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Investigation of age trends in tree-ring stable carbon and oxygen isotopes from northern Fennoscandia over the past millennium

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A B S T R A C T

Although tree-ring stable carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotopes are increasingly used for climate reconstructions, it remains unclear whether isotopic ratios from the two chemical elements and different tree species exhibit age-related trends that require removal prior to any paleoclimatic interpretation. Here, we present 2,355 $\delta^{13}C$ and 2,237 $\delta^{18}O$ decadal measurements of living and relict Scots pines (*Pinus sylvestris* L.) from northern Fennoscandia to investigate the occurrence of isotope-specific age trends at both the individual tree and chronology level between 941 and 2010 CE, together with total-ring width and maximum density data. We show that $\delta^{13}C$ values increase by ~0.035‰ per 10 years of tree age, and therefore require detrending, which is not the case for $\delta^{18}O$ that only contains minor changes related to age. This study provides independent evidence for the unique paleoclimatic value of stable $\delta^{18}O$ isotopic ratios from the cellulose of living and relict pine wood to reconstruct high-to low-frequency climate variability. Conversely, caution is advised when information from diverse tree-ring parameters, species and regions is combined in multi-proxy climate reconstructions.

1. Introduction

Tree-ring stable isotope (TRSI) records are increasingly used to assess past environmental changes. Due to the high cost and labor intensities, TRSI records are not as common as traditional tree-ring variables such as tree-ring width (TRW) or maximum latewood density (MXD). However, stable carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) ratios have been shown to contain important information on past climatic conditions (e.g., Gagen et al., 2011; Hartl-Meier et al., 2015). Multi-centennial $\delta^{13}C$ and $\delta^{18}O$ chronologies have been used as predictors in reconstructions of drought (Büntgen et al., 2021; Kress et al., 2010; Labuhn et al., 2016), cloud cover (Helama et al., 2018; Loader et al., 2013; Young et al., 2012), sunshine hours (Hafner et al., 2014), temperature (Esper et al., 2015; Szymczak et al., 2012; Treydte et al., 2009), relative humidity (Edwards et al., 2008; Haupt et al., 2011), and precipitation (Rinne et al., 2013; Treydte et al., 2006; Young et al., 2015). When used together with TRW or MXD data, isotope-based reconstructions can provide a more comprehensive understanding of the interaction between different climatological parameters (Linderholm et al., 2018; McCarroll and Loader, 2004). Joint analyses of past temperatures reconstructed from TRW and MXD (Esper et al., 2012a; McCarroll et al., 2013) with local and regional cloud cover reconstructions based on $\delta^{13}C$ measurements (Gagen et al., 2011; Loader et al., 2013; Young et al., 2012) have disentangled the coexistence of opposing cloud-cover temperature feedbacks at short- and long-term timescales in northern Fennoscandia and advanced our knowledge of cloud cover forcing (Young et al., 2019).

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