Belowground processes in Terrestrial Biosphere Models, the forgotten half

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Drought stress is an important threat for plants in tropical forests, especially in the context of human-induced increase of drought frequency and severity observed in regions like the Amazon basin. Terrestrial Biosphere Models are key tools to predict the future of tropical ecosystems as they allow estimating the resilience of ecosystems by simulating various future scenarios. Previous vegetation model runs have suggested a complete dieback of the Amazon or a rapid transition towards Savannah-like ecosystems because of increasing drought frequency while others have forecasted an overall greenup due to fertilization. A part of the discrepancy between those predictions stems from the representation of below-ground processes that substantially differ between models. How sensitive those models are to soil parameters and below-ground processes has been only sporadically addressed to this date, while answering this question is critical to make reliable predictions.

In this study, we compared the sensitivities of three state-of-the-art Terrestrial Biosphere Models, namely ORCHIDEE (big-leaf), ED2 (cohort-based), and LPJ-GUESS (individually-based) to the variability in soil properties over the Amazon. These three models are representative of the existing range of vegetation models but differ in their representation of the rooting system, the soil hydraulic properties and the plant below-ground functioning. We ran multiple model simulations with different soil maps and compared how the growth primary productivity, evapotranspiration and drought stress simulated by each model varied with soil properties. Those soil maps were derived from Soilgrids by retaining the most frequent soil class for each simulated pixel, or the one with the lowest or the highest clay content. The analysis revealed that all three models were weakly sensitive to soil texture, making clear that Terrestrial Biosphere Models require a better representation of below-ground processes in order to accurately simulate drought stress and water competition.