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Climate engineering to mitigate the projected 21st-century terrestrial drying of the Americas: a direct comparison of carbon capture and sulfur injection

Yangyang Xu[1], Lei Lin[2], Simone Tilmes[3], Katherine Dagon[4], Lili Xia[5], Chenrui Diao[1], Wei Cheng[6], Zhili Wang[7], Isla Simpson[3], and Lorna Burnell[8]

[1]Department of Atmospheric Sciences, Texas A&M University, College Station, TX 77843, USA
[2]School of Atmospheric Sciences and Guangdong Province Key Laboratory for Climate Change and Natural Disaster Studies, Sun Yat-Sen University, Zhuhai, Guangdong, 519000, China
[3]Atmospheric Chemistry, Observations and Modeling Laboratory, National Center for Atmospheric Research, Boulder, CO, USA
[4]Climate and Global Dynamics Laboratory, National Center for Atmospheric Research, Boulder, CO, USA
[5]Department of Environmental Sciences, Rutgers University, New Brunswick, NJ, USA
[6]Mechanical and Aerospace Engineering, Cornell University, Ithaca, NY, USA
[7]State Key Laboratory of Severe Weather and Key Laboratory of Atmospheric Chemistry of CMA, Chinese Academy of Meteorological Sciences, Beijing, China
[8]School of Mathematical Sciences, University of Nottingham, UK

To mitigate the projected global warming in the 21st century, it is well-recognized that society needs to cut CO2 emissions and other short-lived warming agents aggressively. However, to stabilize the climate at a warming level closer to the present day, such as the “well below 2 C” aspiration in the Paris Agreement, a net-zero carbon emission by 2050 is still insufficient. The recent IPCC special report calls for a massive scheme to extract CO2 directly from the atmosphere, in addition to decarbonization, to reach negative net emissions at the mid-century mark. Another ambitious proposal is solar-radiation-based geoengineering schemes, including injecting sulfur gas into the stratosphere. Despite being in public debate for years, these two leading geoengineering schemes have not been directly compared under a consistent analytical framework using global climate models.

Here we present the first explicit analysis of the hydroclimate impacts of these two geoengineering approaches using two recently available large-ensemble model experiments conducted by a family of state-of-the-art Earth system models. Our analysis focuses on the projected aridity conditions over the Americas in the 21st century in detailed terms of the potential mitigation benefits, the temporal evolution, the spatial distribution (within North and South America), the relative efficiency, and the physical mechanisms. We show that sulfur injection, in contrast to previous notions of leading to excessive terrestrial drying (in terms of precipitation reduction) while offsetting the global mean greenhouse gas (GHG) warming, will instead mitigate the projected drying tendency under RCP8.5. The surface energy balance change induced by sulfur injection, in

addition to the well-known response in temperature and precipitation, plays a crucial role in determining the overall terrestrial hydroclimate response. However, when normalized by the same amount of avoided global warming in these simulations, sulfur injection is less effective in curbing the worsening trend of regional land aridity in the Americas under RCP8.5 when compared with carbon capture. Temporally, the climate benefit of sulfur injection will emerge more quickly, even when both schemes are hypothetically started in the same year of 2020. Spatially, both schemes are effective in curbing the drying trend over North America. However, for South America, the sulfur injection scheme is particularly more effective for the sub-Amazon region (southern Brazil), while the carbon capture scheme is more effective for the Amazon region. We conclude that despite the apparent limitations (such as an inability to address ocean acidification) and potential side effects (such as changes to the ozone layer), innovative means of sulfur injection should continue to be explored as a potential low-cost option in the climate solution toolbox, complementing other mitigation approaches such as emission cuts and carbon capture (Cao et al., 2017). Our results demonstrate the urgent need for multi-model comparison studies and detailed regional assessments in other parts of the world.