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Disparities in hydrological impacts of Solar Radiation Management and Carbon Dioxide Removal

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Solar Radiation Management (SRM) and Carbon Dioxide Removal (CDR) methods are proposed to prevent climate warming if fast enough carbon dioxide emission reductions are not put into action and the climate will warm in the near future. SRM methods are aiming to increase the Earth's solar reflectivity which would result in cooling at the surface. However, it has been shown that if the temperature increase due to increased greenhouse gases is compensated by SRM, it will lead to a decrease in the global mean precipitation. This is because of the changes in the radiative flux between the top of the atmosphere and the surface, which are then compensated by a reduced latent heat flux which in turn reduces the global mean precipitation.

Here we have studied geoengineering scenarios in this century. These are compared against a representative concentration pathway 4.5 scenario which, compared to current climate, would lead to a 1.20-1.30 K warming and a 1.75 % increase in the global mean temperature and the precipitation, respectively, before the end of 21st century. All geoengineering scenarios are based on RCP 4.5 for the years 2010-2100. In the first two scenarios, the global mean temperature or precipitation is kept stable by SRM. In the third scenario, 1% of the atmospheric CO_2 load is removed each year until the year 2070. Model simulations are done by using MPI-ESM and CESM. In these models the stratospheric aerosol fields for SRM are included as prescribed fields, from an aerosol-climate model ECHAM-HAMMOZ simulation.

The results show that in average 110 Tg(S) and 104 Tg(S) sulfur is needed in MPI-ESM and CESM, respectively, for keeping the precipitation at the 2010 level until year 2100. However, keeping the temperature at the 2010 level requires almost double the amount of sulfur (306 Tg(S)) in MPI-ESM compared to the simulations with CESM (178 Tg(S)). Compared to the current climate, this will lead to -1.42% and -0.7% reductions in the global mean precipitation in MPI-ESM and CESM simulations, respectively. Thus, temperature and precipitation responses of SRM depend on the model used and how the radiation will change at the top of the atmosphere and at the surface. For example if a different ocean albedo for diffused and direct radiation is taken into account, in the case of SRM, responses in the radiative budget and climate are significantly different.

Modelled CDR scenarios prevent warming which is seen in scenario RCP 4.5 with no geoengineering and the global mean temperature is roughly the same in the last decades in the 21st century as in the beginning of the simulation (2010). Surprisingly, the global mean precipitation is still 0.5% larger in 2100 than in 2010, even though global mean temperature is the same. This this because of the difference in the radiative fluxes in 2010 and end of the simulation in the CDR scenario, which further leads to a different latent heat flux and an increase in global mean precipitation.