Tree rings floating on ice cores

Reimer, P., & Hughen, K. A. (2008). Tree rings floating on ice cores. *Nature Geosciences*, 1(4), 218-219.

Published in:
Nature Geosciences

Queen's University Belfast - Research Portal:
[Link to publication record in Queen's University Belfast Research Portal](#)

General rights

Copyright for the publications made accessible via the Queen's University Belfast Research Portal is retained by the author(s) and / or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

The Research Portal is Queen's institutional repository that provides access to Queen's research output. Every effort has been made to ensure that content in the Research Portal does not infringe any person's rights, or applicable UK laws. If you discover content in the Research Portal that you believe breaches copyright or violates any law, please contact openaccess@qub.ac.uk.

PALAEOCLIMATE

Tree rings floating on ice cores

Because of difficulties in creating a radiocarbon calibration that covers the end of the last glaciation, defining the timing and duration of the Younger Dryas cold event has been a challenge. Linking related cosmogenic isotopes in tree rings and ice cores may provide new insights into abrupt climate changes.

Paula J. Reimer¹ and
Konrad A. Hughen²

are at ¹the ¹⁴CHRONO Centre for Climate, the Environment & Chronology, School of Geography, Archaeology and Palaeoecology, Queen's University Belfast, Belfast, BT7 1NN, UK;

²Woods Hole Oceanographic Institution, Department of Marine Chemistry & Geochemistry, Woods Hole, Massachusetts 02543 USA.

e-mail: p.j.reimer@qub.ac.uk

Radiocarbon measurements on tree rings of known age are considered the gold standard for converting terrestrial radiocarbon ages to calendar years. This is necessary for estimating absolute dates because atmospheric radiocarbon content has varied over time, and therefore the initial radiocarbon content of a sample can not be known precisely. However so far, there are no absolutely dated tree-ring records that span the end of the last glaciation (20,000 to 10,000 years ago), a period when large and rapid climate changes such as the Younger Dryas cold reversal occurred. Several tree-ring time series of radiocarbon approximately spanning the last deglaciation have been constructed. However, the dating of these time series is not directly linked to the present, and they are therefore termed 'floating'. On page 263 of this issue, Muscheler and co-authors¹ provide a firmer timescale for a floating tree-ring chronology from the Younger Dryas period, by anchoring it to a Greenland ice core.

The characteristic ring widths deposited each year by many species of trees in temperate zones enable dendrochronologists to link records from different trees through the comparison of overlapping periods to form time series that span thousands of years. Scientists have used these chronologies, and the radiocarbon (¹⁴C) measured from the individual rings, to reconstruct variations in atmospheric radiocarbon concentration caused by solar variability and changes

Figure 1 Comparison of two calibrations of a hypothetical radiocarbon-dated event. The radiocarbon chronologies based on the floating tree-ring record¹ (red dashed line) and the internationally accepted IntCal04⁵ combined record (blue dashed line) are shown at the top of the figure. Both curves are plotted as uncertainty envelopes (2σ). A hypothetical event with a measured radiocarbon age of $10,850 \pm 50$ ^{14}C BP (black) is calibrated using the respective calibrations. The potential dates that would be given by the tree-ring time series (red) and IntCal04 (blue) calibrations are shown by the probability distribution functions on the bottom calendar axis. A calendar-dated event (thick black line) that could be obtained from, for example, a U/Th-dated speleothem, is shown at $12,800 \pm 25$ BP with gray shading representing the uncertainty (2σ). Depending on which calibration curve is used, the radiocarbon-dated event could be interpreted as either leading or lagging the U/Th-dated event.

in the carbon cycle. When the tree-ring chronologies end, around 12,400 years ago, marine ¹⁴C records, based on independently dated coral and foraminifera have been used to extend the calibration².

These records are, however, affected by an additional uncertainty due to potential changes in the marine reservoir age, that is, the regionally variable difference in ¹⁴C content between the ocean and atmosphere. This uncertainty makes it difficult to determine leads and lags in climate system changes of the past, and it presents a particular challenge in reconstructions of the Younger Dryas, a relatively short-lived cold event at the end of the deglaciation

that is probably associated with a reduction in the meridional overturning circulation in the North Atlantic Ocean and consequent changes in the concentration of atmospheric ¹⁴C.

In order to address these uncertainties, Muscheler and co-authors make use of the relationship between ¹⁴C and ¹⁰Be, which are both produced by the interaction of cosmic rays with the upper atmosphere. Following production, radiocarbon is oxidized to ¹⁴CO₂, which is mixed throughout the atmosphere and then taken up by trees through photosynthesis. By contrast, ¹⁰Be is precipitated with rain and snow and is preserved within annual

layers in ice cores. Cosmic ray flux is modulated by solar activity so records of both isotopes contain periodicities related to solar activity, from the familiar 11-year solar cycle to centennial-scale fluctuations. By comparing these fluctuations in the ^{10}Be record obtained from Greenland ice cores to the floating ^{14}C record from tree rings, Muscheler *et al.* place the floating tree-ring records on the GICC05 timescale of the North Greenland Ice Core Project, which is based on counting the annual signals in multiple proxies in the ice³.

There is still some error in the ice-core timescale, and in the transfer of timescales from the ice core of the Greenland Ice Sheet Project 2 (GISP2) — in which the ^{10}Be record was actually measured⁴ — to the North Greenland Ice Core Project timescale. But despite the uncertainties, this positioning of the floating tree-ring record has important implications, for the calibration of radiocarbon dates from the last deglaciation as well as for our understanding of the ocean circulation during the Younger Dryas cold event.

Although a shift in age of just a few hundred years may not sound terribly important for dating events around 12,500 years ago, in studies of abrupt past climate changes it could change the interpretation between one event triggering another or the reverse. For example, if a hypothetical event with a radiocarbon age of $10,850 \pm 50$ ^{14}C BP is calibrated

using Muscheler and co-authors' tree-ring chronology instead of the internationally accepted IntCal04 curve², the respective probability distributions of the calibrated age would be offset by several hundred years (Fig. 1). If this event was compared with an event at 12,800 BP dated with uranium–thorium ratios, the different calibrated radiocarbon ages would lead to a very different understanding of the lead–lag relationship of these two events.

And what does the placement of the floating tree ring chronology imply about ocean circulation? If the tree rings are correctly positioned, the age of the carbon dioxide in the surface waters of the Cariaco basin must have decreased dramatically for a brief interval near the beginning of the Younger Dryas event. Equally low reservoir ages are observed in coral data from Barbados, but not in corals from the Pacific basin⁵. Decreased reservoir ages suggest that surface waters of the subtropical North Atlantic gyre may have become strongly stratified and isolated from deeper waters, possibly resulting from a reduction in deep mixing due to a brief but complete shutdown of the meridional overturning circulation. Similar shutdowns may have occurred during past Heinrich events, and could also be associated with changes in marine reservoir age, at least for some locations. Unfortunately, abrupt climate shifts, such as those associated with reductions in overturning circulation, are

often the events that most need accurately calibrated ^{14}C ages.

Incorporating the newly positioned floating tree-ring timescale¹ into the radiocarbon calibration curve is not necessarily as helpful as it may initially seem. Because the tree rings are tied to the ice-core timescale, adding this chronology would introduce circularity in determining the relative timing between events in radiocarbon-dated records and those in some of our most valuable climate archives, the Greenland ice cores, as well as any other record that was placed on the ice-core timescale.

Until the tree rings are linked dendrochronologically, or the ice-core chronologies for this time period firmly anchored to calendar dates, we can only use the floating tree rings to inform our choices of which datasets (or portions thereof) we incorporate into the next calibration curves. Specifically, in light of this evidence it seems prudent to exclude marine records from the subtropical North Atlantic gyre for periods of known changes in reservoir age, at least until such changes are quantified.

References

1. Muscheler, R. *et al.* *Nature Geosci.* **1**, 263–267 (2008).
2. Reimer P. J. *et al.* *Radiocarbon* **46**, 1029–1058 (2004).
3. Rasmussen, S. O. *et al.* *J. Geophys. Res.* **111**, D06102 (2006).
4. Finkel, R. C. and Nishiizumi, K. *J. Geophys. Res.* **102**, 26699–26706 (1997).
5. Hughen, K. A. *et al.* *Radiocarbon* **46**, 1059–1086 (2004).