Significant impact of forcing uncertainty in a large ensemble of climate model simulations

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Abstract

Forcing due to solar and volcanic variability, on the natural side, and greenhouse gas and aerosol emissions, on the anthropogenic side, are the main inputs to climate models. Reliable climate model simulations of past and future climate change depend crucially upon them. Here we analyze large ensembles of simulations using a comprehensive Earth System Model to quantify uncertainties in global climate change attributable to differences in prescribed forcings. The different forcings considered here are those used in the two most recent phases of the Coupled Model Intercomparison Project, namely CMIP5 and CMIP6. We show significant differences in simulated global surface air temperature due to volcanic aerosol forcing in the second half of the 19th century and in the early 21th century. The latter arise from small-to-moderate eruptions incorporated in CMIP6 simulations but not CMIP5 simulations. We also find significant differences in global surface air temperature and Arctic sea ice area due to anthropogenic aerosol forcing in the second half of the 20th century and early 21st century. These differences are as large as those obtained in different versions of an Earth System Model employing identical forcings. In simulations from 2015 to 2100, we find significant differences in the rates of projected global warming arising from CMIP5 and CMIP6 concentration pathways that differ slightly but are equivalent in terms of their nominal radiative forcing levels in 2100. Our results highlight the influence of assumptions about natural and anthropogenic aerosol loadings on carbon budgets, the likelihood of meeting Paris targets, and the equivalence of future forcing scenarios.

Keywords: climate change, climate model, external forcing, large ensemble

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