Geophysical Research Abstracts
Vol. 21, EGU2019-3283-1, 2019
EGU General Assembly 2019

An optimization approach to partitioning eddy covariance water flux components

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Partitioning evapotranspiration (ET) into its constitutive components is essential for linking plant-water use (T) and carbon assimilation (GPP) interactions to environmental variability. In this contribution we present a new approach for partitioning eddy covariance (EC) ET measurements based on model-data integration. The method enables FLUXNET data users to partitioning ET fluxes as well as to deriving relevant ecosystem functional properties. The algorithm was successfully evaluated against independent data collected with lysimeter measurements and benchmarked with other existing state of the art micrometeorological approaches.
Firstly, an optimal "internal" leaf-to-ambient CO_2 concentration (χ) – a key aspect of plant-water use efficiency (WUE; defined as GPP/T) – was predicted theoretically in the light of stomatal optimality theory. Within a big-leaf representation accounting for the influence of boundary layer conductance, estimated χ provided a means to investigate stomatal behavior (gs) in accordance with the EC GPP estimates. With the objective of accounting for the coordinated effect of soil moisture on χ and gs, a novel optimization approach was implemented to develop solutions for an optimal gs model that maximizes WUE. The gs model offered the backbone on which optimal T estimates were derived. The evaporation from soil and/or other wet surfaces (Es) was then calculated as a residual between the observed ET and modeled T. The proposed method was applied to long-term EC measurements collected above a Mediterranean tree-grass ecosystem.
Estimated Es agreed with independent lysimeter measurements during the dry periods when evaporation from rainfall or dewfall interception are neglected (MAE = 0.49 mmol m-2 s-1, slope = 0.95, r = 0.69). They also agreed with other partitioning methods derived from similarity theory and conditional sampling applied to turbulence measurements, which appeared to be highly sensitive to different χ parameterization schemes. In particular, we showed that T was overestimated by 30% when χ was assumed constant. A surprising result was the large contribution of Es to the total ET during the wet period (approx. 70%), as well as the dry period (approx. 40%). Our results confirmed that a first-principle representation of χ provides a means for predicting T in the absence of water stress. However, a seasonal χ pattern was characterized in response to soil dryness. Therefore, further theoretical frameworks detailing the interplay of χ and gs in carbon assimilation for conditions with varying water availability are required in dynamic ecosystem models, which make exciting future inquiry. The robustness of the results provides a new perspective on ET partitioning of EC fluxes and can be utilized across a wide range of climates and biomes.