On constraining the strength of the terrestrial CO_2 fertilization effect in an Earth system model

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Earth system models (ESMs) explicitly simulate the interactions between the physical climate system components and biogeochemical cycles. Physical and biogeochemical aspects of ESMs are routinely compared against their observation-based counterparts to assess model performance and to evaluate how this performance is affected by ongoing model development. Here, we assess the performance of version 4.2 of the Canadian Earth system model against four, land carbon cycle focused, observation-based determinants of the global carbon cycle and the historical global carbon budget over the 1850-2005 period. Our objective is to constrain the strength of the terrestrial CO_2 fertilization effect which is known to be the most uncertain of all carbon cycle feedbacks. The observation-based determinants include (1) globally-averaged atmospheric CO_2 concentration, (2) cumulative atmosphere-land CO_2 flux, (3) atmosphere-land CO_2 flux for the decades of 1960s, 1970s, 1980s, 1990s and 2000s and (4) the amplitude of the globally-averaged annual CO_2 cycle and its increase over the 1980 to 2005 period. The optimal simulation that satisfies constraints imposed by the first three determinants yields a net primary productivity (NPP) increase from ~ 58 Pg C yr^{-1} in 1850 to about ~ 74 Pg C yr^{-1} in 2005; an increase of ~ 27 % over the 1850-2005 period. The simulated loss in the global soil carbon amount due to anthropogenic land use change over the historical period is also broadly consistent with empirical estimates. Yet, it remains possible that these determinants of the global carbon cycle are insufficient to adequately constrain the historical carbon budget, and consequently the strength of terrestrial CO_2 fertilization effect as it is represented in the model, given the large uncertainty associated with LUC emissions over the historical period.

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