Tree rings may underestimate climate response to volcanic eruptions: study

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Some climate cooling caused by past volcanic eruptions may not be evident in tree-ring reconstructions of temperature change because large enough temperature drops lead to greatly shortened or even absent growing seasons, according to climate researchers, who compared tree-ring temperature reconstructions with model simulations of past temperature changes.

"We know these tree rings capture most temperature changes quite well," said Michael Mann, professor of meteorology and geosciences and director of the Penn State Earth System Science Center. "But the problem appears to be in their response to the intense short-term cooling that occurs following a very large volcanic eruption. Explosive volcanic eruptions place particulates called aerosols into the stratosphere, reflecting back some fraction of incoming sunlight and cooling the planet for several years following the eruption."

Tree rings are used as proxies for climate because trees create unique rings each year that often reflect the weather conditions that influenced the growing season that year. For reconstructing climate conditions, tree-ring researchers seek trees growing at the extremes of their growth range. Inferring temperature changes required going to locations either at the tree line caused by elevation or at the boreal tree line, the northern most place where the trees will grow.

For these trees, growth is almost entirely controlled by temperature, rather than precipitation, soil nutrients or sunlight, yielding a good proxy record of surface temperature changes.

"The problem is that these trees are so close to the threshold for growth, that if the temperature drops just a couple of degrees, there is little or no growth and a loss of sensitivity to any further cooling. In extreme cases, there may be no growth ring at all," said Mann. "If no ring was formed in a given year, that creates a further complication, introducing an error in the chronology established by counting rings back in time."

The researchers compared temperature reconstructions from actual tree-ring data with temperature estimates from climate models driven with past volcanic eruptions.

Comparing the model-simulated temperatures to the Northern Hemisphere temperatures reconstructed from tree-ring thickness, Mann, working with Jose D. Fuentes, professor of meteorology, Penn State, and Scott Rutherford, associate professor of environmental science, Roger Williams University, found the overall level of agreement to be quite good.

However, they report in the current issue of *Nature Geoscience* that "there is one glaring inconsistency; the response to the three largest tropical eruptions -- AD 1258/1259, 1452/1453 and the 1809+1815 double pulse of eruptions -- is sharply reduced in the reconstruction."

Following the 1258 eruption, the climate model simulations predict a drop of 3.5 degrees Fahrenheit, but the tree ring-based reconstruction shows only about a 1 degree Fahrenheit dip and the dip occurs several years too late. The other large eruptions showed the same type of discrepancy.

Using a theoretical model of tree-growth driven by the simulated temperature changes, the team determined that the cooling response recorded by the trees after a volcanic eruption was limited by biological growth effects. Any temperature drop exceeding roughly 1 degree Fahrenheit would lead to minimal tree growth and an inability of trees to record any further cooling. When growth is minimal enough, it is likely that a ring will not be detectable for that year.

The potential absence of rings in the first one to three years following eruption further degrades the temperature reconstruction. Because tree-ring information is averaged across many locations to obtain a representative estimate of northern hemisphere temperature, tree-ring records with and without missing rings for a given year are merged, leading to a smearing and reduced and delayed apparent cooling.

The researchers also noted that aerosol particles forced into the air by volcanoes block some direct sunlight causing cooling and they produce more indirect, scattered light at the surface. Trees like indirect sunlight and grow better under those conditions. However, this effect is small compared to that of lower temperatures and shorter growing seasons.

By accounting for these various effects in the tree growth model, the researchers were able to reproduce the reduced and smeared cooling seen in the actual tree-ring temperature reconstruction, including the near absence -- and delay -- of cooling following the massive 1258 eruption.

"Scientists look at the past response of the climate to natural factors like volcanoes to better understand how sensitive Earth's climate might be to the human impact of increasing greenhouse gas concentrations," said Mann. "Our findings suggest that past studies using tree-ring data to infer this sensitivity have likely underestimated it."

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