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How are environmental variations reflected in tree carbon isotope signatures?

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Stable carbon isotopes from tree rings and other organic materials are widely used as indicators for climatic and environmental variations. But the correlations of plant based proxies with climate data is not always straightforward. For example, the recent increases in atmospheric CO2 concentration and nitrogen deposition can affect the physiology of trees, and mask the environmental signals. Thus, the interpretation of plant based records requires a more detailed analysis of the interactions between trees and the environment. In this context, we explore how tree physiological processes and environmental factors shape carbon isotope signatures as well as carbon and water fluxes from leaf to ecosystem levels, and across different timescales. We present data on the carbon isotope composition of sun and shade leaves along a rainfall gradient in Mediterranean ecosystems. In all systems, shade leaves had more depleted carbon isotope signatures than sun leaves. In addition, carbon isotope signatures were increasingly depleted towards the higher rainfall sites, but this was more pronounced for the shade leaves. As a consequence, the isotopic difference between sun and shade leaves increased with annual rainfall. We used a coupled model to analyse the observed trends in the carbon isotope values. The model calculates gas exchange and carbon isotope signatures at the leaf level (for comparison with leaf samples), and propagates both gas exchange and isotope values to long-term trends in carbon-water exchange and carbon isotope signatures at the canopy scale (for comparison with samples of annual resolution). This allows to analyse the relative importance of light and water limitations in determining the performance of shade plants in dry ecosystems. For example, the depleted carbon isotope signatures may indicate a higher water use efficiency of shade plants. This approach is also useful for exploring the sensitivity of carbon isotope ratios and carbon-water exchange of plants to simultaneous changes in external and internal factors, for example when interpreting trends in carbon isotope signatures obtained from tree rings.