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Predicting Forest Gross Primary Productivity and Leaf Area Index by Coupling Light Use Efficiency and Leaf Phenology in a Parsimonious Canopy Model

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Temperate forest ecosystems play a crucial role in governing global carbon and water cycles, that are both sensitive to global warming due to its various effects on the functionality of the forest ecosystems. The total carbon uptake of ecosystems by photosynthesis (GPP) is the largest flux between the land and the atmosphere within the carbon cycle. GPP quantification has thus a direct consequence on carbon budget estimations. However, this carbon flux has one of the largest uncertainties for estimates of the global carbon cycle. Similarly, for the water cycle a prognostic simulated vegetation leaf area index (LAI) would substantially improve representation of the water cycle components in hydrological models (e.g., evapotranspiration), while GPP predictions would benefit from simulated soil water storage. Those two key variables can be estimated using the light use efficiency concept, total carbon uptake by plants (GPP), and partly allocation of that to the leaves carbon pool. Although many models have been successfully developed to estimate GPP, they either use satellite-based LAI/fPAR (fraction of photosynthetically active radiation) data which are subjected to uncertainty and/or the level of the model complexity (when LAI is also simulated) prohibits their integration into hydrologic models. In this study, we develop a parsimonious forest canopy model to simulate the daily development of both GPP and LAI, while ensuring adequate level of complexity to be coupled into hydrological models. We test the model on deciduous broad-leafed forest sites located in Europe and North America selected from the FLUXNET network. A mass balance approach, the difference between daily carbon uptake and carbon loss in the plant canopy pool, is used to calculate daily leaf biomass. The model consists of several sub-models including routines for the estimation of soil hydraulic parameters based on pedotransfer functions, vertically weighted soil moisture considering the underground root distribution, phenology, and leaf litter generation. We analyze the model parameter sensitivity on the resulting carbon flux dynamics (GPP) and stock (leave pool). The model performance is evaluated in a validation period against in-situ measurements of GPP and LAI. Finally, we test the cross-location transferability of model parameters and derive a compromise parameter set to be used across sites. We identified on average 10 sensitive parameters for the

model at each study site (e.g., LUE, SLA, etc). The model adequately captures the daily dynamics of observed GPP and LAI at each study site (e.g., with KGE (Kling-Gupta-Efficiency) values varying between 0.79 and 0.92). It also shows reasonable performance regarding a compromise single set of parameters obtained from the model transferability assessment with a slight loss in model skill. In this presentation, we discuss on the suitability of the model structure and important observations made during the investigation. The model will be implemented into the existing mesoscale Hydrologic Model (mHM) in order to improve representation of water and carbon cycle components.