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Modelling aspects of the sulfate aerosol evolution after recent volcanic activity

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Volcanic activity is one of the main natural climate forcings and therefore an accurate representation of volcanic aerosols in global climate models is essential. However, direct modelling of sulfur chemistry, sulfate aerosol microphysics and transport is a complex task involving many uncertainties including those related to the volcanic emission magnitude, vertical shape of the plume, and observations of atmospheric sulfur. This study aims to investigate some of these uncertainties and to analyse the performance of the aerosol-chemistry-climate model SOCOL-AERv2 for three medium-sized volcanic eruptions from Kasatochi in 2008, Sarychev in 2009 and Nabro in 2011. In particular, we investigate the impact of different estimates for the initial volcanic plume height and its SO2 content on the stratospheric aerosol burden. The influence of internal model variability and of modelled dynamics is addressed by three free-running simulations and two nudged simulations at different vertical resolutions. Comparing the modelled evolution of the stratospheric aerosol loading and its spread with the Brewer-Dobson-Circulation (BDC) to satellite measurements reveals in general a very good performance of SOCOL-AERv2 during the considered period. However, the large spread in emission estimates logically leads to significant differences in the modelled aerosol burden. This spread results from both the uncertainty in the total emitted mass of sulfur as well as its vertical distribution relative to the tropopause. An additional source of modelled uncertainty is the tropopause height, which varies among the free-running simulations. Furthermore, the validation is complicated by disagreement between different observational datasets. Nudging effects on the tropospheric clouds were found to affect the tropospheric SO2 oxidation paths and the cross-tropopause transport, leading to increased background burdens both in the troposphere and the stratosphere. This effect can be reduced by nudging only horizontal winds but not temperature. A higher vertical resolution of 90 levels (as opposed to 39 in the standard version) increases the stratospheric residence time of sulfate aerosol after low-latitude eruptions by reducing the diffusion speed out of the tropical reservoir. We conclude that the model's uncertainties can be largely defined by both its set-up as by the volcanic emission parameters.