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Volcanic forcing of climate since 1850 in an interactive aerosol-chemistry-climate model

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Reconstructions of volcanic aerosol forcing and its climatic impacts are undermined by uncertainties in both the models used to build these reconstructions as well as the proxy and observational records used to constrain those models. Reducing these uncertainties has been a priority and in particular, several modelling groups have developed interactive stratospheric aerosol models. Provided with an initial volcanic injection of sulfur dioxide, these models can interactively simulate the life cycle and optical properties of sulfate aerosols, and their effects on climate. In contrast, most climate models that took part in the Coupled Model Intercomparison Project Phase 5 and 6 (CMIP6) directly prescribe perturbations in atmospheric optical properties associated with an eruption. However, before the satellite era, the volcanic forcing dataset used for CMIP6 mostly relies on a relatively simple aerosol model and a volcanic sulfur inventory derived from ice-cores, both of which have substantial associated uncertainties.

In this study, we produced a new set of historical simulations using the UK Earth System Model UKESM1, with interactive stratospheric aerosol capability (referred to as interactive runs hereafter) instead of directly prescribing the CMIP6 volcanic forcing dataset as was done for CMIP6 (standard runs, hereafter). We used one of the most recent volcanic sulfur inventories as input for the interactive runs, in which aerosol properties are consistent with the model chemistry, microphysics and atmospheric components. We analyzed how the stratospheric aerosol optical depth, the radiative forcing and the climate response to volcanic eruptions differed between interactive and standard runs, and how these compare to observations and proxy records. In particular, we investigate in detail the differences in the response to the large-magnitude Krakatoa 1883 eruption between the two sets of runs. We also discuss differences for the 1979-2015 period where the forcing data in standard runs is directly constrained from satellite observations. Our results shed new light on uncertainties affecting the reconstruction of past volcanic forcing and highlight some of the benefits and disadvantages of using interactive stratospheric aerosol capabilities instead of a unique prescribed volcanic forcing dataset in CMIP's historical runs.