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Mechanistic controls of surface warming by ocean heat and carbon uptake: Experiments using idealised ocean models with and without overturning

Anna Katavouta (1), Richard Williams (1), and Philip Goodwin (2)

(1) Department of Earth, Ocean and Ecological Sciences, School of Environmental Science, University of Liverpool, Liverpool, UK, (2) School of Ocean and Earth Sciences, University of Southampton, Southampton, UK

Transient climate response to emissions (TCRE) is an empirically derived index that relates global surface warming to cumulative carbon emissions in Earth system models. TCRE is nearly constant (i.e. surface warming is proportional to carbon emissions), and independent of the emissions pathway and model complexity, for reasons that are not yet fully understood. In our view, this proportionality is driven by ocean ventilation. To explore the link between TCRE and ocean heat and carbon uptake, we use an idealised 1-D atmosphere-ocean model with three layers (i.e. atmosphere, ocean mixed layer, interior ocean) with or without circulation. The model is forced using idealised carbon emission scenarios and drives the temperature and carbon concentration for each layer. The experiments reveal that an increase in carbon emissions eventually leads to ocean declining heat uptake, which causes the dependence of surface warming on radiative forcing from anthropogenic carbon to increase with time. In contrast, an increase in carbon emissions amplifies the ocean carbon uptake which acts to decrease the dependence of radiative forcing on carbon emissions. These two partially compensating effects lead to the nearly linear dependence between surface temperature and cumulative carbon emissions. The linear dependence holds in experiments with and without circulation. However, the TCRE value depends on the circulation and associated ventilation of heat and carbon. Hence, differences in circulation patterns amongst climate models may be responsible for the spread in their response.