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A millennial hydrogen isotope chronology from tree–ring cellulose contradicts the mechanistic model describing the incorporation of stable water isotopes into cellulose

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Abstract

In the present study we investigated deuterium (δD) isotopes on a millennial larch (*Larix decidua*) tree–ring chronology from alpine sites in Valais, Switzerland. Cellulose in annual tree rings is formed from atmospheric CO_2 and soil water which is eventually derived from meteoric water. Due to fractionation processes in the atmosphere, meteoric water contains a temperature signal. Climate induced signals such as the isotopic composition of cellulose is stored in annual increments of trees: source water is assimilated by the roots without any isotopic fractionation and further on transported to the leafs where isotopic ratios of the leaf water are changed by evapotranspirative enrichment and further biochemical fractionations. Finally, cellulose is synthesized from photosynthates and medium water. δD and stable oxygen isotopes ($\delta^{18}O$) in tree–ring cellulose are therefore expected to reflect ancient humidity and temperature in annual resolution. We applied a conventional isotope ratio mass spectrometry technique to analyse δD in α–cellulose (Filot, 2006). The investigated δD series cover the period 1000–2004 AD in three cohorts (each consisting of five trees) with a 50–year gap around 1200 AD. This required the development of methods to merge these tree–ring isotope series to assess the common signal within the different cohorts. A comparison of the δD series with the corresponding $\delta^{18}O$ chronology revealed a common variance of around 20% in the different cohorts, which is lower than expected from the mechanistic model (Roden, 2000) – the model assumes similar pathways and fractionation processes of δD and $\delta^{18}O$ from source water uptake to cellulose synthesis. Assessing the sensitivity of δD to changing climate variables leads to conflicting results: while temperature, sunshine duration and precipitation signals in $\delta^{18}O$ are clearly visible, climate signals in δD are hardly detectable. Note that isotopic signals in tree–ring cellulose are not controlled by one dominating factor but are usually a combination of several climate variables such as temperature, relative humidity or precipitation. Further quantified meteoric data such as relative humidity, barometric pressure or wind speed are not imprinted in the δD series neither and δD from meteoric water from a proximate meteo station reveals no significant correlations with δD from cellulose in the period 1984–2004 AD. These results lead to the conclusion that δD and $\delta^{18}O$ fractionation processes in trees differ — undiscovered biochemical fractionations in δD after leaf water enrichment are likely to account for deviating signals in the water isotopes of cellulose. The lack of climate signals in our millennial δD series raises the questions if (a) a more detailed analysis method concerning the different positions of hydrogen isotopes in cellulose molecules such as suggested by Augusti et al. (2008) would be more appropriate to detect climate signals in δD or (b) not climatically induced δD fractionation processes in trees are superimposing the climate signal from source water and leaf water enrichment in such a way that the original climate signals can not be retrieved from δD in tree–ring cellulose.

References

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