Characterization of the impacts of the physiological response of vegetation to increasing levels of atmospheric carbon dioxide

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Abstract:

Increasing atmospheric carbon dioxide (CO_2) directly affects plant physiology. Using a coupled land-atmosphere model, multiple simulations have been conducted to examine the impact of the physiological response of vegetation to varying levels of CO_2 near the leaf surface. Results showed that the impact of increased CO_2 on stomatal conductance generally led to statistically significant changes in latent heat flux (LHF), temperature, and rainfall, at global to regional scales. The CO_2-induced reduction in stomatal conductance decreased LHF from the surface, resulting in warming over large areas. The coupling of the physiological response to elevated CO_2 and moisture availability was evident in simulations over Australia in summer. The influences of seasonality and moisture availability on the physiological response varied according to vegetation type where the influences are stronger over grass and shrubs than forests. Probability density functions (PDF) of the regional LHF and temperature indicated the non-uniform effects of the physiological response to increased CO_2, with a higher sensitivity at the upper tails of the distribution. The shift of the PDF towards lower values for LHF and towards higher values for temperature suggest that the physiological response increases the probability of higher temperature or sustains the high temperatures for a longer period, when evaporation is unlimited under high net radiation. The anomalous warming over the Murray-Darling Basin in 2002 was also investigated and was found to be unlikely caused by the physiological effect of CO_2.

The robustness of the results and their general agreement with the literature indicate that the physiological forcing requires further examination in observations and numerical experiments. The small physiological impact of increased CO_2 from pre-industrial to present day levels suggests that the exclusion of the physiological response likely does not significantly affect historical climate change assessments. However, the increase in magnitude and areal extent of the changes in climate accompanying higher levels of CO_2 underlines the need for the physiological response to be included in future climate projections to avoid underestimating the scale of future regional climate change.