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Climate sensitivity to atmospheric CO2 concentrations with optimally adapted vegetation

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Terrestrial vegetation is an important component of the climate system. Vegetation, through its form and functioning, affects the exchange fluxes of energy and mass at the land surface and the overlying atmosphere. It is unique in its ability to adapt to its climatic environment at the individual plant scale and through changes in ecosystem composition. This adds many degrees of freedom and flexibility to land surface, enabling the exchange fluxes of energy and mass to be partitioned in many different ways. This implies that the energy and mass balances do not determine but only act to constrain and the emergent state of the climate-vegetation system. We hypothesize that the most probable steady state of the climate-vegetation system is one at which terrestrial vegetation is optimally adapted in such a way that it maximizes its productivity. Earlier studies have shown optimal adaptation and maximum productivity are consistent with the general principle of Maximum Entropy Production. Optimal values for properties such as maximum stomatal conductance, root-shoot partitioning, and canopy roughness at which productivity is maximized should exist because all of these properties affect the relative availability of incoming light, water, and carbon necessary for photosynthesis. As climatic conditions change, altering the relative importance of light versus water/carbon, the optimum values of vegetation properties for maximum productivity are likely to shift. Ignoring these shifts in optimality will likely lead to an underestimation of terrestrial productivity under global change scenarios and may result in biases in the simulated vegetation feedbacks to climatic change. In this study, we quantify the magnitude of this bias in climate sensitivity to change and its impacts on terrestrial productivity by conducting sensitivity simulations and vegetation optimizations for different atmospheric CO2 concentrations. We apply the concept of optimal adaptation to the parameterization of several vegetation properties in Planet Simulator, a coupled dynamic vegetation-climate system model. We maxi-

mize simulated productivity for the present-day climate by optimizing the parameter values jointly at each grid cell. The optimizations are repeated for two scenarios of global change representing the last glacial maximum and a doubling of atmospheric CO2. The results of these optimizations are then compared to simulations where the vegetation parameters are held static at the present-day optimum values. This will allow us to quantify the degree to which terrestrial productivity is underestimated when vegetation properties remain static compared to those reflecting optimal adaptation to new conditions and the associated climatic impacts.