Towards probabilistic climate projections based on the CMIP6 multi-model ensemble

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Research on climate change mitigation uses a climate model emulator that represents the average and range over a specific multi-model ensemble of complex climate simulations. The Coupled Model Intercomparison Project (CMIP) has provided such multi-model ensembles, and its latest Phase 6 (CMIP6) results are being revealed. As a first step to applying the CMIP6 results to probabilistic climate projections, we focus on the distribution of key parameters representing atmospheric CO_2-induced forcing and transient temperature responses.

In this study, we develop a procedure to determine the forcing-response parameters of a complex climate model. We simultaneously fit a curve built on an impulse response function to the global mean time series of the model's surface temperature anomaly and top-of-atmosphere energy imbalance from two basic CO_2 -forced experiments, i.e., an abrupt quadrupling and a 1%-per-year increase in atmospheric CO_2 concentration. This scheme serves as an improved alternative to the widely-used regression method of Gregory et al. (2004). Furthermore, it makes a complete set of parameters to emulate the target model from which equilibrium climate sensitivity (ECS) and transient climate response (TCR) are derived. The properties of a multi-model ensemble are quantified through a statistical approach including a principal component analysis for the parameters.

The two CO_2-forced experiments are included in the set of common experiments which is designed to maintain continuity across different CMIP phases. Here, we compare the parameters of individual CMIP6 models with those of the previous-phase CMIP5 models. The parameters of the CMIP5 ensemble have several features. The ratio of TCR to ECS is distributed in the range of approximately 0.5 to 0.7, and for models with large ECS, the ratio tends to decrease. The scaling parameter for the effective radiative forcing of CO_2 varies from model to model and tends to be less than a reference value used in a conventional formula of CO_2 radiative forcing. Although the number of CMIP6 models is currently limited, their parameters show similar distributions within the CMIP5 ranges.

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