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How well do we characterize the biophysical effects of vegetation cover change? Benchmarking land surface models against satellite observations.

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Changes in vegetation cover can affect the climate by altering the carbon, water and energy cycles. The main tools to characterize such land-climate interactions for both the past and future are land surface models (LSMs) that can be embedded in larger Earth System models (ESMs). While such models have long been used to characterize the biogeochemical effects of vegetation cover change, their capacity to model biophysical effects accurately across the globe remains unclear due to the complexity of the phenomena. The result of competing biophysical processes on the surface energy balance varies spatially and seasonally, and can lead to warming or cooling depending on the specific vegetation change and on the background climate (e.g. presence of snow or soil moisture).

Here we present a global scale benchmarking exercise of four of the most commonly used LSMs (JULES, ORCHIDEE, JSBACH and CLM) against a dedicated dataset of satellite observations. To facilitate the understanding of the causes that lead to discrepancies between simulated and observed data, we focus on pure transitions amongst major plant functional types (PFTs): from different tree types (evergreen broadleaf trees, deciduous broadleaf trees and needleleaf trees) to either grasslands or crops. From the modelling perspective, this entails generating a separate simulation for each PFT in which all 1° by 1° grid cells are uniformly covered with that PFT, and then analysing the differences amongst them in terms of resulting biophysical variables (e.g net radiation, latent and sensible heat). From the satellite perspective, the effect of pure transitions is obtained by unmixing the signal of different 0.05° spatial resolution MODIS products (albedo, latent heat, upwelling longwave radiation) over a local moving window using PFT maps derived from the ESA Climate Change Initiative land cover map. After aggregating to a common spatial support, the observation and model-driven datasets are confronted and analysed across different climate zones.

Results indicate that models tend to catch better radiative than non-radiative energy fluxes. However, for various vegetation transitions, models do not agree amongst themselves on the magnitude nor the sign of the change. In particular, predicting the impact of land cover change on the partitioning of the available energy between latent and sensible heat proves to be a challenging task for vegetation models. We expect that this benchmarking exercise will shed a light on where to prioritize the efforts in model development as well as inform where consensus between model and observations is already met. Improving the robustness and consistency of land-model is essential to develop and inform land-based mitigation and adaptation policies that account for both biogeochemical and biophysical vegetation impacts on climate.