Application of an optimality-based model to operate at half-hourly timestep to implement plant acclimation within a land-surface modelling framework

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Vegetation and atmosphere are linked through the perpetual exchange of water, carbon and energy. An accurate representation of the processes involved in these exchanges is crucial in forecasting Earth system states. Although vegetation has become an undisputed key component in land-surface modelling (LSMs), the current generation of models differ in terms of how key processes are formulated. Plant processes react to environmental changes on multiple time scales. Here we differentiate a fast (minutes) and a slower (acclimated – weeks to months) response. Some current LSMs include plant acclimation, even though they require additional parameters to represent this response, but the majority of them represent only the fast response and assume that this also applies at longer time scales. Ignoring acclimation in this way could be the cause of inconsistent future projections. Our proposition is to include plant acclimation in a LSM schema, without having to include new plant-functional-type-dependent parameters. This is possible by using an alternative model development strategy based on eco-evolutionary theory, which explicitly predicts the acclimation of photosynthetic capacities and stomatal behaviour to environmental variations. So far, this theory has been tested only at weekly to monthly timescales. Here we develop and test an approach to apply an existing optimality-based model of gross primary production (GPP), the P model, at the sub-daily timestep necessary for use in an LSM, making an explicit differentiation between the fast and slow responses of photosynthesis and stomatal conductance. We test model performance in reproducing the diurnal cycle of GPP as recorded by flux tower measurements across different biomes, including boreal and tropical forests. The extended model requires only a few meteorological inputs, and a satellite-derived product for leaf area index or green vegetation cover. It is able to manage both timescales of acclimation without PFT-dependent photosynthetic parameters and has shown to operate with very good performance at all sites so far investigated. The model structure avoids the need to store past climate and vegetation states. These findings therefore suggest a simple way to include...
both instantaneous and acclimated responses within a LSM framework, and to do so in a robust way that does not require the specification of multiple parameters for different plant functional types.