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Using coupled CO_2/O_2 measurements to study respiration in tree stems, soil, and carbon fluxes between them

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Terrestrial ecosystems exchange CO_2 and O_2 in similar rates. However, in individual ecosystem components this balance is not necessarily observed. For example, the ratio of CO_2 efflux to O_2 influx (ARQ, apparent respiratory quotient) in tree stems, expected to be 1.0 according to carbohydrates metabolism, deviated strongly from unity. The mean ARQ of 85 tropical, temperate, and Mediterranean forest trees from 9 different species was 0.59. Assuming that O_2 uptake provides a measure of in situ stem respiration (due to the low solubility of O_2), the overall mean indicates that on average 41% of CO_2 respired in stems is not emitted from the local stem surface. ARQ did not vary as expected if dissolution and transport of respired CO_2 in the xylem stream was the main driver of the CO_2 retention. We hypothesize that refixation of respired CO_2 by the enzyme PEPC is the main driver for low ARQ values. Since in the ecosystem level the CO_2 and O_2 fluxes are expected to balance, ARQ >1.0 must show up elsewhere. Such elevated ARQ values are predicted in catabolism of organic acids, which are products of PEPC refixation and also an important component of root exudates to the soil. In first attempt to investigate potential stem-soil ARQ balance, we measured ARQ of soil air, bulk soil incubations, and stem core incubations in bimonthly intervals in a Mediterranean oak forest. Mean values (range) were respectively 0.76 (0.60-0.92), 0.65 (0.48-0.80), and 0.39 (0.19-0.70). Assuming soil air composition is derived from bulk soil respiration and root and rhizosphere respiration with equal contributions, the mean (range) calculated ARQ of root and rhizosphere respiration was 0.87 (0.59-1.16). Those calculated ARQ >1.0 values provide an evidence of organic acids catabolism in the roots environment, but overall stem-soil ARQ balance was not observed. Measurements of actual CO_2 and O_2 fluxes can probably further resolve the CO_2/O_2 balance. In summary, measurements of O_2 fluxes in plants, now cost effective and easier to implement at the field, can provide more accurate respiration rate estimation than CO_2 efflux. In addition, the coupled CO_2/O_2 (ARQ) measurements can reveal internal carbon fluxes and can be used for soil respiration partitioning.