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Insights from concurrent in situ measurements of sun-induced fluorescence and eddy covariance CO_2 and COS fluxes in two contrasting European ecosystems.

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Terrestrial gross photosynthetic uptake (GPP) is the largest carbon dioxide (CO_2) flux in the global carbon cycle and has a pivotal importance in offsetting the anthropogenic emission of this greenhouse gas and mitigating the resulting global warming. Therefore, quantitative understanding of GPP and its response to environmental variables is critical for understanding the feedbacks of ecosystems to the changing climate. However, it is a particularly difficult challenge for the environmental scientific community as GPP cannot be measured directly, and can only be estimated via flux partitioning of eddy covariance (EC) measurements of net ecosystem exchange (NEE). Such conceptual and methodological difficulties result in significant uncertainties when modeling future greenhouse gas forcing and climate change. For this reason, adding scale-appropriate extra-information on flux partitioning and canopy physiological status is crucial for constraining carbon cycle models.

In this contribution, we focus on two novel tracers for inferring ecosystem-scale GPP, i.e. carbonyl sulfide (COS) and sun-induced fluorescence (SIF), respectively. COS has been proposed as an alternative tracer for GPP as it shares a similar diffusion pathway with CO_2 into the leaf, but while the latter can be respired back to the atmosphere, COS is irreversibly converted by the enzyme carbonic anhydrase. The principle underlying the use of SIF as a tracer of GPP is based on the fact that the light energy absorbed by chlorophyll molecules can can proceed into three different pathways: photochemistry, heat loss, and chlorophyll fluorescence. Since these processes directly compete for the excitation energy, measurements of SIF and non-photochemical quenching (NPQ) can provide information on photosynthetic performance.

To address the challenge of providing new independent constraints on GPP we conducted concurrent ecosystem-scale EC-COS and SIF measurements at two contrasting ecosystems: a temperate mountain grassland in Austria and a Mediterranean tree-grass ecosystem in Spain, in which EC and optical measurements were accompanied with active chlorophyll fluorescence measurements. Due to the complex structure of the Spanish site, the CO_2 and COS fluxes were partitioned with a subcanopy and an above canopy EC tower. Similarly, an additional tower for optical measurements equipped with a rotating arm allowed alternating observations of the tree and grass layer.

In the non-stressed grassland site the seasonal patterns of GPP, COS fluxes and SIF were mainly driven by changes in absorbed photosynthetically active radiation (APAR) and grassland management. In the Mediterranean tree-grass ecosystem COS and CO_2 fluxes along with SIF decoupled from APAR, which was relatively constant during the measurement campaign, in response to physiological reactions resulting from low soil water content and high evaporative demand and air temperatures.