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The origin and limits of the near proportionality between transient climate warming and cumulative CO_2 emissions

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The transient climate response to cumulative CO_2 emissions (TCRE) is a useful metric of climate warming that directly relates the cause of climate change (cumulative carbon emissions) to the most used index of climate change (global mean near surface temperature change). In this presentation analytical reasoning is used to investigate why TCRE is near constant over a range of cumulative emissions up to 2000 Pg of carbon. In addition, a climate model of intermediate complexity, forced with linear emissions of CO_2, is used to explore the effect of the terrestrial carbon cycle feedback strength on TCRE. The analysis reveals that TCRE emerges from the diminishing radiative forcing from CO_2 per unit mass being compensated for by the diminishing ability of the ocean to take up heat and carbon. The relationship is maintained as long as the ocean uptake of carbon, which is simulated to be a function of CO_2 emissions rate, dominates changes in the airborne fraction of carbon. Strong terrestrial carbon cycle feedbacks have a dependence on the rate of carbon emission and when present lead to TRCE becoming rate dependent. Despite these feedbacks TCRE remains roughly constant over the range of the Representative Concentration Pathways and therefore maintains its primary utility as a metric of climate change.

Additional climate model experiments and analytical analysis suggests that a TCRE like metric also emerges in scenarios where CO_2 is artificially removed from the atmosphere. However, this reverse TCRE is smaller in magnitude than the TCRE when net CO_2 emissions are positive.