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# Controls of the TCRE in Earth system models

**Ric Williams**[1], Paulo Ceppi[2], and Anna Katavouta[1,3]
[1]Liverpool University, School of Environmental Sciences, Earth, Ocean & Ecological Sciences, Liverpool, United Kingdom of Great Britain – England, Scotland, Wales (ric@liv.ac.uk)
[2]Grantham Institute, Imperial College London, London, UK
[3]National Oceanography Centre, Liverpool, United Kingdom

The controls of a climate metric, the Transient Climate Response to cumulative carbon Emissions (TCRE), are assessed using a suite of Earth system models, 9 CMIP6 and 7 CMIP5, following an annual 1% rise in atmospheric CO2 over 140 years. The TCRE is interpreted in terms of a product of three dependences: (i) a thermal response involving the surface warming dependence on radiative forcing (including the effects of physical climate feedbacks and planetary heat uptake), (ii) a radiative response involving the radiative forcing dependence on changes in atmospheric carbon and (iii) a carbon response involving the airborne fraction (involving terrestrial and ocean carbon uptake). The near constancy of the TCRE is found to result primarily from a compensation between two factors: (i) the thermal response strengthens in time from more surface warming per radiative forcing due to a strengthening in surface warming from short-wave cloud feedbacks and a declining effectiveness of ocean heat uptake, while (ii) the radiative response weakens in time due to a saturation in the radiative forcing with increasing atmospheric carbon. This near constancy of the TCRE at least in complex Earth system models appears to be rather fortuitous given the competing effects of physical climate feedbacks, saturation in radiative forcing, changes in ocean heat uptake and changes in terrestrial and ocean carbon uptake.

Intermodel differences in the TCRE are mainly controlled by the thermal response, which arise through large differences in physical climate feedbacks that are only partly compensated by smaller differences in ocean heat uptake. The other contributions to the TCRE from the radiative and carbon responses are of comparable importance to the contribution from the thermal response on timescales of 50 years and longer for our subset of CMIP5 models, and 100 years and longer for our subset of CMIP6 models.