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Stable C and O isotope signals of drought in Mediterranean pines on inter- and intra-annual scales

D. Sarris (1), R. Siegwolf (2), and Ch. Körner (3)

(1) Division of Plant Biology, Department of Biology, University of Patras, Patra, Greece (disarris@cc.uoi.gr), (2) Lab for Atmospheric Chemistry, Stable Isotopes and Ecosystem Fluxes, Paul Scherrer Institut, Villigen, Switzerland (rolf.siegwolf@psi.ch), (3) Institute of Botany, University of Basel, Basel, Switzerland (ch.koerner@unibas.ch)

In dry years radial growth for *Pinus halepensis* (a Mediterranean conifer) does not extend into late spring/early summer, where drought impact should be the strongest. This lack of assimilation and tissue formation should not allow the accurate recording of the stable isotopic signal related to severe drought stress on tree-rings. However, on an inter-annual scale of 30 years drought clearly reduced tree-ring width and ^{13}C discrimination (Δ). Inta-annually the highest δ^{13}C signals were found in early to mid autumn (on the second growth period after the growth cessation due to summer drought) when rainfall resumed and climate was less dry compared to late spring/early summer (the period just before growth cessation). Therefore, autumn wood (late-wood) may incorporate carbon fixed during the summer drought period. This explains why in extremely dry years, despite the earlier growth cessation due to summer drought, we still find a δ^{13}C increase corresponding to the severity of drought when complete tree-rings (early-wood plus late-wood) are analyzed. Additionally, inter-annual δ^{18}O in tree-rings declined (linked to very low δ^{18}O in early-wood), in contrast to the year by year rise in temperature. In wet years, when pine growth extends into late spring/early summer, intra-annual δ^{18}O in tree-rings again declined, despite the seasonal temperature rise from spring to summer. Thus, any evaporative enrichment of leaf water in the heavier isotope under drought appears to be masked by the source water utilized for tree growth. Source water when arriving from deeper moisture pools is less enriched in $H_2^{18}O$ compared to surface water. Thus, as drought intensifies between years or within a year, pines seem to use water less enriched in $H_2^{18}O$ from deeper soil layers. This water accumulates from precipitation over a series of years and also appears to determine Δ^{13}C and tree growth, as both were best correlated with multiple years of past precipitation.