High frequency stable isotope signals as proxy for physiological responses to climate - Dual isotope approach at a European scale

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Introduction

Despite a broader variability in growth at temperate sites than at growth-limited sites, changes in physiological performance due to environmental conditions can be retrieved from stable C and O isotopes of tree rings and – in combination with growth data – provide indications for future optimum species ranges. *Picea abies* and *Fagus sylvatica*, are two of the most important tree species in Europe, and their responses to climate are being extensively investigated especially at the limits of their distribution. However, their physiology at temperate sites is not yet fully understood. In a European tree-ring network, 10 sites along a climate gradient were sampled throughout Central Europe and $\delta^{18}O$, $\delta^{13}C$ and tree ring chronologies were created for the last 100 years, and previously explored by Klesse et al (2018) for long-term trends.

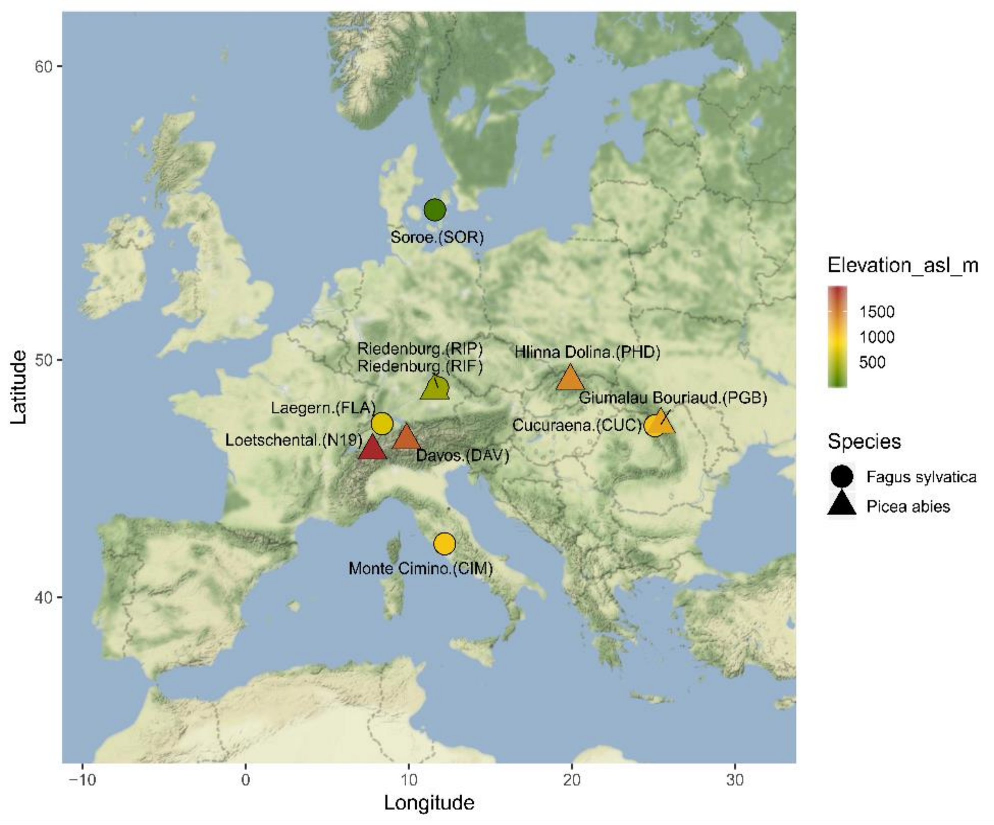

Fig.1 Study sites location map. Different shapes describe species sampled at each site, and site elevation is indicated by the symbol colour.

To enhance the year to-year signal we transformed the three chronologies (TRW, 13C, 18O) with a first-order difference (FirstDiff). The signal of these high frequency chronologies was tested to asses the correlations between sites at long distances and the consistency of their climatic correlations, to finally pose the question:

What insight can be deduced from a dual-isotope approach about the future prospects for *Fagus sylvatica* and *Picea abies* across Central Europe?

Correlations across space

$\delta^{18}O$ shows a much higher and consistent synchronization between sites even at large distances, compared to $\delta^{13}C$ and tree ring width.

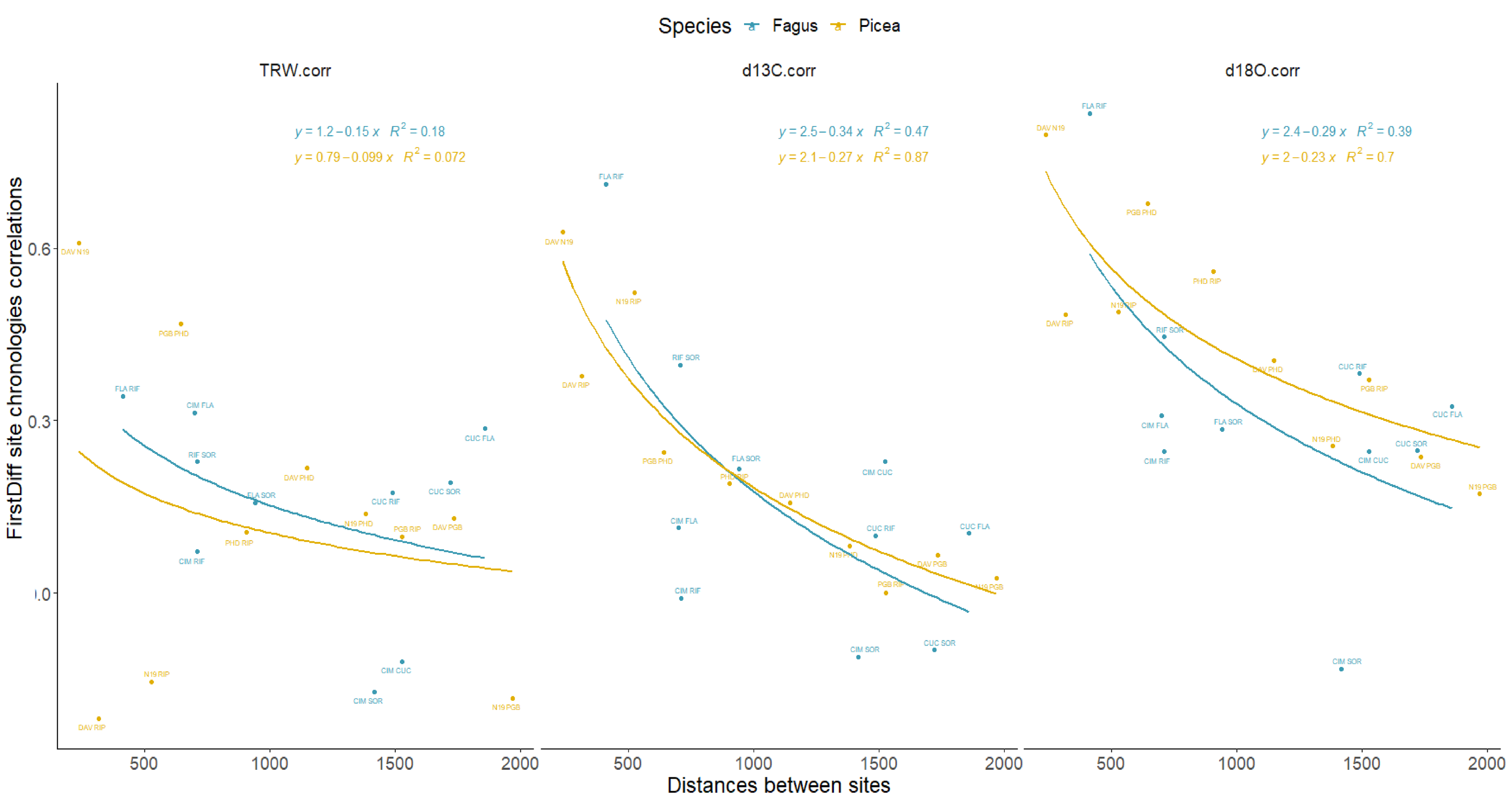

Fig 2. Between sites correlation of FDiff TRW (a), δ13C (b) and δ18O (c) chronologies. Distances between sites are indicated in km. Model lines are fitted as y=log(x).

Climate correlations

Both $\delta^{18}O$, $\delta^{13}C$ show a strong and consistent climate correlation pattern with June, July, August climate. On the contrary TRW show a more site dependent correlation.

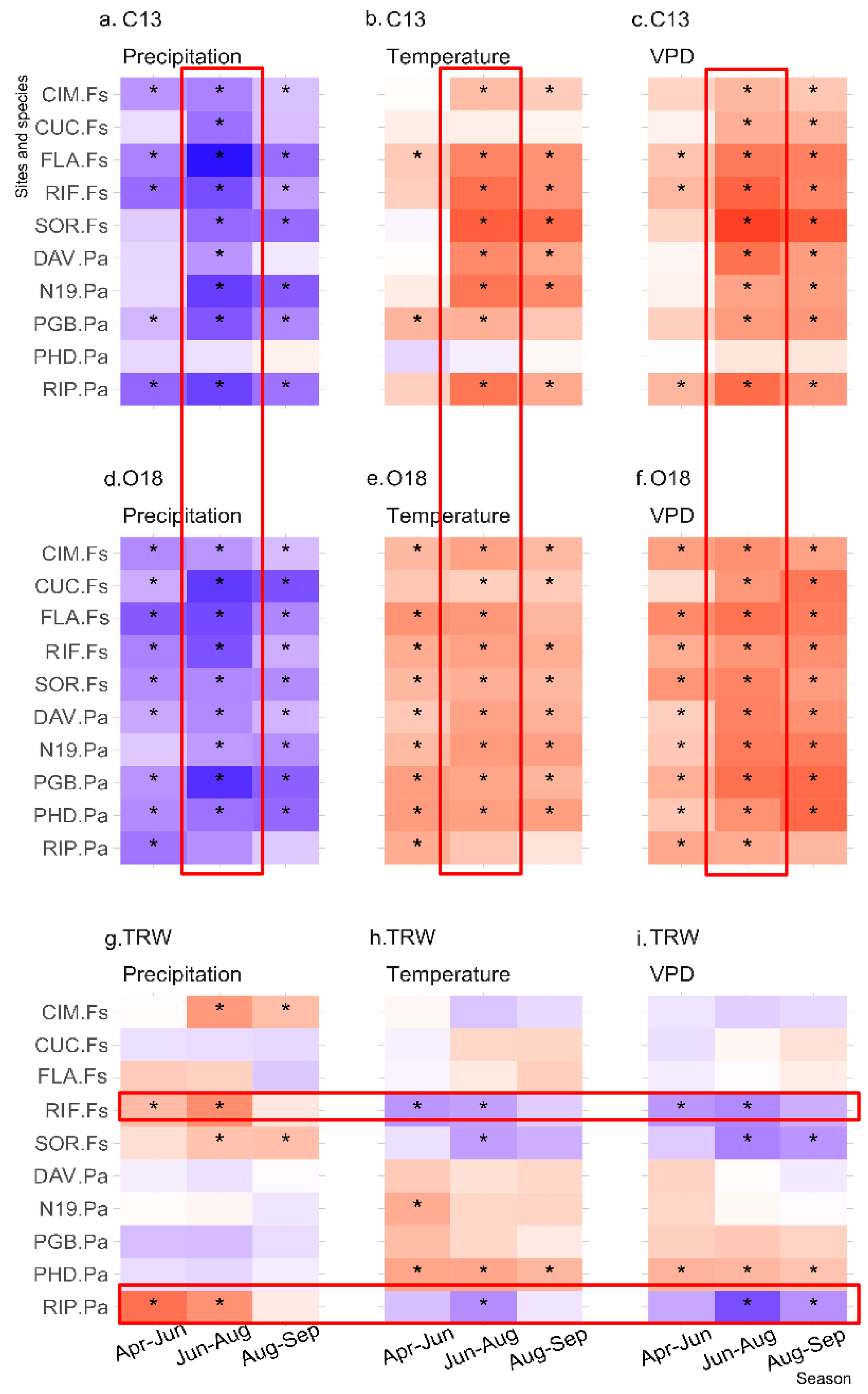

Fig. 3 Pearson's correlation of FirstDiff chronologies of δ13C (atm.corr.; upper panels a-c), δ18O (middle panels, d-f) and tree-ring width (lower panels, g-i) with year-to-year difference in climate parameters of early summer (AMJ), mid-summer (JJA) or late summer (JAS) for temperature, VPD, precipitation and water balance. Correlations span the time-period 1935-2012 with a mean of n≥4 trees per year. Significant correlations (p<0.05=*) are indicated by the asterisk.

Dual isotope approach

In the last decades, shifts in the isotopes relationships occurred, driven by climate change and atmospheric CO_2 increase. These processes lead to changes in photosynthetic rates and stomatal conductance. They can be quantified through the Scheidegger dual isotope approach. At warmer sites we observe an increase of both $\delta^{13}C$ and $\delta^{18}O$. The consequent decrease of photosynthetic rates and stomatal conductance highlights their dependency on atmospheric moisture demand and soil water availability.

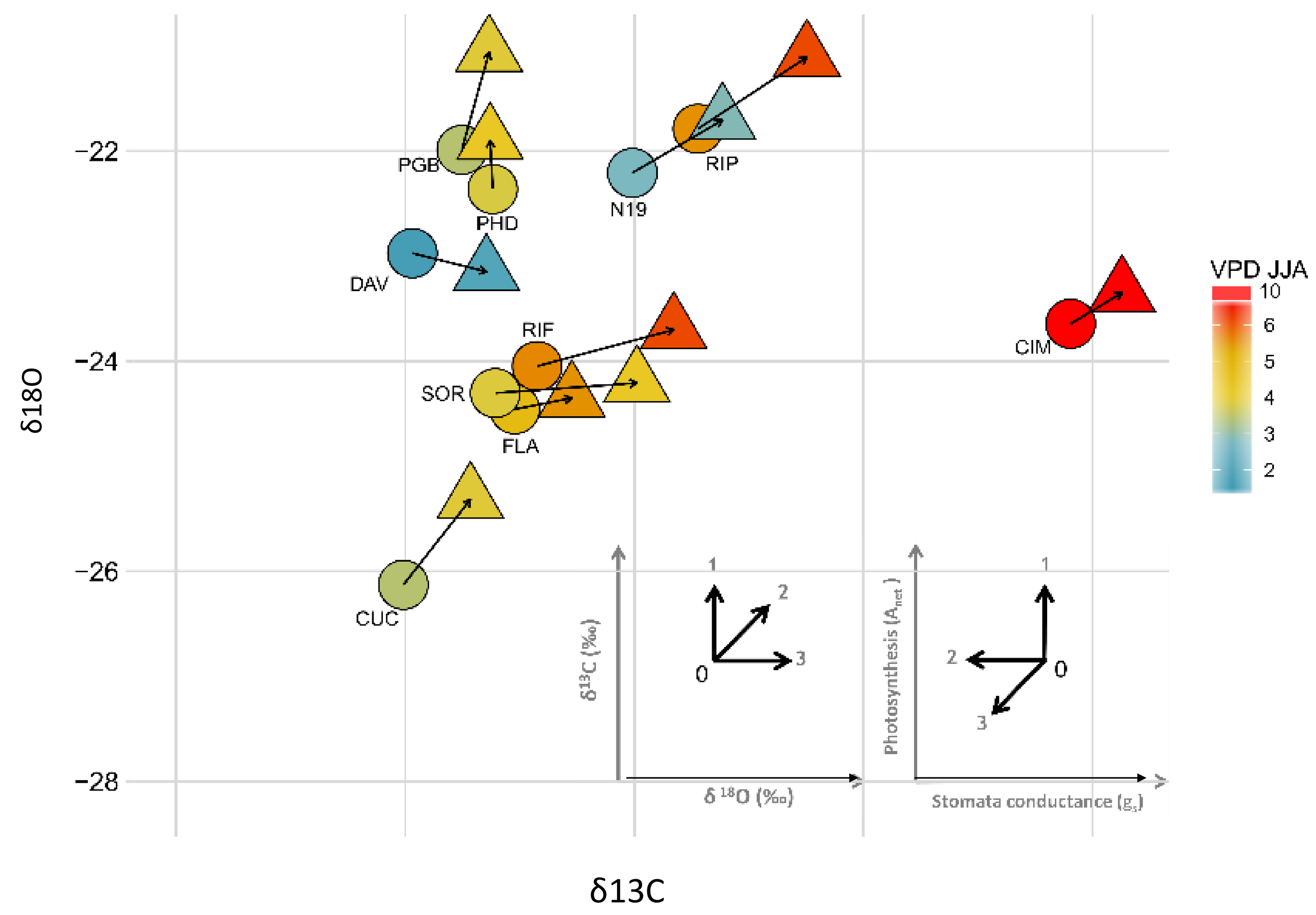

Fig. 4 Shift in mean isotope values per site and crown status between the two distinguished time periods 1935-1979 (circle) and 1980-2012 (triangle). Arrows indicate significant changes in δ13C and/or δ18O at p<0.05. Direction of shift corresponds to changes in photosynthesis (Anet) and stomatal conductance (gs) according to the dual isotope model after Scheidegger et al. (2000), as depicted in the lower panel.

Conclusions

Understanding the underlying physiological mechanisms controlling the short-term variation in tree-ring records will help with defining the performance of these ecologically and economically important tree species under future climate conditions. We show how $\delta^{13}C$ and $\delta^{18}O$ can be helpful to decipher tree responses to past climate conditions in mid-latitude, temperate environments especially when tree-ring width signal is lacking, and asses species future physiological strategies to changes in VPD and consequent water-use efficiency.

Citations:
1. Klesse S, et al.(2018) Oxygen isotopes in tree rings are less sensitive to changes in tree size and relative canopy position than carbon isotopes. *Plant, cell & environment*, **41**, 2899–2914.
2. Scheidegger Y, Saurer M, Bahn M, Siegwolf R (2000) Linking stable oxygen and carbon isotopes with stomatal conductance and photosynthetic capacity: a conceptual model. *Oecologia*, **125**, 350–357.

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