

Current Status and Issues in Scientific Understanding of Solar Radiation Modification

*Shingo Watanabe¹

1. Japan Agency for Marine-Earth Science and Technology

Climate change poses a serious threat to human society and ecosystems. Efforts to mitigate climate change need to be accelerated, including more effective reductions in greenhouse gas emissions and their removal from the atmosphere, and reductions in short-lived climate forcing factors such as aerosols and tropospheric ozone, which offset or contribute to the warming effect, in ways that do not exacerbate the warming as much as possible. And what if that doesn't help?" Solar Radiation Modification (SRM), a method of offsetting the collapse of the Earth's radiation budget caused by the increase in greenhouse gases by reducing solar radiation, has been attracting attention in international political forums such as the Conference of the Parties (COP) and in the scientific community, especially in the United States and the United Kingdom. However, interest in Japan remains very low.

The GeoMIP (Geoengineering Model Intercomparison Project), which quantitatively evaluates the effects, side effects, and uncertainties of several SRM ideas using Earth system models for global warming prediction, started in 2011. The results were cited in IPCC-AR5/AR6 and the latest WMO Ozone Layer Report (2022) [1].

The most well-studied and relatively low technical hurdle to implementation is the Stratospheric Aerosol Injection (SAI), which is a method to inject fine particles such as aerosols of sulfuric acid into the stratosphere. Several experiments of SAI in the lower equatorial stratosphere have been conducted at GeoMIP to evaluate the degree of ozone depletion, a feared side effect, and the response of the climate system, including extremes, and its uncertainties. In the Geoengineering Large Ensemble Project (GLENS), a large ensemble SAI experiment conducted by NCAR in the U.S., and subsequent studies, the simulations report that it is possible to measure and control the feedbacks of the climate system on SAI while maintaining the target level of warming, while minimizing side effects by strategically designing the altitude, latitude, and season of the SAI.

Another method that many researchers are working on is marine cloud brightening (MCB), in which fine particles such as sea salt particles are sprayed onto the marine boundary layer, where stratocumulus clouds tend to form. In GeoMIP, experiments were conducted to virtually increase the concentration of cloud particles in lower clouds over the ocean. Although this method is limited in its applicable regions compared to SAI, it has become the second major SRM method, perhaps because many cloud researchers are working on it as an extension of their own research.

The most important scientific challenge common to SAI and MCB is that, although the idea is to mimic phenomena that have been observed, there is a lack of observational and experimental understanding of microphysical and turbulent processes, such as how fine particles or their precursors behave in the stratosphere or marine boundary layer. The Stratospheric Controlled Perturbation Experiment (SCoPEX) project, in which water and calcite are injected from a gondola suspended from a balloon in the stratosphere, has been proposed but not been realized. Uncertainties in Earth system models for large-scale transport and mixing processes, such as the stratospheric Brewer-Dobson circulation and subtropical barriers, are also a major issue for SAI.

Acknowledgment: This work was supported by JSPS Grant-in-Aid for Scientific Research (JP21H03668).

References

[1] Visiolini, D., et al. 2022, Atmos. Chem. Phys. doi:10.5194/acp-2022-766

Keywords: Climate Change, Climate Intervention, Solar Radiation Modification