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Optimizing stratospheric sulfur geoengineering by seasonally changing sulfur injections

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Solar radiation management (SRM) by stratospheric sulfur injection has been shown to have potential in counteracting global warming if reducing of greenhouse gases has not been achieved fast enough and if climate warming will continue. Injecting large amounts of sulfate particles to the stratosphere would increase the reflectivity of the atmosphere and less sunlight would reach the surface. However, the effectivity (per injected sulphur mass unit) of this kind of geoengineering would decrease when amount of injected sulfur is increased. When sulfur concentration increases, stratospheric particles would grow to larger sizes which have larger gravitational settling velocity and which 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 from where sulfur is spread equally to both hemispheres. However, the solar intensity will change locally during the year and sulfate has been assumed to be injected and spread to the hemisphere also during winter time, when the solar intensity is low. Thus sulfate injection could be expected to be more effective, if sulfur injection area is changed seasonally.

Here we study effects of the different SRM injection scenarios by using two versions of the MPI climate models. First, aerosol spatial and temporal distributions as well as the resulting radiative properties from the SRM are defined by using the global aerosol-climate model ECHAM6.1-HAM2.2-SALSA. After that, the global and regional climate effects from different injection scenarios are predicted by using the Max Planck Institute's Earth System Model (MPI-ESM).

We carried out simulations, where 8 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. Results show that changing the sulfur injection area seasonally would lead to similar global mean shortwave radiative forcing (-4.41 W/m2 at top of atmosphere) as if sulfur is injected only to the equator (-4.40 W/m2). However zonal mean distribution would be different and forcing is concentrated relatively more to the midlatitudes and less to the equator. Cooling effect from the geoengineering and warming effect from the increased greenhouse gas has been shown in many studies to lead to cooling in the equator and warming in the poles compared the preindustrial conditions. Changing the injection area seasonally might prevent this from happening and lead globally to more homogeneous temperature change.