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The linearity between global warming and cumulative CO_2 emissions: examining the effect of ocean mixing, heat, and carbon fluxes

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The ratio between global mean temperature change and cumulative emissions is known as Transient Climate Response to cumulative Emissions (TCRE). The TCRE has been shown to be approximately constant over a wide range of cumulative CO_2 emissions. Therefore, it can potentially be useful for estimating the total allowable amount of emissions for a certain warming target. Additionally, by combining both physical and biogeochemical uncertainties of climate models, the TCRE is a valuable benchmark for model inter-comparison. However, as models include different processes, the TCRE differs notably between models and the underlying processes for the constancy of the TCRE are still not well understood. Ocean heat and carbon flux and their governance by similar mechanisms have been suggested as an explanation for the constancy of the TCRE. This hypothesis is questionable, as it does not take into account land carbon uptake that in turn affects atmospheric CO_2 levels and temperature. In this study the role of ocean heat and carbon uptake in the constancy of the TCRE is explored but also the role of land carbon uptake is considered. A climate model of intermediate complexity is used: the University of Victoria Earth System Climate Model (UVic ESCM). The model has a 3-dimensional, dynamic ocean, which is coupled to a sea-ice model, and a simple 1-dimensional atmosphere. Furthermore, it contains a land-surface scheme coupled to a dynamic vegetation model. All model parts include a carbon cycle. Simulations are conducted under varying ocean mixing parameterizations, an important source of uncertainty in climate models. Differences in ocean mixing alter ocean heat and carbon fluxes, which in turn affect the TCRE. The relationship between global mean temperature change and cumulative emissions remains linear within a mixing setting over the range of mixing parameter values and parameterization schemes used in this study. However, TCRE values vary between different ocean mixing settings. If land carbon fluxes are not taken into account, the TCRE deviates more strongly from constant values.