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Estimating transpiration and the sensitivity of carbon uptake to water availability in a subalpine forest using a simple ecosystem process model informed by measured net CO_2 and H_2O fluxes.

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Modeling how the role of forests in the carbon cycle will respond to predicted changes in water availability hinges on an understanding of the processes controlling water use in ecosystems. Recent studies in forest ecosystem modeling have employed data assimilation techniques to generate parameter sets that conform to observations, and predict net ecosystem CO_2 exchange (NEE) and its component processes. Since the carbon and water cycles are linked, there should be additional process information available from ecosystem H_2O exchange. We coupled SIPNET (Simple Photosynthesis EvapoTranspiration), a simplified model of ecosystem function, with a data assimilation system to estimate parameters leading to model predictions most closely matching the net CO_2 and H_2O fluxes measured by eddy covariance in a high-elevation, subalpine forest ecosystem. When optimized using measurements of CO_2 exchange, the model matched observed NEE (RME = 0.4934 g C m^{-2}) but underestimated transpiration calculated independently from sap flow measurements by a factor of 4. Consequently, the carbon-only optimization was insensitive to imposed changes in water availability. Including eddy flux data from both CO_2 and H_2O exchange to the optimization reduced the model fit to the observed NEE fluxes only slightly (RME = 0.5259 g C m^{-2}), however this parameterization also reproduced transpiration calculated from independent sap flow measurements (r^2 =0.67, slope =0.6). A significant amount of information can be extracted from simultaneous analysis of CO_2 and H_2O exchange, which improved the accuracy of transpiration estimates from measured evapotranspiration. Conversely, failure to include both CO_2 and H_2O data streams can generate results that mask the responses of ecosystem carbon cycling to variation in the precipitation. In applying the model conditioned on both CO_2 and H_2O fluxes to the subalpine forest at the Niwot Ridge AmeriFlux site, we observed that the onset of transpiration is coincident with warm soil temperatures. However, after snow has covered the ground in the fall, we observed significant interannual variability in the fraction of evapotranspiration that is reflected in transpiration; evapotranspiration was dominated by transpiration in years when late fall air temperatures were high enough to maintain photosynthesis, but by sublimation from the surface of the snowpack in years when late fall air temperatures were colder and forest photosynthetic activity had ceased. Data assimilation techniques and simultaneous measurements of carbon and water exchange can be used to quantify the response of net carbon uptake to changes in water availability by using an ecosystem model where the carbon and water cycles are linked.