Inside the race to rescue clues to Earth’s past from melting glaciers

New Scientist, June 16, 2021

Glacial ice records all manner of precious information about the planet’s environmental history, but it is melting fast. The Ice Memory project is scrambling to extract samples for posterity before it’s too late

MARGIT SCHWIKOWSKI and her team were attempting to drill into the Corbassiére glacier in the Swiss Alps when the weather started to turn. They were camped among the soaring peaks of the Grand Combin massif. The only way off this vast sheet of ice in a storm is to descend a steep mountain wall or traverse the jagged glacier surface itself, which claims several lives a year. Instead, they retreated by helicopter before it was too late.

For Schwikowski, an environmental chemist at the Paul Scherrer Institute in Villigen, Switzerland, the risks of missions like this October 2020 expedition to Corbassiére are worth it. The team she was leading is part of an international enterprise that aims to preserve the “memories” frozen into mountain glaciers across the world, by drilling out long samples all the way from the young surface snow down to the old, compacted ice at the base of a glacier.

These ice cores are loaded with information about Earth’s past that could be crucial in our fight against global warming. Locked within them is a picture of how the planet’s climate has changed over time, as well as evidence of human activity as far back as the Romans, clues about the evolution of microorganisms and much more. Now, scientists are racing rising temperatures to rescue ice cores from the world’s glaciers before they melt.

Mountain glaciers, also known as alpine glaciers, are slow-flowing rivers of ice. They begin life at high altitudes where the amount of snow settling in winter significantly exceeds the amount that melts in the summer. Over time, the snowpack builds up and the overlying weight causes snowflakes in the deeper layers to gradually transform into blue-tinted glacier ice, which eventually creeps downhill under its own weight.

“Deep within glaciers there is an amazing process, where ancient air is preserved from the time when it became trapped in the ice,” says Schwikowski, describing an effect of the increasing density with depth. This critical depth where not even air can escape is around 45 metres in the European Alps (see “What a glacier remembers”). The trapped air is just one relic that will be lost forever if sample ice cores aren’t gathered before the glaciers melt. Schwikowski and her team are rushing to extract samples from the planet’s most vulnerable glaciers. “There are not so many groups in the world who can do this ice-core drilling and so we have to focus our forces.”

Sadly, in the case of the Corbassiére glacier it is already too late. Even before the weather turned, the mission was scuppered. At each attempt to extract an ice core, the scientists hit a hard layer known as an ice lens. These form when glacier surface layers melt, causing water to percolate through the snow, before refreezing into a thick ice sheet below. With the chronology of ice layers mixed up like this, valuable scientific information is lost forever.

The glacier appeared to be in good shape during a test run in 2018, but two exceptionally warm summers must have taken their toll. “The way this ice archive was damaged so extensively within just two years tells you how sensitive these glaciers are,” says Schwikowski.

It is a similar story across the world. Glaciers are shrinking at alarming rates. More than 9 trillion tonnes of glacier ice was lost between 1961 and 2016, adding 27 millimetres to the average global sea level, according to a 2019 study led by Michael Zemp, director of the World Glacier Monitoring Service. That corresponds to an ice block the size of the UK with an average thickness of 44 metres, he says. If current melting rates continue, glaciers will vanish entirely from Europe, New Zealand and the west of North America, among other parts of the world, by the end of the century.

The result will be a further rise in sea levels globally, with all the knock-on effects for people, especially those living near coasts and in rural communities that rely on water from seasonal ice melt. For scientists like Schwikowski, the melting of the glaciers also endangers an unparalleled archive in the ice of Earth’s environmental past, prompting the launch of the Ice Memory project in 2015. Now backed by UNESCO, the United Nations Educational, Scientific and Cultural Organization, this international effort brings together researchers from various fields. “We had to take action before it is too late. These archives are formidable records of our past and they must be preserved for future generations of scientists,” says Carlo Barbante, a chemist at the University of Venice, Italy, and a co-founder of the project.

Geologically speaking, mountain glaciers hold a fairly young ice record, typically spanning the past 1000 to 10,000 years. One thing they can’t do is build a picture of the really long-term climate. For this, scientists mostly rely on older ice samples from continental ice sheets in Antarctica and Greenland. These are also threatened by global warming, but their shrinkage will occur over thousands of years, so they are beyond the scope of the Ice Memory project.

Although younger, mountain glaciers have one major advantage over the ice sheets – their geographical spread. They exist on all continents except Australia. This helps us to build a truly global picture of relatively recent past climates and means the information they contain is also highly region-specific.

Since ice-core projects investigating European glaciers began in the 1970s, they have identified a range of clues to conditions at various times, from local biological matter to Saharan sand and volcanic dust blown by the wind. These glaciers also tend to be close enough to human activities to carry a record of our impact, too. Nitrogen oxides from cars, heavy metals from industry and radioactive pollutants from the 1986 Chernobyl disaster have all left their mark in the ice. Studies have even found lead and antimony linked to the production and use of pipes and silver coins by the Romans.

That’s all important, but understanding past climates is the real draw when it comes to ice cores from mountain glaciers. Information is encoded in the different types of water at different depths in the ice. During warmer periods, larger quantities of heavier forms of water – where the hydrogen and oxygen atoms in the water molecules have more than the usual number of neutrons – evaporate from the oceans. Some of this heavier water ends up falling back to Earth as snow on glaciers, providing a nifty way of reconstructing past temperatures.

Frozen life

It may even be possible to unpick some of the impact of past changes in climate on ecosystems. One way to do that is through the microorganisms stored inside mountain glaciers. Traditionally, investigations of ice-dwelling microbes involved growing them from field samples, which favoured certain "lab-happy" microorganisms. However, genetic sequencing technologies are bypassing this requirement, enabling biologists to gain a more complete picture of glacial ecosystems directly from the field samples themselves.

"There are so many questions we can start to ask," says Catherine Larose, a microbiologist at école Centrale de Lyon in France. "If you have these ancient ice cores, can you find very old forms of life? Are things that existed in the past similar to what we see now?" One line of this research is to build a picture of an ecosystem by tracking how microorganisms and their genes have evolved in response to environmental pressures. For instance, an abundance of genes linked with mercury resistance would imply the presence of this highly toxic element, whose natural sources include volcanoes and forest fires.

Eager not to miss out on these clues to the past, researchers involved with the Ice Memory project have fanned out across the world to gather samples. In 2016, the launch mission extracted three ice cores from the Col du Dôme glacier at an altitude of 4300 metres on Mont Blanc in France. Since then, cores have been extracted in 2017 from the Illimani glacier in Bolivia – where glaciers hold records dating back 18,000 years – and from two sites in Russia during 2018. The plan is to extract cores from a further 20 sites across the world over the next 10 to 15 years.

The scientists drill near the highest points of glaciers, where snow and ice accumulates, rather than lower down the glacier tongue, where downhill flow mixes the ice record. But nature doesn't always play ball. Patrick Ginot at the Institute of Environmental Geosciences (IGE) in Grenoble, France, who led the Bolivia mission, recalls battering winds and heavy snowfall for two weeks at 6300 metres above sea level. "There were days on the summit of Illimani when we could not work at all."

Poor weather last month also led to Ice Memory researchers postponing a May mission to the Colle Gnifetti glacier on the Monta Rosa massif on the Italian-Swiss border until June, when they extracted cores down to the bedrock. At 4500 metres, Colle Gnifetti's accumulation zone is the highest in Europe, with ice dating back 15,000 years. "Besides a long climate record, the site also contains information about human history, for example changes in land use and crop cultivation or pre-industrial mining activities," says Schwikowski.

Beyond Europe, the next target is Mount Kilimanjaro in Tanzania, where you can find the only glacier left in Africa with enough ice to be useful for climate studies. At an altitude of almost 6000 metres, the ice on Kibo, Kilimanjaro's highest peak, provides a unique opportunity to study the past composition of the tropical middle troposphere – an important region of the atmosphere for global weather and climate processes. But the clock is ticking, as roughly 85 per cent of Kilimanjaro's icy cap has melted over the past century.

The long view

Battling the elements isn't the only challenge for these expeditions, there are logistical hurdles to navigate, too. The scientists need permits from governments, local assistance with transport and a reliable refrigeration chain to ensure that samples don't melt. These local partnerships are an essential element of Ice Memory. Project scientists are acutely aware of the damage that could be done by European scientists "parachuting in" to less scientifically developed nations to extract samples for the benefit of their careers. "Our way is always to start by building a collaboration with local scientists and then to organise the operation from there," says Ginot.

Even after all this, retrieving the ice cores is only half the battle, as they also need to be stored. The plan is to house them in a purpose-built "ice sanctuary" facility at the French-Italian Concordia Research Station, more than 1000 kilometres inland from the south-east coast of Antarctica. The location was chosen for being politically neutral and reliably cold over the long term, so there is no threat of freezer failure wiping out millennia of data. There, cores will be kept in ice caves, created by inflating a sausage-shaped balloon covered in snow in a process reminiscent of papier mâché. The caves will be 10 metres below the surface, with an ambient temperature of -50° C. Schedules have been stalled by the covid-19 pandemic, but the first cores could reach the ice sanctuary as early as 2023.

While storage is far from trivial, it is key to the Ice Memory project. On a typical mission, expedition teams aim to retrieve three ice cores, with only one for immediate analysis and ideally two saved for future generations of scientists. It is hoped that with knowledge and technology we don't yet have, more information can be extracted from these ice archives than we can dream of now. For example, Larose says biologists are just starting to understand how microorganisms communicate with each other, as well as the complex role that viruses play in nature, bringing useful survival genes to bacteria on the one hand, while decimating their populations on the other. "There's this constant evolutionary feedback and it would be cool to trace that over time," she says.

Even the immediate analysis of the cores is conducted with a long-term view: to create reference data for future studies, which will be made available in a public database. As such, key centres for immediate analysis have attracted significant investment. For instance, the IGE has been transformed over the past two years with €1 million from Ice Memory, internal sources and private donors. At its heart is a "continuous-flow analysis" system, where ice core sections are transformed into water and gas, before measurements are taken.

The Ice Memory project's long view, centred on future generations of scientists, contrasts starkly with the short-term political wrangling that so often frustrates climate negotiations.

For Barbante, excitement over the new tools being developed to decipher the lessons from the past only heightens the urgency of preserving ice samples. "In a few decades from now, when these techniques will be available to unravel further insights of the climate, the ice of many high-altitude glaciers will no longer be available." There really is no time to lose.