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Sensitivity of radiative forcing and surface temperature to sulfate injection area in stratospheric geoengineering.

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Geoengineering by injecting sulfur to the stratosphere has been shown to have a potential to counteract global warming. In the future, such a method may be considered as an option in slowing down global warming, if reducing of greenhouse gases has not been achieved fast and effectively enough. In the stratosphere sulfate particles reflect solar radiation back to space and thus cool the climate. Cooling effect would last 1-2 years because of the stability of the stratosphere combined with lack of effective removal processes. Usually sulfur is assumed to be injected as SO_2 which oxidizes and forms sulfate particles after injections. However, if the amount of injected sulfur is increased, its effect can be saturated and the increase in the stratospheric sulfate burden and global radiative forcing becomes smaller. When sulfur concentration increases, stratospheric particles would grow to larger sizes, which have a shorter lifetime in the atmosphere and do not reflect radiation as efficiently as smaller particles. In many previous studies, sulfur has been assumed to be injected along the equator where yearly mean solar intensity is the highest and where sulfur is spread more or less equally to both hemispheres. Because of this, sulfate has been assumed to be injected and spread to the hemisphere also during winter time, when solar intensity is low. Thus sulfate injection would be more effective, if sulfur injection area is changed seasonally.

In this study we use global aerosol-climate model ECHAM6.1-HAM2.2-SALSA to investigate radiative forcing from the different injection areas and to study if a more effective injection strategy would be varying the injection area seasonally. The model describes aerosol size distribution by 10 size sections and calculates the microphysical processes of nucleation, condensation, coagulation and hydration. Thus the formation from gaseous SO_2 to sulfate particles, particle growth and also how sulfate is distributed in the atmosphere after different injection strategies are described in the model. We will also use coupled climate-ocean model MPI-ESM to study climate effects from these scenarios by using aerosol effective radius and aod fields from simulations by ECHAM6.1-HAM2.2-SALSA.

We carried out simulations, where 5 Tg of sulfur is injected as SO_2 to the stratosphere at height of 20-22 km in an area ranging over a 20 degree wide latitude band. Preliminary results show that global radiative forcing is slightly larger if the injection area is changed depending on the season of the year compared to a case where sulfur is injected to the area between 10 N and 10 S. Oxidation time from SO_2 to sulfate particles and the time that new particles needs to grow particles large enough has major role to how effective temporally depended injection scenarios are.