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Partitioning water and carbon fluxes in a Mediterranean oak woodland using stable oxygen isotopes

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Water is a key factor driving ecosystem productivity, especially in water-limited ecosystems. A separation of the component fluxes is needed to gain a functional understanding on the development of net ecosystem water fluxes and their coupling with biogeochemical cycles. Oxygen isotope signatures are valuable tracers for water movements within the ecosystem because of the distinct isotopic compositions of water in soil and vegetation. In the past, determination of isotopic signatures of evaporative or transpirational fluxes has been challenging since measurements of water vapor isotopes were difficult to obtain using cold-trap methods, delivering data with low time resolution. Recent developments in laser spectroscopy now enable direct high frequency measurements of the isotopic composition of atmospheric water vapor (δv), evapotranspiration (δET), and its components and allow validations of common modeling approaches for estimating δE and δT based on Craig and Gordon (1965).
Here, a novel approach was used, combining a custom build flow-through gas-exchange branch chamber with a Cavity Ring-Down Spectrometer in a Mediteranean cork-oak woodland where two vegetation layers respond differently to drought: oak-trees (Quercus suber L.) avoid drought due to their access to ground water while herbaceous plants survive the summer as seeds. We aimed at 1) testing the Craig and Gordon equation for soil evaporation against directly measured δE and 2) quantifying the role of non-steady-state transpiration under natural conditions. Thirdly, we used this approach to quantify the impact of the understory herbaceous vegetation on ecosystem carbon and water fluxes throughout the year and disentangle how ET components of the ecosystem relate to carbon dioxide exchange.
We present one year data comparing modeled and measured stable oxygen isotope signatures (δ18O) of soil evaporation, confirming that the Craig and Gordon equation leads to good agreement with measured δ18O of evaporation (Dubbert et al. 2013). Moreover, we found continuously strong deviations from isotopic steady-state in plant transpiration combined with large isoforcing on the atmosphere. This implies that assuming plant transpiration to be in the steady-state can have a huge impact at least for studies that distinguish relatively short time intervals (hours, e.g. partitioning studies). Finally. partitioning ecosystem ET and NEE into its three sources revealed a strong contribution of soil evaporation (E) and herbaceous transpiration (T) to ecosystem ET during spring and fall. In contrast, soil respiration (R) and herbaceous net carbon gain contributed to a lesser amount to ecosystem NEE during spring and fall, leading to consistently smaller water use efficiencies (WUE) of the herbaceous understory compared to the cork-oaks.

Craig H, Gordon, LI. 1965. Deuterium and oxygen-18 variations in the ocean and the marine atmosphere. Paper presented at the Stable Isotopes in Oceanographic Studies and Paleotemperatures, Spoleto, Italy.

Dubbert M, Cuntz M, Piayda A, Maguas C, Werner C, 2013: Partitioning evapotranspiration - Testing the Craig and Gordon model with field measurements of oxygen isotope ratios of evaporative fluxes. J Hydrol.