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Evaluation of climate impacts after a large volcanic eruption during stratospheric sulfur injections

Anton Laakso (1), Harri Kokkola (1), Antti-Ilari Partanen (2,3), Ulrike Niemeier (4), Claudia Timmreck (4), Kari Lehtinen (1,5), Hanne Hakkarainen (6), and Hannele Korhonen (2)

(1) Finnish Meteorological Institute, Atmospheric Research Centre of Eastern Finland, Kuopio, Finland , (2) Finnish Meteorological Institute, Climate Research, Helsinki, Finland, (3) Department of Geography, Planning and Environment, Concordia University, Montréal, Québec, Canada, (4) Max Planck Institute for Meteorology, Hamburg, Germany, (5) Department of Applied Physics, University of Eastern Finland, Kuopio campus, Kuopio, Finland, (6) A. I. Virtanen Institute for Molecular Sciences, University of Eastern Finland, Kuopio, Finland

Solar radiation management (SRM) by injecting sulfur to the stratosphere is one of the most discussed geoengineering methods, because it has been suggested to be affordable and effective and its impacts have been thought to be predictable based on volcanic eruptions. Injecting sulfur to the stratosphere could be seen as an analogy of large volcanic eruptions, where large amounts of sulfur dioxide are released into the stratosphere. In the atmosphere sulfur dioxide oxidizes and forms aqueous sulfuric acid aerosols which reflect incoming solar radiation back to space. If SRM is ever used to cool the climate it is possible that a large volcanic eruption could happen also during the SRM, which would lead temporally to a very strong cooling.

The simulations in this study were performed in two steps. In the first step, we used the aerosol-climate model MAECHAM5-HAM-SALSA to define global aerosol fields in scenarios with stratospheric sulfur injections and/or a volcanic eruption. In the second step of the study we performed climate simulations using Max-Planck-Institute's Earth system model (MPI-ESM) by using aerosol fields defined by MAECHAM5-HAM-SALSA. We studied scenarios of volcanic eruptions in two different locations and seasons and during the SRM sulfur injections and without injections.

According to our simulations the radiative impacts of the eruption and SRM are not additive and the radiative effects and climate changes occurring after the eruption depend strongly on whether SRM is continued or suspended after the eruption. Adding to this, sulfate burden and radiative forcing after the volcanic eruption decrease significantly faster if the volcanic eruption happens during the geoengineering injections. In this situation, sulfur from the eruption does not only form new particles but it also condenses into pre-existing particles. Furthermore, the new small particles that are formed after the eruption coagulate effectively with the existing larger particles from the SRM injections. This leads to a smaller number and larger sulfate particles compared to the eruption in a non-SRM world. This also means that the observations of strong volcanic eruptions cannot be applied when estimating the consequences of an eruption during geoengineering. If the eruption took place in the high latitudes, the resulting global forcing would be highly dependent on the season of the eruption.