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Evaluating the vegetation-atmosphere coupling strength of ORCHIDEE land surface model

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Plant transpiration plays a central role in regulating water cycle and land surface energy budget. Correctly representing the controls of such processes in Earth system models is thus critical to accurately project future climate. Transpiration is controlled by physiological processes of stomatal regulation in response to water and temperature stress, and by canopy structure through the aerodynamic transport of water vapor in the boundary layer from leaves to the atmosphere. The strength of the vegetation coupling to the atmosphere can be summarized by a decoupling coefficient Ω. A value of Ω of 0 implies a strong coupling, leaving a dominant role to stomatal conductance in regulating H2O and CO2 fluxes, while Ω of 1 implies a complete decoupling of leaves from the atmosphere, that is, the transfer of H2O and CO2 is limited by aerodynamic transport. In this study, we investigate how well the state-of-the-art land surface model, ORCHIDEE, simulates the decoupling of vegetation to atmosphere using observation-based empirical daily estimates of Ω at 106 FLUXNET sites. We also tested whether calibration of parameters controlling the dependence of the stomatal conductance to the water vapor deficit (VPD), or using observation based canopy height improves the simulated Ω. A set of random forest models were built to further investigate the impacts of different factors on Ω. Our results show that Ω is underestimated by ORCHIDEE (0.20) compared with the observation-based estimates (0.28), and that the calibration of stomatal conductance parameters improved the simulated Ω (0.24). Nevertheless, the bias of simulated Ω remains large in grasslands and croplands after the calibration. We also found that in observation vegetation tends to be more decoupled to atmosphere when there is low wind speed, high temperature, low VPD, large leaf area index (LAI) and in short vegetation. ORCHIDEE generally agrees with this pattern but underestimated the VPD impact when VPD is high, overestimated the contribution of LAI and did not correctly simulate the temperature dependence when temperature is high. Canopy height does not show strong direct impact on Ω. Our results highlight the importance of observational constraints on simulating the vegetation-atmosphere coupling strength, which can help improve the predictive accuracy of water fluxes in Earth system models.