A synthesis of a global stomatal conductance database under an optimal stomatal behaviour framework: patterns from leaf to ecosystem

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Abstract: Stomatal conductance (g_s) is a key land surface attribute as it links transpiration, the dominant component of global land evapotranspiration and a key element of the global water cycle, and photosynthesis, the driving force of the global carbon cycle. Despite the pivotal role of g_s in predictions of global water and carbon cycles, a global scale database and an associated globally applicable model of g_s that allow predictions of stomatal behaviour are lacking. We present a unique database of globally distributed g_s obtained in the field for a wide range of plant functional types (PFTs) and biomes. We employed a model of optimal stomatal conductance to assess differences in stomatal behaviour, and estimated the model slope coefficient, g_1, which is directly related to the marginal carbon cost of water, for each dataset. We found that g1 varies considerably among PFTs, with evergreen savanna trees having the largest g_1 (least conservative water use), followed by C_3 grasses and crops, angiosperm trees, gymnosperm trees, and C_4 grasses. Amongst angiosperm trees, species with higher wood density had a higher marginal carbon cost of water, as predicted by the theory underpinning the optimal stomatal model. There was an interactive effect between temperature and moisture availability on g_1: for wet environments, g_1 was largest in high temperature environments, indicated by high mean annual temperature during the period when temperature above 0^oC (T_m), but it did not vary with T_m across dry environments. We examine whether these differences in leaf-scale behaviour are reflected in ecosystem-scale differences in water-use efficiency using eddy flux data set around the world. These findings provide a robust theoretical framework for understanding and predicting the behaviour of stomatal conductance across biomes and across PFTs that can be applied to multi-scale modelling of productivity and ecohydrological processes in a future changing climate in Australia and in the world.

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