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Limitations of the 1% experiment as the benchmark idealized experiment for carbon cycle evaluation in Earth System Models

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Idealized climate change simulations are used as benchmark experiments to facilitate the comparison of ensembles of climate models. In the Fifth phase of the Climate Model Intercomparison Project (CMIP5) the 1% experiment was used to compare Earth System Models with full representations of the global carbon cycle. However the 1% experiment was never intended for such a purpose and implies a rise in atmospheric CO_2 concentration at double the rate of the instrumental record. Here we examine this choice by using an intermediate complexity climate model to compare the 1% experiment to an idealized CO_2 pathway derived from a logistic function. The comparison shows three key differences in model output when forcing the model with the Logistic experiment. (1) The model forced with the logistic experiment exhibits a transition of the land biosphere from a carbon sink to a carbon source, a feature absent when forcing the model with the 1% experiment. (2) The ocean uptake of carbon comes to dominate the carbon cycle as emissions decline, a feature that cannot be captured when forcing a model with the 1% experiment. (3) The permafrost carbon feedback to climate change under the 1% experiment forcing is less than half the strength of the feedback seen under logistic experiment forcing. Using the logistic experiment also allows smooth transition to zero or negative emission states, allowing these states to be examined without sharp discontinuities in CO_2 emissions. Given the limitations of the 1% experiment as the benchmark experiment for carbon cycle intercomparisons, adding a logistic or similar idealized experiment to the protocol of the CMIP7 is recommended.