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Solid particle SAI with a fully coupled atmosphere-ocean-aerosol-chemistry-climate model SOCOLv4.0

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Solid particles, such as alumina, calcite, and diamond, have been proposed as an alternative material for the stratospheric aerosol injection (SAI) studies. The traditional SAI set-up based on sulphate aerosols was shown to have several limitations such as stratospheric heating, due to absorption of long wave radiation, or ozone depletion, due to chlorine activation at the particle surfaces. Solid particles are thought to potentially overcome these limitations by having better optical properties and/or larger chemical inertness. In our work, we use for the first time a fully coupled atmosphere-ocean-aerosol-chemistry-climate model SOCOLv4.0, which incorporates a solid particle emission scheme, to assess the SAI effects of the alumina, calcite, and diamond. For each solid particle type, we followed the GeoMIP protocols and performed G4 and G6 experiments, which are cooling efficiency calibration runs and the transient ensemble runs to bring decadal surface temperatures of the SSP5 scenario to the ones from the SSP2 scenario, respectively. For all considered SAI substances, we find that the resulting burden is close to the yearly emission quantity, suggesting an average lifetime of approximately one year. Diamond has the highest burden-per-emission ratio, suggesting a higher lifetime, which is explained by its small particle radius. Sulfur, alumina, and calcite provide very similar cooling per emission, while diamond has a cooling efficiency of about a factor of three higher. Diamond also has the lowest absorption in the long wave, which allows it to show the weakest heating of the lower stratosphere, no increase in the stratospheric water vapour, and smallest dynamical effects on ozone. In terms of surface climate artifacts, those species that show the weakest heating in the stratosphere (calcite and diamond) also show the least anomalies in atmospheric and oceanic circulation patterns compared to the SSP2 scenario. Information on the interaction between alumina, calcite and ozone-relevant chemical cycles is available, but has not been sufficient so far for implementing their ozone chemistry with high confidence in the results. Additional laboratory studies, thus, are required for further modelling research on this subject.