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The Limits of Acclimation of land plants in a Terrestrial Ecosystems Model

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In this study, we examine the role of the terrestrial carbon cycle and the ability of different plant types to acclimate to a changing climate at the centennial scale using a global ecosystems model with updated biogeochemical processes related to moisture, carbon, and nitrogen. Elevated level of atmospheric carbon dioxide (CO_2) increases CO_2 fertilization, resulting in more CO_2 uptake by vegetation, whereas the concomitant warming increases autotrophic and heterotrophic respiration, releasing CO_2 to the atmosphere. Additionally, warming will enhance photosynthesis if current temperatures are below the optimal temperature for plant growth, while it will reduce photosynthesis if current temperatures are above the optimal temperature for plant growth.

We present a series of ensemble simulations to evaluate the ability of plants to acclimate to changing conditions over the last century and how this affects the terrestrial carbon sink. A set of experiments related to (a) the varying relationship between CO_2 fertilization and the half saturation constant, (b) the factors related to gross primary productivity and maintenance respiration, and (c) the variables related to heterotrophic respiration, were conducted with thirteen plant functional types. The experiments were performed using the Terrestrial Ecosystem Model (TEM) with a present-day vegetation distribution without the effects of natural or human disturbance, and a closed Nitrogen cycle, at a half-degree resolution over the globe.

The experiment design consisted of eight scenarios that are consistent with past and future ecosystem conditions, presented in other scientific studies. The significance of model trends related to runoff, soil moisture, soil carbon, Net Primary Productivity (NPP), crop yield, and Net Ecosystem Productivity (NEP) for different seasons, as well as surface temperature, precipitation, vapor pressure, and photosynthetically active radiation are analyzed for various ecosystems at the global and regional scale. We find that cause and effect relations between pairs of dependent variables cannot be treated in isolation, as their mutual dependence on other variables controls their interaction. Magnitudes and directions of some historical trends are projected to change in response to climate forcing. Our results reveal that some model variables are not well constrained in projections, yet they control the responses of other variables that are more tightly constrained. As such, it may be possible in the future to use the more reliably projected variables as proxies for those that are less reliable.