Improved radiocarbon dating and understanding of Earth's environmental processes during glacial times

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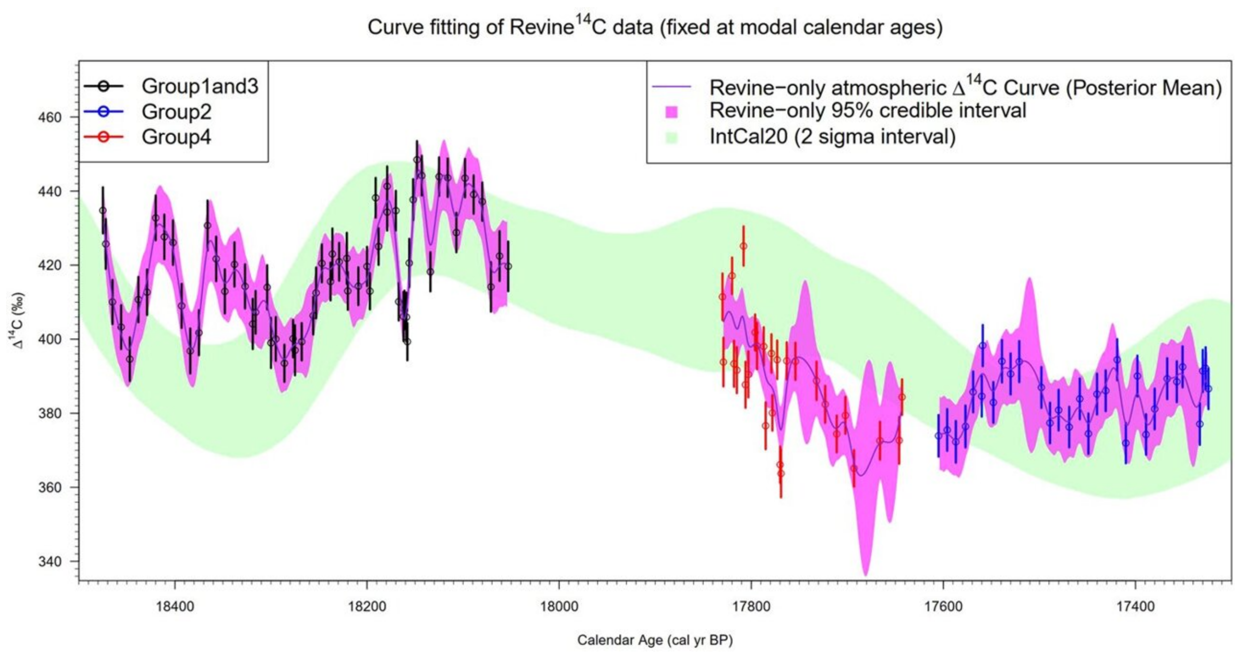

Reconstruction of Δ^{14}C. Atmospheric ^{14}C reconstruction based on Revine ^{14}C tree-ring sequences located at their most likely (marginal posterior mode) calendar ages compared to IntCal20 estimate (green shape). The Revine observations are plotted with 1σ error bars, while the IntCal and Revine curves show 95% (or 2σ) probability intervals. Credit: *Communications Earth & Environment* (2023). DOI: 10.1038/s43247-023-00929-9

The development of a high precision record of atmospheric radiocarbon shifts beyond 14,000 calendar years BP—obtained through combined studies (e.g., dendrochronology, radiocarbon dating and comparisons with other radionuclide records)—represents a crucial improvement within the widely applied radiocarbon dating method, allowing more accurate dating of sub-fossil samples and hence, establishing the chronology of past environmental and climate changes during glacial times.

This improvement will play a key role in the construction of the future radiocarbon dating calibration curve.

The present upgrade, which captures considerable variations of atmospheric radiocarbon levels based on the construction of a 1000-year long tree-ring chronology, was published in *Communications Earth & Environment*.

The study is led by Professor Sahra Talamo, director of the BRAVHO Lab at University of Bologna, in collaboration with international experts in the field of dendrochronology, radiocarbon, cosmogenic radionuclides in ice cores, and modeling from the University of Hohenheim, University of Heidelberg, the Alfred Wegener Institute (Germany), the University of Leeds, (UK), Lund University, (Sweden), and ETH Zurich (Switzerland).

This interdisciplinary research represents an important contribution to the IntCal group, committed to the elaboration of a globally agreed reconstruction of ^{14}C levels in three main environments (Northern Hemispheric atmosphere, Southern Hemispheric atmosphere and the surface oceans).

The team was able to detect greater variations of atmospheric radiocarbon levels between 18,475 and 17,350 calendar years BP than previously shown by the last calibration curve, known as IntCal20. A new tree-ring chronology was obtained using 33 larch subfossil trees from the site of Revine, located in the Venetian Prealps (Northeastern Italy), that grew during important intervals of deglaciation.

The comparison with ^{10}Be in ice cores, another cosmogenic radionuclide that is, like ^{14}C, produced when cosmic rays enter the atmosphere, led the research group to connect the reconstructed changes in atmospheric radiocarbon to periodic changes in solar activity, widely attested within the Last Glacial.

The core of the study is to supplement the existing calibration curve with ^{14}C-series from annually resolved tree rings, which track the variation of ^{14}C in the atmosphere much better than the previous archives from lake sediments, stalagmites and marine sediments. Thus, being extremely accurate in the reconstruction of atmospheric radiocarbon values through time allows both to become more precise with radiocarbon dating and to infer climate and cosmic ray flux, which occurred in the past.

"The more accurate our knowledge of past ^{14}C levels, the more accurately we can calibrate a ^{14}C measurement to obtain the sample's calendar age," says Sahra Talamo, leader of the research group and PI of the ERC_StG RESOLUTION, which aims to increase the dating accuracy to solve key questions within human evolution.

This higher level of accuracy was only reached through the first establishment of three tree-ring series covering a 1200-year period between 18,475 and 17,350 calendar years BP in this crucial climate period and just before the starting point of the even more accurate and well-established, tree-ring based part of the radiocarbon calibration curve.

"The new robust tree-ring chronologies of the Glacial trees from Revine represent the solid basis for our high-resolution ^{14}C series described in this work," says Michael Friedrich, the dendrochronology specialist based at the University of Hohenheim, Stuttgart.

Then, another analysis was carried out on exploiting ^{10}Be stored in ice cores. "Due to their own dating uncertainties, ice cores cannot be used to provide strong (independent) constraints on the precise calendar ages of the Revine trees during this period," says Florian Adolphi, a specialist on cosmogenic radionuclides. "Nonetheless, the ^{10}Be record is still able to provide useful inferential support."

Indeed, comparing ^{14}C values of Revine chronologies with ^{10}Be of ice cores resulted in the determination of the cause of the reconstructed atmospheric radiocarbon changes during this critical time period.

"This work clearly shows the strength of the combined studies of dendrochronology, radiocarbon dating and ^{10}Be to develop new floating tree-ring width chronologies and high-resolution ^{14}C-data sequences from sub-fossil trees grown during the most recent glacial period," says Bernd Kromer, a physicist expert in tree-ring based radiocarbon calibration.

"In general, our tree-ring Revine data appear to confirm the sequence of the Chinese Hulu cave speleothem ^{14}C data but with a resolution that is 10 times greater and with a reduced level of smoothing," states Timothy J. Heaton, responsible for the estimation of absolute calendar ages for the Revine radiocarbon chronologies developed in the present study.

"This pivotal research in the field of radiocarbon underlines the importance of having a robust chronology as the basis for reconstructions not only of our human past events but of key climate and Earth processes," concludes Prof. Talamo.

More information: Sahra Talamo et al, Atmospheric radiocarbon

levels were highly variable during the last deglaciation, *Communications Earth & Environment* (2023). DOI: 10.1038/s43247-023-00929-9

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