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 and unevenage forests is not yet fully understood. Ten sites along a climate gradient were sampled throughout Central Europe and the $\delta^{13}C$, $\delta^{18}O$, and tree ring chronologies were created for the last 100 years.

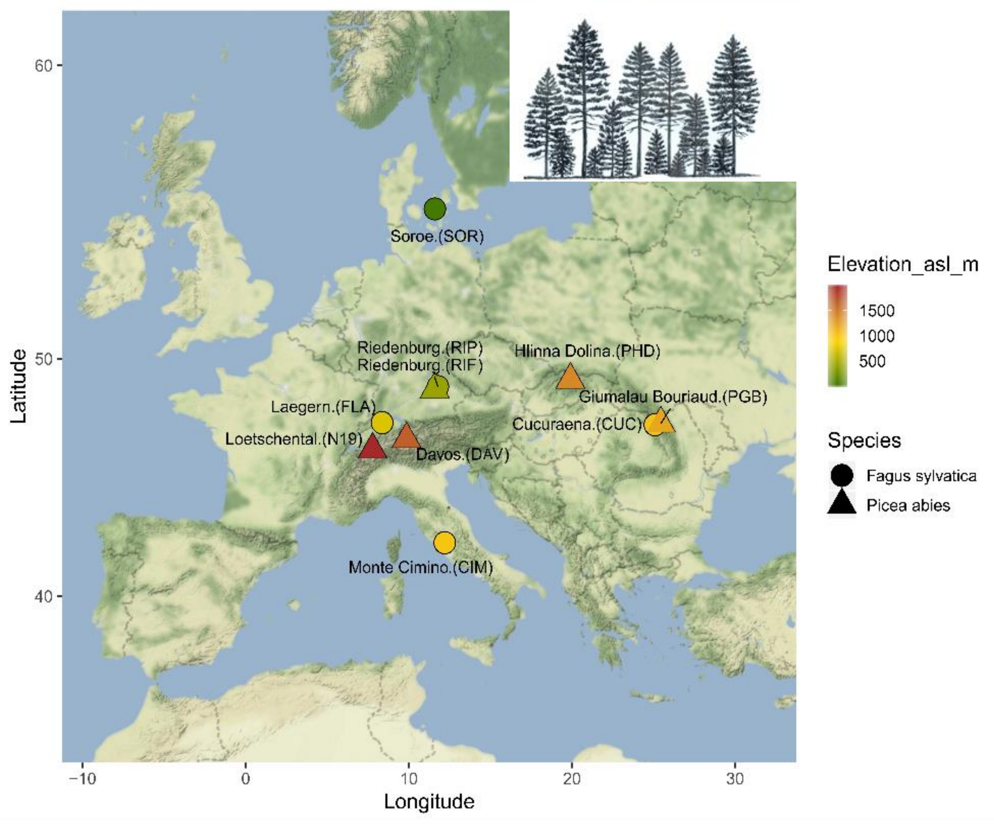

Fig.1 Map of the uneven-aged sampled sites. Different shapes describe species sampled at each site, and site elevation is indicated by the colour scale.

To enhance the year to-year signal we transformed the three chronologies (TRW, $\delta^{13}C$, $\delta^{18}O$) with a first-order difference (FDiff). The signal of these high frequency chronologies was tested to assess 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, with significant correlations above 1500 km, compared to $\delta^{13}C$ (~700 km), and tree ring width.

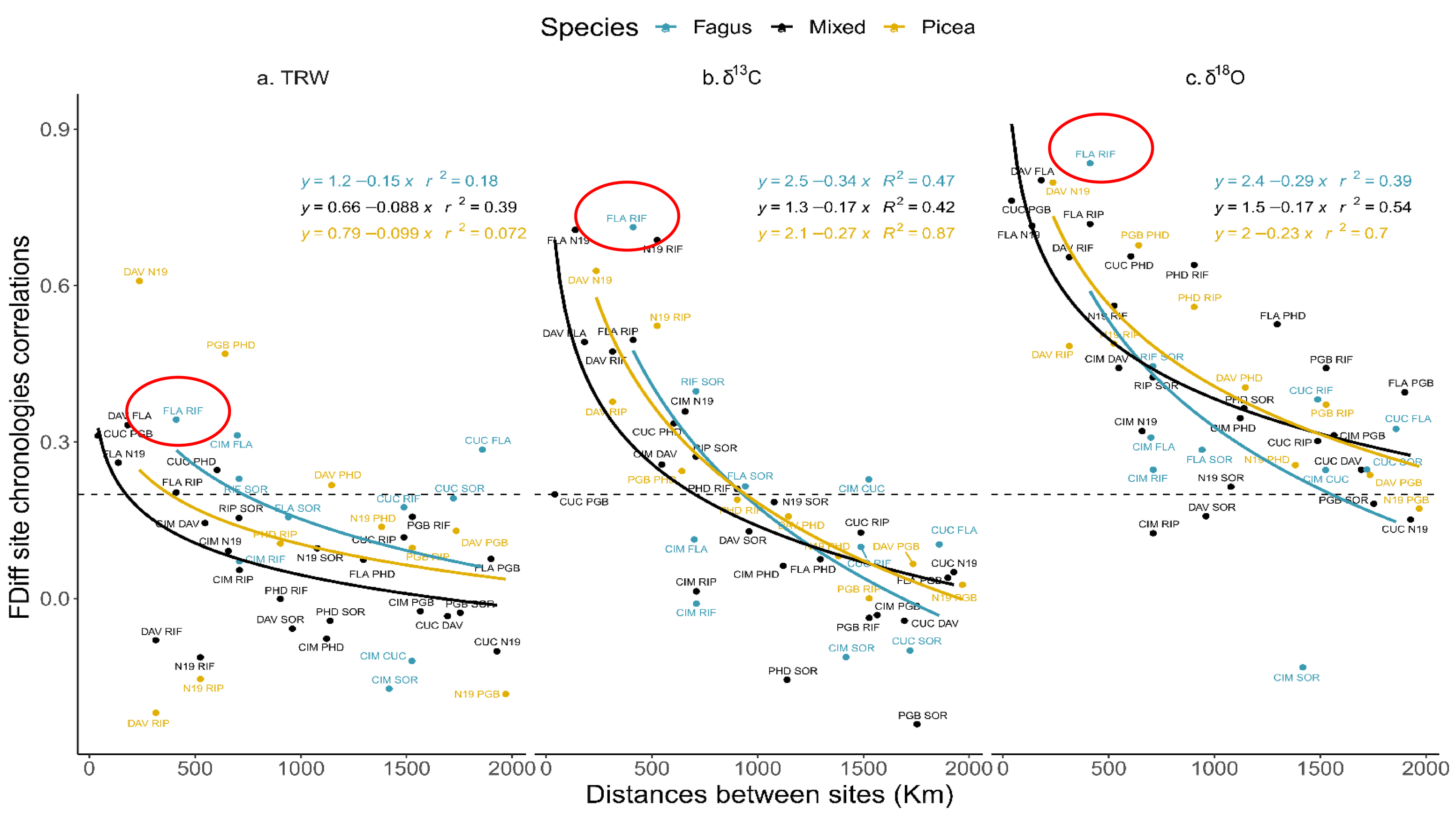

Fig 2. Between sites correlation of FDiff TRW (a), $\delta^{13}C$ (b) and $\delta^{18}O$ (c) chronologies. Distances between sites are indicated in km. Model lines are fitted as y=log(x).
As an example of the declining correlations between parameters, the FLA-RIF pair is highlighted.

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. When considering the 100years chronologies correlations to climate, there is little differences between the two canopy layers.

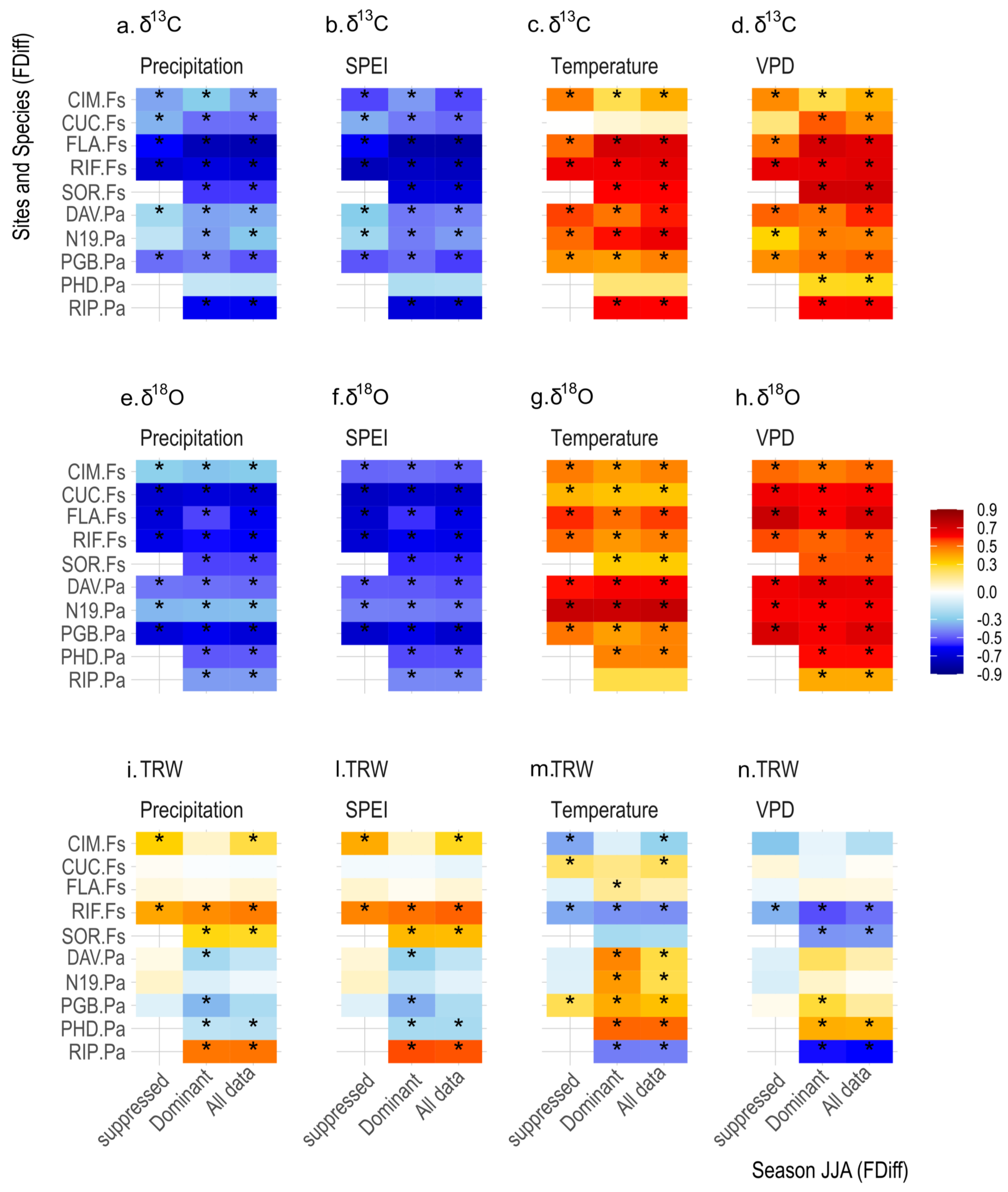

Fig. 3 Pearson's correlation of FirstDiff chronologies of $\delta^{13}C$, $\delta^{18}O$, and tree-ring width, with FDiff climate parameters of for precipitation, SPEI, temperature, VPD for the two canopy layers separately and all data. Correlations span the time-period 1935-2012 with a mean of n≥4 trees 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.

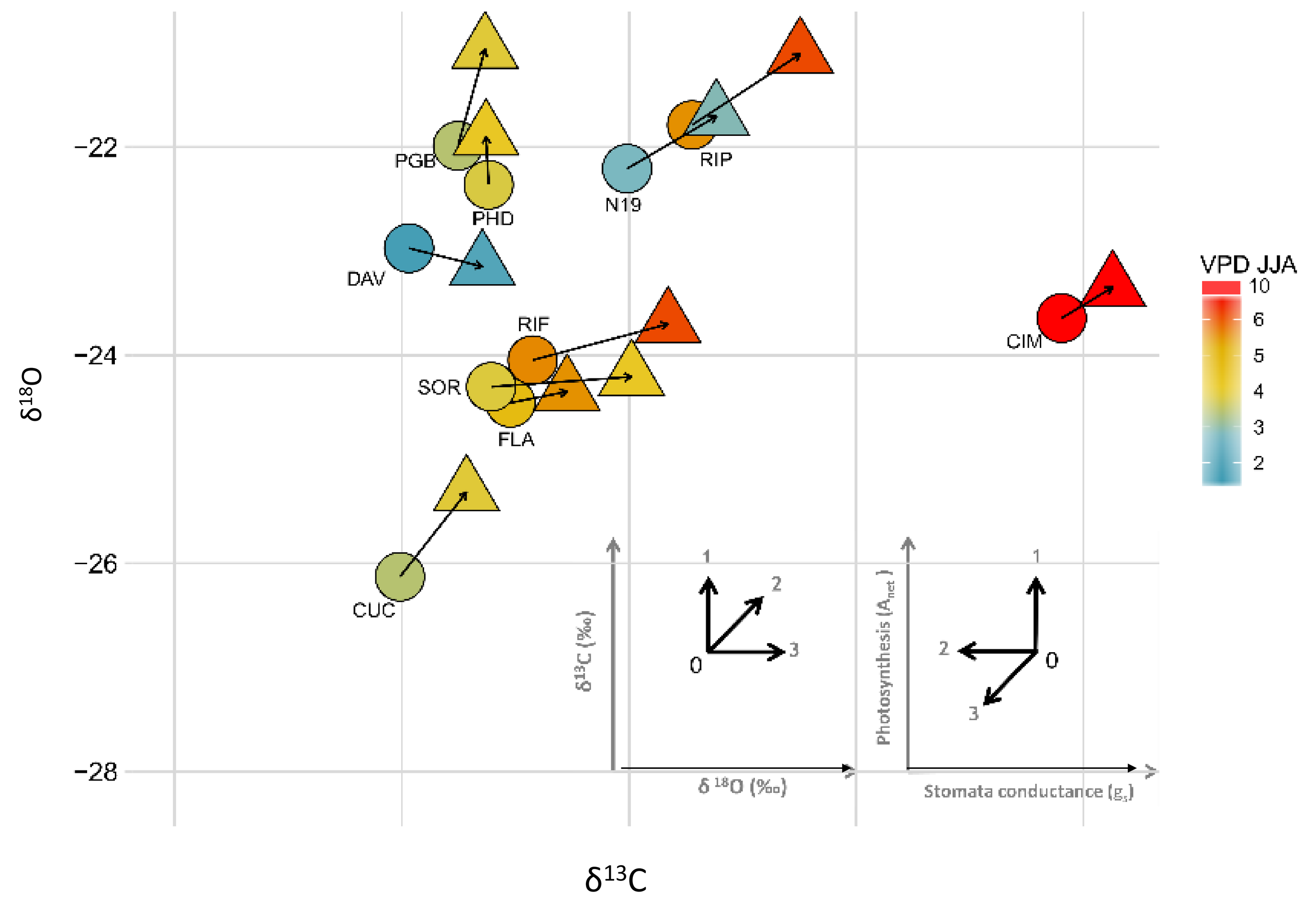

Fig. 4 Shift in mean isotope values per site and crown status between the two distinguished time periods 1935-1979 (circle) and 1980-2012 (triangle). Arrows indicate significant changes in δ13C and/or δ18O at p<0.05. Direction of shift corresponds to changes in photosynthesis (Anet) and stomatal conductance (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 assess species reactions to changes in VPD and water-use efficiency.

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