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Modelling long-term responses of vegetation water use to elevated atmospheric CO_2

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Vegetation has different degrees of freedom for adaptation to its environment. Examples include stomatal conductance at short time scale (minutes), leaf area index and fine root distributions at longer time scales (days-months) and species composition and dominant growth forms at very long time scales (years-centuries). As a result, the overall response of evapotranspiration to changes in environmental forcing may also change at different time scales. The effect of elevated atmospheric CO_2 concentrations (eCO_2) on evapotranspiration is an example for different response patterns at different temporal and spatial scales. At the leaf scale, eCO_2 can induce stomatal closure and reduced transpiration. This effect was incorporated in global models and held responsible for an observed increase in river runoff during the past century. However, stomatal closure is not the only means by which vegetation responds to eCO_2. If, for example, stomatal closure is offset by an increase in vegetation cover in the long term, the effect of eCO_2 on global transpiration could, in fact, be reversed. Long-term effects of eCO_2 are difficult to capture in experiments or to deduce from past observations, because experiments are relatively short and the CO_2 levels expected in 20 years time have never been observed in the past. Instead, predictions of such long-term effects can be derived from models that do not simply extrapolate observed responses into the future. The Vegetation Optimality Model (VOM) allows separation of different scales of adaptation, without the need for parameterisation with observed responses. This frees up observational and experimental data for model testing and could allow predictions about vegetation response at time scales beyond those of free air CO_2 enrichment experiments. This paper discusses model predictions of the eCO_2 effects on vegetation at different temporal scales and puts them in context with experimental evidence from free air CO_2 enrichment experiments.