Water-use efficiency (WUE), the linkage of the terrestrial water and carbon cycles, is largely under the physiological control of stomata. Knowledge of stomatal behavior is commonly gained from leaf-level gas exchange measurements, which are inevitably restricted in their spatial and temporal coverage. Flux measurements based on the eddy covariance (EC) technique can overcome these limitations, as they provide continuous and long-term records of carbon and water fluxes at the ecosystem scale. However, vegetation gas exchange parameters derived from EC data are subject to scale-dependent and method-specific uncertainties that compromise their eco-physiological interpretation as well as their comparability among ecosystems and across spatial scales.

We use estimates of canopy conductance and gross primary productivity (GPP) derived from EC data to calculate a measure of intrinsic WUE ($g_1$,”stomatal slope”) at the ecosystem level at six sites comprising tropical, Mediterranean, temperate, and boreal forests. We assess the following six mechanisms potentially causing discrepancies between leaf and ecosystem-level estimates of $g_1$: 1) non-transpirational water fluxes; 2) aerodynamic conductance; 3) meteorological deviations between measurement height and canopy surface; 4) energy balance non-closure; 5) uncertainties in NEE partitioning; and 6) physiological within-canopy gradients.

Our results demonstrate that an unclosed energy balance caused the largest uncertainties, in particular if it was associated with erroneous latent heat flux estimates. The effect of aerodynamic conductance on $g_1$ was sufficiently captured with a simple representation. $g_1$ was found to be less sensitive to meteorological deviations between canopy surface and measurement height and, given that data are appropriately filtered, to non-transpirational water fluxes. $g_1$ calculated based on GPP derived from the two main NEE partitioning approaches agreed well. The results
highlight the importance of adequately considering the sources of uncertainty outlined here when EC-derived WUE is interpreted in an eco-physiological context.