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Agricultural feedbacks on stratospheric sulfate geoengineering

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Stratospheric sulfate geoengineering is one of the most widely discussed geoengineering schemes to address the problem of global warming. However, it may have side effects. Among them, threats to agricultural production are of great concern because of the combination of climate changes due to stratospheric sulfate geoengineering, such as cooling, reduction of precipitation and solar radiation, and ozone depletion, particularly in regions strongly influenced by the summer monsoon system. To investigate these responses, we used the DSSAT agricultural simulation model driven by observed weather over China for the past 30 years, but perturbed by the climate response to stratospheric geoengineering from NASA GISS ModelE simulations. We found in some provinces in China, that rice and maize productions would decrease in response to a 20-year sulfate injection (5 Mt SO2 per year) and more fertilizer needs to be applied to compensate for this agricultural reduction. If we account for population growth and possible biofuel demand in the future, there will be more agricultural production needed and hence, even more fertilizer would be needed. Since fertilizer has large environmental impacts, it is interesting to also investigate its possible feedbacks on stratospheric sulfate geoengineering. Fertilizer plays an important role in N2O gas concentration in the atmosphere, which is involved in several processes that influence the climate system. During the past two centuries, N2O concentration has increased from 270 ppb to 315 ppb, in which synthetic fertilizer contributes ~40% (another ~40% is from manure). N2O would slightly offset the cooling effect from stratospheric sulfate geoengineering, because it is a strong greenhouse gas with global warming potential 296 times larger than CO2. It can also enhance ozone depletion due to stratospheric geoengineering, as it is the major source of NOx in the stratosphere, which is the dominant substance causing ozone depletion after regulation of CFCs. This might strengthen the negative impacts of stratospheric geoengineering on agriculture productivity. Ozone depletion will cause more UV radiation penetrating through the troposphere. Since one major source of O3 in the troposphere is photochemical reactions, there could be more O3 generated in lower troposphere, which will cause damage to crops. We used the CESM1/CAM4 climate model to simulate possible agricultural impacts on stratospheric geoengineering. If 10% more fertilizer (~16 Mt of fertilizer) were added into the ecosystem every year globally, there would be ~0.3 Mt more N2O emitted into the atmosphere. We ran the model under stratospheric geoengineering conditions with an additional ~0.3 Mt of N2O injection into the troposphere every year. Compared with stratospheric geoengineering only, injection of N2O causes a weaker cooling effect, stronger ozone depletion in the stratosphere, and higher ozone concentration in the lower troposphere.