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Scale effects on the controls on mountain grassland leaf stomatal and ecosystem surface conductance to water vapour

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Stomata are the major pathway by which plants exert control on the exchange of trace gases and water vapour with the aerial environment and thus provide a key link between the functioning of terrestrial ecosystems and the state and composition of the atmosphere. Understanding the nature of this control, i.e. how stomatal conductance differs between plant species and ecosystems and how it varies in response to external and internal forcings, is key to predicting feedbacks plants may be providing to changing climatic conditions.

Despite a long history of research on stomatal functioning, a fully mechanistic understanding of how stomata function in response to biotic and abiotic controls is still elusive which has led to the development of a large number of (semi-)empirical models of varying complexity. Two of the most widely used models go back to Jarvis (1976) and Ball, Woodrow and Berry (1987), termed J-model and BWB-model, respectively, in the following. The J-model simulates stomatal conductance as some maximal value attenuated by a series of multiplicative functions which are bound between zero and unity, while the BWB-model predicts stomatal conductance as a linear function of photosynthesis, relative humidity and carbon dioxide concentration in the leaf boundary layer. Both models were developed for the prediction of leaf-scale stomatal conductance to water vapour, but have been applied for simulating ecosystem-scale surface conductance as well.

The objective of the present paper is to compare leaf- and ecosystem-scale conductances to water vapour and to assess the respective controls using the two above-mentioned models as analysis frameworks. To this end leaf-level stomatal conductance has been measured by means of leaf-gas exchange methods and ecosystem-scale surface conductance by inverting eddy covariance evapotranspiration estimates at a mountain grassland site in Austria.

Our major findings are that the proportionality parameter in the BWB-model is scale-consistent, i.e. does not differ significantly between the leaf- and ecosystem scale, while the residual conductance (at zero light) scales with the amount of above-ground transpiring plant area. Among the environmental forcings, air humidity (either relative humidity or vapour pressure deficit) and carbon dioxide concentration in the boundary layer explained most of the variability of stomatal conductance at the leaf level, while the photosynthetic photon flux density was by far the dominant control at the ecosystem-level.

References:

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