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Effective and equilibrium climate sensitivity

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Atmosphere-ocean general circulation models, as well as the real world, take thousands of years to equilibrate to CO_2 induced radiative perturbations. Equilibrium climate sensitivity – a fully equilibrated 2xCO_2 perturbation – has been used for decades as a benchmark in model intercomparisons, as a test of our understanding of the climate system and paleo-proxies and to predict or project future climate change. Computational costs and limited time lead to the widespread practice of extrapolating equilibrium conditions from just a few decades of coupled simulations. The most common workarounds are the "effective climate sensitivity" – defined through an extrapolation of a 150 year abrupt 2xCO_2 simulation, including the assumption of linear climate feedbacks, and the "2-Layer-Model including ocean heat uptake efficacy" – allowing for changing feedbacks on decadal time scales.

We present an ongoing model intercomparison, the "LongRunMIP", to study century and millennia time scales of AOGCM equilibration and the linearity assumptions around feedback analysis. While all models have a higher equilibrium than effective climate sensitivity – also when accounting for ocean heat uptake efficacy – the 14 participating models show a remarkable spread in reasons for this behavior. We show that not only short wave, but also long wave cloud feedbacks contribute to the non-constant feedbacks and discuss the role of sea ice melt and local warming patterns. We differentiate between forcing magnitude - , temperature - , and equilibration time - dependence of feedbacks and review and compare different explanations for long-term non-constancy of feedbacks in the literature.

We also encourage others to use the dataset for questions other than feedback analyses, such as internal variability in equilibrated warmer states, ocean overturning responses on millennia time scales, or year-round, ice-free Arctic conditions and sea ice dynamics: www.longrunmip.org