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Quantifying the difference between GCM land surface responses using Water Use Efficiency

M. Groenendijk (1,2), B. B. B. Booth (2), F. H. Lambert (1), P. M. Cox (1), and C. Huntingford (3)

(1) University of Exeter, College of Engineering, Mathematics and Physical Sciences, United Kingdom, (2) Met Office Hadley Centre, Exeter, UK, (3) Centre for Ecology and Hydrology, Wallingford, UK

The Water Use Efficiency (WUE) controls the relationship between the ecosystem water and carbon balance. Because WUE responds to environmental changes it can be used as a metric to quantify the effect of climate change on ecosystems, improving the understanding of vegetation responses to climate variables. When the variation of WUE is known, the photosynthesis can be constrained with the hydrological cycle or vice versa.

The ecosystem WUE_{eco} is the ratio of gross primary production and evapotranspiration fluxes. On the leaf scale this is equal to the atmospheric WUE_{atm}, which is a function of the ambient and internal CO_2 concentration, the saturated specific humidity and relative humidity. Using FLUXNET observations and the JULES, IMOGEN and HadCM3 models we explore on which temporal and spatial scales WUE_{eco} and WUE_{atm} are equal, and how they respond to climate change.

WUE values derived from FLUXNET and the different models are within the same range. The relationship between WUE_{eco} and WUE_{atm} from FLUXNET observations is consistent when site average values are used. Annual and monthly values are influenced by seasonal and inter annual variations, which are not directly related to the variables in the used WUE formula. WUE_{eco} and WUE_{atm} diverge mainly during periods of low biological productivity. The global spatial pattern of WUE_{eco} and WUE_{atm} from HadCM3 shows a similar divergence. For the tropical and temperate latitudes the spatial patterns of WUE_{eco} and WUE_{atm} are comparable. The main difference occurs at the northern latitudes, where average annual saturated specific humidity is biased because of low temperatures in winter. This can be improved by selecting data during the growing season only.

Using the HadCM3 QUMP ensemble we can quantify uncertainties in WUE related to uncertainties in parameterised GCM physics. Our results suggest that the variation in WUE can be explained by intermodel differences in simulated atmospheric variables on a large range of scales. The slope of the relationship between WUE_{eco} and WUE_{atm} is a function of atmospheric model parameters, while the intercept is a function of the vegetation carbon storage, which is dependent on the land surface model parameters. This indicates that the water use efficiency can provide valuable information about the interaction between the land surface and the atmosphere in a changing climate.