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Impact of geo-engineered aerosols on stratospheric composition and dynamics

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A recently proposed geo-engineering scheme to limit greenhouse warming is the injection of sulfur into the stratosphere to increase the Earth's albedo. This is expected to reduce tropospheric temperatures, as observed following large volcanic eruptions (for example, Mt. Pinatubo in June of 1991). However, that eruption also enhanced stratospheric ozone loss in the Arctic lower stratosphere via heterogeneous processes on sulfate aerosols. The impact of artificially enhancing the sulfate layer on chemical ozone loss can be is estimated roughly for future chlorine conditions in the stratosphere using an empirical relationship between ozone depletion and chlorine activation. This estimate suggests that a drastic increase in the extent of Arctic ozone depletion and a delay of the recovery of the Antarctic ozone hole between 30-70 years would occur if sulfate aerosols were used to counteract CO_2 doubling.

In comparison, we present results of a transient climate simulation with enhanced anthropogenic sulfate aerosols using a 3D coupled Chemistry Climate Model, the Whole Atmosphere Community Climate Model (WACCM). In contrast to previous model studies, the impacts on stratospheric chemistry, including heterogeneous chemistry in the polar regions, are considered in this simulation. Further, interactions between atmospheric and ocean temperatures are taken into account by means of a coupled slab ocean model. We assume a stratospheric distribution of volcanic-like liquid sulfate aerosols consistent with the injection of 2 Tg S/year. Temperatures, precipitation and sea-ice approximately return to present-day conditions in the geo-engineering scenario. However, significant changes in mid-and high-latitude ozone occur as a result

of strongly enhanced heterogeneous chemistry, in agreement with the observational estimates. We further show that changes in chemistry also affect the radiation budget and feed back on atmospheric transport, resulting in stronger Arctic polar vortices and therefore colder winters (with strong ozone depletion).