On June 8, 1783, a fissure ruptured beneath an Icelandic glacier, triggering the Laki eruption. It would eject some 122 megatons of sulfur dioxide and roughly 5.8 million Olympic swimming pools of magma over the next eight months. Laki was the worst natural disaster in Iceland’s written history.

Despite the fact that the eruption began in warm June, the island plunged into a sudden cold snap according to written records. The frigid summer coupled with poison gas led much of the island’s grass to wither, the livestock to die, and one-fifth of Iceland’s population to starve by spring, explains environmental historian Katrin Kleemann, a postdoctoral researcher at the Leibniz Institute for Maritime History in Bremerhaven, Germany. The winter of 1783 was so brutal, Kleemann says, that a Lutheran priest in a small town near the eruption site journaled that his parishioners ate their leather shoes to survive.

The temperature effects of the eruption didn’t stop at Iceland. North Atlantic winds swept a fog of gases off the island toward mainland Europe, and the Jet Stream carried the plume as far east as China’s Altai Mountains and as far west as North America. Around the northern hemisphere, climate responses varied, but many regions became unseasonably cold.

Standing sentinel from Norway to Alaska, trees took notice. North Alaskan white spruce didn’t grow much late in that summer because of the cold; they only put on a thin annual ring of new, outermost wood. These trees and their rings would serve as time capsules, preserving climate clues of that strangely cold summer, 250 years later.

From a young age, many learn about the apparent power of tree rings: handy indicators of a tree’s age. But the tree rings don’t tell all. The width of a ring offers “a broad view of what climate is doing over this general summer season,” explains paleoclimatologist Julie Edwards, a doctoral candidate at the University of Arizona in Tucson.

To probe the climate past with finer-scale resolution, researchers are looking to an emerging dendrochronology tool: the anatomy of wood cells, whose cell wall thickness and growth rates rapidly track shifts in temperature and precipitation throughout the growing season on the order of weeks to months. By using this approach, researchers can analyze temperature and precipitation, among other environmental conditions, for much shorter time windows than the entire...
growing season—observations that can help them not only paint a more detailed picture of past trends but also gauge the validity of climate models meant to predict future trends.

Reading the Rings

Reading tree rings entails more than just counting. In conifers, for example, concentric black circles are interrupted by thick bands of lighter wood. One band of lighter wood, fading to a black rim at its outer edge, is a tree ring. Typically, this ring begins to grow in spring and stops growing by the end of summer. The large cells at the start of the growing season are lighter in color than the smaller, denser, and hence darker cells in fall. The thickness of the entire ring includes both light and dark wood and, depending on the age of the tree, reveals environmental conditions that occurred tens or even hundreds of years ago.

For centuries, people have realized there are consistent ring patterns among trees, says Flurin Babst, a forest ecologist at the University of Arizona. Formalized tree ring studies began in the 1910s with astronomer Andrew E. Douglass in Arizona, a territory at the time. Douglass and many of his contemporaries knew that counting rings revealed a tree’s age. They also knew that the thickness of growth rings varied from year to year. Many suspected that some environmental condition drove the varying ring thicknesses (1). But they didn’t know which environmental variable was most important. Extensive weather records didn’t yet exist in Arizona.

What Douglass did have access to was trees. He found that all of the pines at his Arizona field sites had the same ring width patterns, such as a thick ring one year, then a thin ring the next, and so on. The discovery confirmed the suspicion that some environmental or climatic factor must be impacting all the pines, resulting in the same tree ring patterns. In 1938, Douglass established the University of Arizona’s Laboratory of Tree-Ring Research, the birthplace of modern dendrochronology, where generations of his students have found that temperature and precipitation are two key factors driving ring width.

Looking to Cells

As illuminating as these rings can be, they only offer a rough sketch. If researchers were to only scrutinize rings, they’d think that the entire summer of 1783 was unusually cold, beginning in May and ending in September. Such an analysis would miss the nuanced drop in temperatures in Iceland and subsequent cooling around the Northern...
Hemisphere—spurred by the eruption shooting sulfur dioxide into the stratosphere and blocking solar radiation. Siberian researchers in the 1990s pioneered methods to analyze wood cells under a microscope and attempts at correlating wood anatomy with climate trends. But the methods initially proved too tedious for popular use. Irina Panyushkina, who pioneered one of the earliest wood anatomy studies in 1998 (2), spent the late ’90s in Krasnoyarsk at the Russian Academy of Sciences, hunched over a microscope, peering down at paper-thin slices of wood from Arctic larch trees. Panyushkina knew that climatic factors can control a tree’s growth, and so she suspected that cellular growth rates would correlate with temperature. Sure enough, she saw that at the start of the growing season in a warm and wet year, larch tree cells looked plump and round. But as the season progressed, the cells shrank and their walls thickened to prepare for winter. When Panyushkina compared cell counts in each ring with instrumental temperature records, she found that total cell number closely correlated with mean June temperature. She also found that cell wall thickness, specifically in the part of the ring formed just before autumn, was a close proxy for July to September temperatures.

In that study, Panyushkina would painstakingly count and measure thousands of wood cells to create a 350-year climate chronology, dating from 1642 to 1993. It was among the most rigorous tree-ring-based reconstructions of past climate at the time, but it was also prohibitively tedious. To image the cells, each thin section first had to be photographed under a microscope, and then the images were imported into a computer and displayed onscreen. Panyushkina then had to click on every cell to tell the program to measure it. All in all, Panyushkina took 9,460 photographs from 1,896 tree rings, in just 11 tree samples. The work took her four years. “It was so intensive and laborious,” says Panyushkina, who’s now at the Laboratory of Tree-Ring Research at the University of Arizona. “I said I’ll never do it again.”

**A Recent Revival**

Fortunately, there’s no longer a need to. Thanks to advances in analytical software and computing power, the cell anatomy approach has become the next frontier in dendrochronology and paleoclimate research. Recent studies sometimes rely on wood anatomical measurements in hopes of reconstructing past climate.

What would have taken weeks in the ’90s now takes days, says tree ring researcher Jesper Björklund at the Swiss Federal Research Institute, known as WSL, in Birmensdorf. “Using the same amount of time you can obtain roughly 100 times more data, increasing the potential for robustness and scope of each study,” he says. The “big jump,” Björklund says, was the development of a software called ROXAS in the early 2000s, which identifies and measures cells from high-resolution scans of tree rings (3).

ROXAS took a few years to catch on, but since 2015, Björklund has noticed an “explosion of studies.” He published a 2019 article comparing various techniques that dendrochronologists use to infer environmental information from trees (4). Looking to millions of Scots pine cells sampled in northeastern Finland beginning in the late 1800s, Björklund used the size of the cells and the thickness of their walls to calculate the density of the wood as a proxy for past temperature. He then compared this density calculation with wood density estimates derived from other popular techniques, including some based on X-rays or flatbed scanners, and found that wood density, calculated from hundreds of cells per year, more closely tracked growing season temperature than other techniques. Edwards published 2021 work on the Laki eruption that echoes those findings (5). She measured cell size and wall thickness in Alaskan white spruce and found that early in the summer of 1783, cells looked normally plump. But later in the growing season, after the Laki eruption, the tree’s cell walls grew unusually thin, suggesting an abrupt disruption attributable to the sudden cold.

South of Alaska in the Canadian Rockies, ancient glacial flows form ice fields that sprawl between mountain peaks. There, Engelmann spruce trees, some long dead and lying on the ground and some still living, offer a combined tree-ring record spanning back nearly 1,000 years. Cross-sections of these rings are key proxies for past Northern Hemisphere temperatures, explains Kristina Seftigen, a dendroclimatologist at the University of Gothenburg in Sweden. She led a 2022 study (6), applying wood anatomical analysis to slices of spruce trees, which researchers collected over many years from The Columbia Icefield in western Canada using chainsaws or small wood drills. By counting and measuring the cells in the rings, Seftigen created the longest existing dendroanatomical dataset for North America, spanning from 1585 to 2014. Then she compared the variance in the cellular measurements with the variance of instrumental temperature measurements since 1901. Seftigen found that fluctuations in the cellular measurements more closely tracked fluctuations in the growing season temperature than did ring width or X-ray based wood density measurements.

Next, Seftigen hopes to reconstruct temperatures even further back in time, some 1,000 years or more, to a period known as the Medieval Climate Anomaly. The Vikings first migrated to Iceland and Greenland during this warm period, and for some parts of the world it’s considered the “closest analog to the warm period we’re experiencing now,” she says. Comparing how the climate behaved back then to how it’s behaving today could reveal how far the modern climate falls outside of natural variability.

And the higher-resolution data can help groundtruth climate models, Edwards explains. For instance, she says, there is some evidence that models simulate too much cooling after volcanic eruptions in comparison with the story told in wood anatomy data. “These tests,” she says, “provide ways to identify where models perform well and where they need improvement.” Climate models, for instance, might predict that the whole summer of the Laki eruption was cold, whereas wood anatomy tells the more nuanced story. “We’re able to say the tree was growing really normally for most of the growing season,” Edwards says, “up until this certain point in time, and then it got really, really cold.”
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