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From over to under, a story about the vertical within-canopy variation of the leaf relative uptake rate of COS

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The gross primary productivity (GPP), which represents the gross uptake of carbon dioxide (CO^2) by plants, cannot be directly measured at the ecosystem level. It must instead be inferred either by applying models or by measuring proxies. A notable proxy is the trace gas carbonyl sulfide (COS), which is particularly interesting because it follows a pathway into plant leaves similar to CO^2 and, unlike CO^2, is generally not reemitted.

To utilize COS as a tracer for GPP, the leaf relative uptake (LRU)—the ratio of the deposition velocities of COS to CO^2 at the leaf level—must be known a priori. Initial studies suggested that LRU values were relatively constrained, around 1.7. However, it has been observed that LRU varies between plant species and is influenced by environmental factors such as drought, vapor pressure deficit (VPD), and photosynthetically active radiation (PAR).

The variation in LRU related to PAR is due to COS primarily being catalyzed by the enzyme carbonic anhydrase in a light-independent reaction, contrasting with CO^2 uptake via photosynthesis, which is dependent on PAR. Consequently, LRU increases under lower light conditions, even when stomatal control on both gases is similar.

This light dependency prompts questions about LRU variation within canopies. While most LRU chamber measurements have been conducted under laboratory conditions or in canopy crowns, additional data on LRU variability within canopies, particularly in lower light conditions, are necessary. A comprehensive understanding of LRU, encompassing both crown and shadow-adapted leaves at various canopy positions and considering stand species composition, is essential for accurately calculating GPP at the ecosystem scale using eddy covariance (EC) measurements.

To investigate how LRU varies within the canopy, particularly in response to environmental factors like PAR and VPD, and to compare the LRUs from different chamber measurements to EC measurements, we conducted a measurement campaign in an Austrian Pine forest. This included ongoing eddy covariance measurements of COS, CO^2, and H^2O, supplemented by manual measurements of the same gases using branch chambers at three levels within the *Pinus sylvestris* canopy and three additional chambers of *Juniperus communis*.

Above 400 µmol photons m^2 s PAR, where we consider the LRU to be light independent, the LRU reached 1.61±0.3 at the top of the crown and decreased to 1.55±0.4 and 1.56±0.3 going consecutively deeper into the canopy of Pinus sylvestris. In contrast, the LRU of Juniperus communis in the understory was notably lower, at 1.41±0.4. Between 100 and 400 µmol photons m^2 s PAR, the LRUs increased to 1.81±0.3 and 1.69±0.5 for the upper and middle canopy layers, respectively, while decreasing to 1.43±0.2 and 1.19±0.2 in the lower parts of *Pinus sylvestris* and *Juniperus communis*, respectively. This decrease in LRU deeper within the canopy is attributed to a greater reduction in COS compared to CO^2 deposition velocity of the leaves. The median LRU above 800 µmol photons m^2 s PAR, based on classical daytime flux partitioning for the summer month of 2022, was 2.5±0.7, indicating the need for further investigation into the observed discrepancy in LRU.