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Project title: **“Implications and Risks of Engineering Solar Radiation to Limit Climate Change (IMPLICC)”**

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1 General remarks

The analysis of simulations on the impact of climate engineering (CE) techniques on the climate started in the EU Project IMPLICC and is currently being continued in the framework of GeoMIP, an endorsed CMIP6 project. Our simulations are contributions to the GeoMIP experiments AccumH2SO4, G6sulfur and G6solar. The simulations for this project have been performed under project account bm0550, while data processing and storage was mostly done within the data project bm0695. Therefore, this report combines both projects.

The overall goal of the project is to significantly increase the level of knowledge about the feasibility and implications of CE options. One of the assumed techniques, the injection of sulfur into the stratosphere, which is also known as stratospheric aerosol intervention (SAI), requires detailed knowledge about the microphysical evolution of sulfur and the transport and distribution of the sulfate particles (Niemeier and Tilmes, 2017). Therefore, CE simulations on SAI were performed with a middle atmosphere version of the General Circulation Model (GCM) ECHAM5 (T63L95) that is interactively coupled to a modified version of the aerosol microphysical model HAM. The GeoMIP simulations have been performed with MPI-ESM. Currently, the goal is to continue with ICON-NWP in the so called seamless version of the model. This version is still under development, e.g. coupling to the ocean and tuning of the troposphere’s climate. In this project the focus is on stratospheric aerosol and their relation to stratospheric dynamical processes. Therefore, first attempts to tune the stratosphere have been started.

2 Injection of sulfate into the stratosphere – Impact on stratospheric dynamics

Different ESMs calculated surface cooling and radiative forcing within the GeoMIP Phase 6 experiment G6sulfur (Kravitz et al, 2015). G6sulfur aimed at lowering global mean surface temperatures from a high emission scenario (SSP5-8.5) to a medium emission scenario (SSP2-4.5) by increasing the simulated stratospheric AOD. MPI-ESM prescribes the AOD of sulfate aerosols, which were calculated with an aerosol micro-physical model, MAECHAM5-HAM (Niemeier et al, 2020). Our model results were recently used for different studies, e.g. Tilmes et al, 2022; Jones et al, 2022; Weisenstein et al, 2022; Chen et al, 2022.

Results of the SAI simulations differ clearly between the models. The different ESMs require very different amounts of sulfur injections to get the same amount of surface cooling (Visioni et al, 2020). The sulfur amount depends on the climate sensitivity of the model, the simulated temperature difference between the two scenarios, but also on details of the aerosol microphysics and stratospheric dynamics. The models simulate different spatial distribution and also different size distribution of the aerosols. Both results in different scattering of solar radiation and different absorption of terrestrial radiation and, consequently, on different surface cooling for a certain amount of injected sulfur.

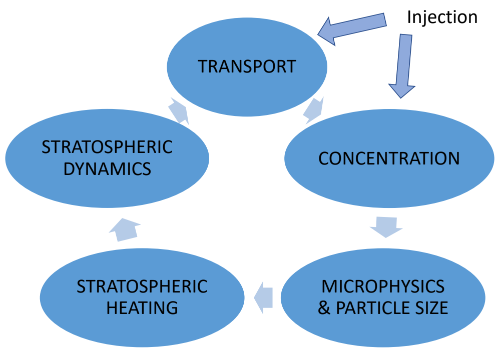

Figure 1: Interaction between different model components after the injection of sulfur. Transport changes concentrations which influences aerosol microphysical processes and particle size. Radiative heating of the aerosols depends strongly on the simulated particle size and impacts transport.

Figure 1 shows the interaction between the different components. The distribution of the initial injection of SO2 depends on the transport pattern within the injection area. They change the concentration of SO2 right after the injections. This has consequences for aerosol microphysical processes which depend on the concentration of species. Aerosol microphysics impact the simulated particle size, stratospheric heating and stratospheric dynamics, e.g. quasi biennial oscillation and meridional transport of the aerosol. This feedback circle can explain quite a large part of the differences in the resulting surface cooling between different models. This is an important outcome of our contribution to GeoMIP. e.g. related to Weisenstein et al. (2022), especially as the role of stratospheric dynamics has been overseen for a long time. The feedback between transport and aerosol microphysics explains also the importance of a well tuned ICON-NWP seamless model. This work started recently and will be continued in 2023.

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