter,

we had to come down and collect the data."

Golden Valley Electric Association's lines don't come anywhere near the site, so researchers depend upon solar panel arrays and battery banks to power the towers.

Some of the panels and their heavy batteries are tipping as the permafrost soils on which they were installed thaws.

Solar panels and batteries power Euskirchen's instruments at the Bonanza Creek Experimental Forest in August 2022.

"Permafrost is a very difficult environment to work in," she noted.

Nevertheless, the solar panels are preferable to fuel-powered generators, which produce carbon dioxide that would skew their results, she said.

The power system restricts the number and type of instruments the researchers can use, a limitation that scientists in much of the Lower 48 don't face.

"People who have line power at their sites just don't understand," Euskirchen said.

The eddy covariance cutting edge

Lower 48 researchers have other challenges, though. When Euskirchen started her flux tower studies in the late 1990s as a Ph.D. student at Michigan Technological University, deer chewed her instrument cables at a site on the state's Upper Peninsula.

At another site, people stole the laptops that researchers were then using to collect data.

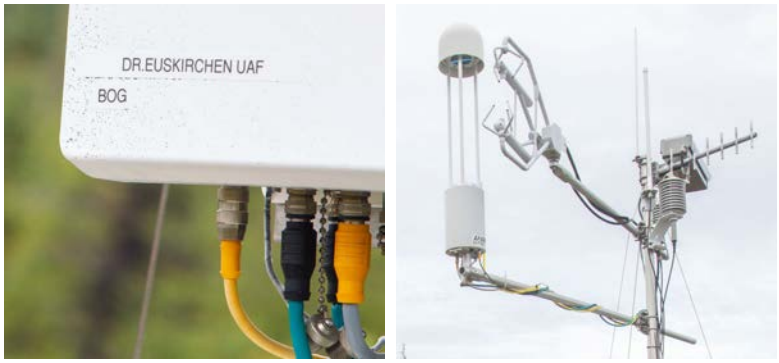
At yet another site, when Euskirchen decided she had to protect a tower with barbed wire, someone stole the roll the night before the planned installation date.

At Bonanza Creek, she's seen no such problems. Animals and people have left the towers and instruments unmolested.

Euskirchen came to UAF in 2004 as a post-doctoral researcher, then moved into a research faculty position and then a teaching faculty position. In 2017, she won the Emil Usibelli Award for Distinguished Research, one of UAF's top faculty honors. She earned tenure this year.

Euskirchen grew up in Ohio, the daughter of a Thomas More College professor and an elementary school French teacher — the source of her unusual first name. Between that and her also unusual last name, she said, many people assume she is from a European country.

"When I first came to UAF as a post-doc, someone sent me an email reminding me to get my visa application in," she said with a laugh.



Left: Cables feed into Euskirchen's data logger box on the bog site's tower. Right: An array of instruments adorns the tower. The upright structure at left is a sensor that records methane concentrations in the air. The two claw-like devices form an anemometer that records wind from multiple directions (eddies). The tubes extending into the space within the anemometer claws contain a gas-analyzing device to reveal carbon dioxide and water vapor levels. The two instruments that look like stacks of inverted plates contain a thermometer and a humidity sensor. The box at back right is a webcam. The two vertical rods in the center are a lightning rod and a communication device.

In the late 1990s, as Euskirchen started her Ph.D. studies in Michigan, only a few dozen researchers used towers and the eddy covariance technique of estimating gas flux. Now there are hundreds of such towers across the country, she said, and the eddy covariance technique is a standard method.

In addition to UAF research professional Colin Edgar, who keeps the towers standing and the instruments working, Euskirchen's frequent fellow collaborators at the Bonanza Creek site hail from across the country. They include Evan Kane of Michigan Tech, Merritt Turetsky of the

University of Colorado at Boulder, Rebecca Neumann of the University of Washington and Mark Waldrop of the U.S. Geological Survey in Menlo Park, California. The USGS and National Science Foundation provide much of the funding for their work.

Sink or source?

When Euskirchen walked out the boardwalk to the Bonanza Creek fen in late July, she found three graduate students from Outside universities working on their doctoral studies.

The students, Nora Serock and Jessica Czarneck of Michigan Tech and Barrett Sullivan of Ball State University, had spent much of the summer trying to improvise their work in the flooded conditions.

From left, students Evan Donnachie of Brown University in Rhode Island, Margaret Haney of North Carolina State University, and Nora Serock and Jessica Czarneck (with

mosquito head net) of Michigan Tech talk about research being conducted at the fen site in the Bonanza Creek Experimental Forest in July 2022. UAF photo by Sam Bishop.

Before LTER staff installed the new boardwalk, they paddled inflatable plastic rafts to research plots in the fen's center. There, among other tasks, they measured methane and carbon dioxide releases by trapping the gases under floating plexiglass cells.

The inundated fen has been a regular phenomenon since summer 2014, when the Fairbanks area received more rain than any other summer in 100 years. Annual precipitation since then has continued to be higher than normal.

The flooding has contributed to the variability of the research area's annual carbon release, which scientists quantify in grams per square meter.

Before 2014, Euskirchen said, the overall research site combined generally formed a carbon "sink," meaning it absorbed more carbon than it released. Since the wetter years began, though, carbon dioxide releases in particular have increased, turning the area into a carbon "source."

But the releases haven't been consistent. The annual standard deviation in the "net ecosystem

exchange," or carbon flux, was about 100 grams per square meter from 2011-2021, the researchers reported at the December 2021 AGU meeting.

The cause isn't entirely clear. In 2014, the rain-flooded fen released a relatively enormous net 266 grams of carbon from each square meter, even though researchers recorded a much reduced methane component that year. In 2017, groundwater and snowmelt runoff flooded the fen. Euskirchen and her colleagues found relatively low carbon dioxide production that year and estimated net carbon release at about zero, despite a methane component more than three times greater than 2014's.

The extremely different methane releases under flooded conditions likely were caused by the different sources of water, the researchers reported at the AGU in December 2018. Rainwater flooding seems to oxidize and destroy methane, while groundwater seems to release it.

Such mysteries illustrate to Euskirchen the value of continuing the research. With data going back to 2010, the flux tower work has greater longevity than many experiments. She hopes it continues for many years.

"The longer you collect the data, the more valuable it becomes," she said while driving the

six miles from the fen site back to the Parks Highway in late August. “For a science experiment, it’s a long time, but in the grand scheme it’s a drop in the bucket.”

Viewed from a nearby bluff, this fen about 25 miles southwest of Fairbanks is one of four sites in the Bonanza Creek Experimental Forest at which UAF professor Eugénie Euskirchen is measuring the production and absorption of the greenhouse gases carbon dioxide and methane. A boardwalk used by Euskirchen and other researchers crosses the center of the fen. During recent summers, the fen has often been entirely flooded, as pictured here on July 21, 2022. In earlier years and seasons, the fen more often appeared as a meadow, with the water remaining obscured below the vegetation or even below the ground surface. UAF photo by Sam Bishop.

Aurora home