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Explaining spatial patterns of sap flow: day-to-day shifts in relevance of site- and tree-specific controls

Sibylle K. Hassler (1), Markus Weiler (2), and Theresa Blume (1)
(1) Helmholtz Centre Potsdam GFZ, 5.4, Potsdam, Germany, (2) Albert-Ludwigs-University of Freiburg, Freiburg, Germany

Transpiration is a key process in the hydrological cycle and a sound understanding and quantification of transpiration is essential for management decisions and for hydrological and climatological modelling. To assess transpiration at the tree scale sap flow velocity is commonly measured. Besides atmospheric conditions and soil moisture state, tree-specific characteristics such as species, size or social status control sap flow of individual trees. Within forest stands, properties such as species composition, basal area or stem number also affect sap flow via competition or facilitation mechanisms. Finally, sap flow patterns might also be influenced by landscape-scale characteristics such as geology, slope position or aspect because they affect water and energy availability; however, so far little is known about these larger-scale controls.
We studied the relative importance of various tree- and site-specific characteristics with linear statistical models for daily sap velocity observations on 38 trees at 12 locations in mixed beech and oak forests in a catchment in Luxemburg. The temporal variation of the predictors' importance for sap velocity patterns was then related to hydro-meteorological conditions. Results indicate that a combination of tree- and site-specific controls influence sap velocity patterns, namely tree species, tree diameter, stand basal area, geology and aspect. The temporal dynamics of these controls are related to hydro-meteorological conditions, with tree-specific controls dominating when the atmospheric gradient is strong, i.e. the vapour pressure deficit is large, leading to higher sap velocities, whereas landscape-scale site characteristics are more important during weak atmospheric gradients. The importance of individual predictors also varies between spring and summer, probably due to different soil moisture and atmospheric conditions of the two periods. We conclude that both tree- and site-specific characteristics control sap velocity patterns and the temporal dynamics of their importance is dependent on hydro-meteorological conditions. Thus, transpiration estimates at the landscape scale should on the one hand consider hydro-meteorological conditions and tree characteristics, but on the other hand should also include site characteristics such as geology and aspect in order to improve the spatial representation and prediction of hydrological processes.