An overview of geoengineering of climate using stratospheric sulphate aerosols

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Abstract

We provide an overview of geoengineering by stratospheric sulphate aerosols. The state of understanding about this topic as of early 2008 is reviewed, summarizing the past 30 years of work in the area, highlighting some very recent studies using climate models, and discussing methods used to deliver sulphur species to the stratosphere. The studies reviewed here suggest that sulphate aerosols can counteract the globally averaged temperature increase associated with increasing greenhouse gases, and reduce changes to some other components of the Earth system. There are likely to be remaining regional climate changes after geoengineering, with some regions experiencing significant changes in temperature or precipitation. The aerosols also serve as surfaces for heterogeneous chemistry resulting in increased ozone depletion. The delivery of sulphur species to the stratosphere in a way that will produce particles of the right size is shown to be a complex and potentially very difficult task. Two simple delivery scenarios are explored, but similar exercises will be needed for other suggested delivery mechanisms. While the introduction of the geoengineering source of sulphate aerosol will perturb the sulphur cycle of the stratosphere signicantly, it is a small perturbation to the total (stratosphere and troposphere) sulphur cycle. The geoengineering source would thus be a small contributor to the total global source of 'acid rain' that could be compensated for through improved pollution control of anthropogenic tropospheric sources. Some areas of research remain unexplored. Although ozone may be depleted, with a consequent increase to solar ultraviolet-B (UVB) energy reaching the surface and a potential impact on health and biological populations, the aerosols will also scatter and attenuate this part of the energy spectrum, and this may compensate the UVB enhancement associated with ozone depletion. The aerosol will also change the ratio of diffuse to direct energy reaching the surface, and this may influence ecosystems. The impact of geoengineering on these components of the Earth system has not yet been studied. Representations for the formation, evolution and removal of aerosol and distribution of particle size are still very crude, and more work will be needed to gain confidence in our understanding of the deliberate production of this class of aerosols and their role in the climate system.

Keywords: climate change | geoengineering | sulphate aerosols | global warming

Footnotes

One contribution of 12 to a Theme Issue 'Geoscale engineering to avert dangerous climate change'.

↵Sulphur emissions and burdens are frequently expressed in differing units. They are sometimes specified with respect to their molecular weight. Elsewhere they are specified according to the equivalent weight of sulphur. They may be readily converted by multiplying by the ratio of molecular weights of the species of interest. We use only units of S in this paper, and have converted all references in other papers to these units. Also, in the stratosphere, we have assumed that the sulphate binds with water in a ratio of 75/25 H_2SO_4/water to form particles. Hence

$$3\ \mathrm{Tg\ SO_4^{2-}} = 2\ \mathrm{Tg\ SO_2} = 1\ \mathrm{Tg\ S} \approx 4\ \mathrm{Tg\ aerosol\ particles.}$$

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