Barrels of ancient Antarctic air aim to track history of rare gas

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A drones-eye view of the Law Dome drilling site, during the Law Dome Hydroxyl Project. Credit: Richard Smith

Ancient air samples from one of Antarctica's snowiest ice core sites may add a new molecule to the record of changes to Earth's atmosphere over the past century and a half, since the Industrial Revolution began burning fossil fuels on a massive scale.

While carbon dioxide and methane are well known, researchers at the University of Washington and the University of Rochester are part of a team working to trace a much rarer gas, present at less than one in a trillion molecules. Though rare, the atmospheric detergent known as hydroxyl can scrub the atmosphere and determine the fate of more plentiful gases that affect Earth's climate.

An Antarctic field campaign last winter led by the U.S. and Australia has successfully extracted some of the largest samples of air dating from the 1870s until today. These samples are a first step to learning the changes in hydroxyl concentration over the past 150 years. Early results from the fieldwork were shared this week at the American Geophysical Union's annual fall meeting in San Francisco.

"It's probably the most extreme atmospheric chemistry you can do from ice core samples, and the logistics were also extreme," said Peter Neff, a postdoctoral researcher with dual appointments at the UW and at the University of Rochester.

But the months the team spent camped on the ice at the snowy Law Dome site paid off.

"This is, to my knowledge, the largest air sample from the 1870s that anyone's ever gotten," Neff said. His 10 weeks camped on the ice included minus-20 degrees Fahrenheit temperatures and several snowstorms, some of which he shared from Antarctica via Twitter.

Air from deeper ice cores drilled in Antarctica and Greenland has provided a record of carbon dioxide and methane, two greenhouse gases, going back thousands of years. While carbon dioxide has a lifetime of decades to centuries, an even more potent gas, methane, has a lifetime of just nine or 10 years.

Pinpointing the exact lifetime of methane, and how it has changed over the years, depends on the concentration of hydroxyl. That number is important for the global climate models used to study past and future climate.

To trace the history of hydroxyl, a fleeting molecule with a lifetime of less than a millionth of a second, a field campaign in late 2018 and early 2019 drilled ice to study this very reactive gas by examining its slightly more plentiful companion, carbon with 14 neutrons bonded to an oxygen atom, or "carbon-14 monoxide," which is chemically destroyed by hydroxyl and so tracks hydroxyl's concentrations.

Researchers get the carbon-14 monoxide gas from bubbles in the ice that form when snow is compressed.

"The special thing about glacier ice is that it always has these air bubbles," Neff said. "Any glacier in the world is going to have that bubbly texture, because it started as a pile of six-fingered snowflakes, and between those fingers is air."

One or several decades after hitting the ground, bubbles become completely sealed off from their surroundings due to compression under layers of snow. The heavy snow accumulation at Law Dome means plenty of air bubbles per year, and provides a thick enough shield to protect the carbon-14 monoxide from solar radiation.

The international team extracted about two dozen 3-foot-long sections of ice per day, then put the tubes of ice in a snow cave to protect them from cosmic rays that are stronger near the poles. Those rays can zap other molecules and distort the historic record.

"Once the samples are at the surface, they're hot potatoes," Neff said.

The day after extracting a core, the team would clean the ice and place it in a device of Neff and his University of Rochester postdoctoral supervisor Vasilii Petrenko's design: a 335-liter vacuum chamber in a warm bath to melt the ice and process the samples at their source, to avoid contamination and collect the biggest air samples.

"A single sample size was about 400 or 500 kilograms of ice, about the same weight as a grand piano, to get enough of that carbon-14 monoxide molecule," Neff said. "At the field camp we turned 500 kilos of ice into one 50-liter canister of air."

The team retrieved 20 barrel-shaped canisters of air from various time periods.

Analysis over the coming months will aim to produce a concentration curve for carbon-14 monoxide and hydroxyl over the decades, similar to the now-famous curves for carbon dioxide and methane. The curves show how gas concentrations have changed in the atmosphere since the industrial era.

Throughout the effort, Neff has also explored more lighthearted combinations of ice and air. During a trip in early 2016 to prepare for this effort, Neff did an unofficial experiment that went viral on social media when he posted it in February 2018. The video captures the sound a piece of ice makes when dropped down the tunnel created by an ice core drill.

He shared more photos and videos during this past winter's expedition to Antarctica, sometimes within hours of returning from a remote camp to an internet-connected research station.

"It's great to be able to share something about Antarctica, from Antarctica," Neff said. "It's a way that we as geoscientists can share with people the work that they help to support."

Provided by University of Washington

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