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Earth System Dynamics
Discussions

Interactive comment on "Climate engineering to mitigate the projected 21st-century terrestrial drying of the Americas: Carbon Capture vs. Sulfur Injection?" *by* Yangyang Xu et al.

Anonymous Referee #3

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In this study, the authors compared model-simulated hydrological cycle change in two scenarios: a scenario in which global mean temperature, equator-to-pole temperature gradient, and interhemispheric temperature gradient, are all stabilized at present day level under the RCP8.5 background scenario through stratospheric sulphate aerosol injection (GLENS ensemble simulations); and a scenario in which atmospheric CO2 is reduced to achieve the temperature stabilization goal of 1.5 degree (carbon capture and storage). The stratospheric sulphate injection simulations are done with CESM-WACCM, and the carbon capture and storage simulations are done using CESM1-CAM5. The main metrics used in the analysis are precipitation (P), potential evapo-transpiration (PET), and the ratio of P to PET. The regions focused on is North and

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South America.

My biggest concern is to what extend hydrological cycle change in these two scenarios can be compared with each other. By experiment design, compared to the present-day climate, the global mean temperature is near zero in the GELENS, and 1.5 degree warming in carbon capture and storage simulation. Different amount of temperature change would certainly be one of the major factors responsible for different hydrological cycle change. The authors also presented changes that are normalized by global mean temperature change, but to what extend these hydrological metrics, in particular PET, scales with global mean temperature at the regional scale? CESM-WACCM and CESM1-CAM5 also has different model configuration and climate sensitivity, which further complicates the comparison between two sets of simulations.

In the conclusion, the author states that 'As a result, we emphasize that the main purpose of this paper is not to examine the effectiveness of these two climate engineering schemes in the sense of absolute values. Instead, we aim to highlight the physical mechanisms at play, especially when distinct between the two approaches'. But most of the study is actually devoted to the comparison of these two scenarios quantitatively, and I really don't see a clear presentation of the fundamental physical mechanisms gained from this study.

Specific comments:

Abstract: 'these two leading geoengineering schemes have not been carefully examined under a consistent numerical modelling framework.'

Does it imply that this study is the first to carefully examine these two schemes in a consistent modelling framework? This is clearly not true.

'Here we present a comprehensive analysis of climate impacts . . .'

This is not true. This study only analyzes some hydrological metrics for some specific regions. This is not a comprehensive analysis. Introduction:

Line 64: The reference of Xu and Ramanathan, 2017 and Miller et al., 2017 is missing in the reference list. (please also check other references. Quite a few are missing in the reference list)

Line 64-65: Climate engineering is proposed as a potential method to mitigate global warming, but it is a too strong statement saying that climate engineering is needed in climate mitigation. In fact, in the abstract of Lawrence et al. (2018), as cited here, it states: "Based on present knowledge, climate geoengineering techniques cannot be relied on to significantly contribute to meeting the Paris Agreement temperature goals"

Line 65: Please provide reference for these approaches. In particular, what is 'spraying sea water over sea ice' and 'oceanic evaporation enhancement' approaches?

Line 67-70: It is confusing to state that they are global-scale schemes. In theory, each of the schemes described here can be implemented at either global or local scales.

Line 70: This sentence needs some rewriting. Stratospheric sulphate injection is usually considered to be relatively inexpensive.

Method:

In addition to fundamental difference between GLENS and CO2 mitigation, these two sets of simulations use different versions of CESM, which adds another uncertainty to the results presented here.

By just reading the paragraph of the carbon capture and storage experiment, it's not clear to me whether this is emission-driven or concentration driven. It says net emission is reached at year 2050, and then says the corresponding CO2 concentration is prescribed rather than simulated. Also, a figure showing the emission (or concentration) pathway for the carbon capture and storage experiment should be presented.

2.4 Hydroclimate variables examined: The authors state: "we focus on climate quantities over land due to their close relevance to agriculture, ecosystems, and the carbon cycle ..". Why not also analyse some variables directly related to agriculture and carbon

cycle, such as terrestrial gross and net primary production? They are available from CLM output.

Page 6, line 71: “Climate model output cannot be taken at its face value”. This statement is not true. It depends on purpose. For climate modelling studies that aim to understand fundamental mechanisms, no bias correction is needed at all.

3. Mitigation at the global scale Most of this section is devoted to the presentation of numerical values and the characteristics for temporal evolutions of temperature, precipitation, and potential evapotranspiration. This kind of discussion should be shortened and replaced by scientific discussions of the underlying mechanisms.

It is not surprising that temperature response to SAI is quicker than that to carbon capture because of the long timescale associated with CO2 forcing, but I think more analyse should be done for the change in hydrological cycle. How does the change in PET compare the change in soil moisture as presented by Cheng et al. (2019)?

For carbon capture simulation, what is the role of the direct CO2 effect on land through the influence on stomatal opening, leaf area index, and vegetation dynamics (if any)? Anyway, just to present numbers does not help much to improve our scientific understanding.

3.1 temperature The lengthy discussion of global temperature change does not really provide any scientific insight. All it says it that SAI stabilize temperature change and carbon capture maintains 1.5 degree warming by the end of this century, both of which are achieved by experiment design. We can just use a few sentences to cover this info.

Page 9 line 43: What is ‘carefully introduced’?

Page 9, line 47: “Because of the careful experiment design here’. Does it imply that previous experiments are not carefully designed? Please rephrase.

Page, 10, lines 87-88 “For example, the mid-century projected PET increase is 102.2 mm/year, but the Sulfur Injection can lower that by 127.8 mm/year, which drops the

absolute value of PET by 25.6 mm/year”

102.2 mm/year is lowed by 127.8 mm/year? Please check the math and expression here.

Regional change: How does the presented PET change for GLENS compare with soil moisture change presented by Cheng et al. (2019)? This should be discussed.

Page 15, lines 50-53: As clearly stated here, there is no direct comparison between GLENS and carbon capture experiment here. First of all, temperature change is not the same, which masks the usefulness of this study.

5. Normalized change To what extend PET change scales with global mean temperature change at regional scale?

Page 16, lines 71-75: There are many studies on the different precipitation sensitivity to CO2 and aerosol forcing. The authors should discuss some of them, in addition to their own study (Lin et al., 2016)

Page 16, lines 76-77: I don’t understand how this conclusion is drawn. In this paragraph, only CESM model is mentioned.

Page 16, lines 83-84: I just don’t understand this sentence.

Page 17, lines 9-10: Does the contribution from different climate variables to PET add linearly to their combined effect?

Page 17, line 18: What does the weaker sensitivity of sulphur injection mean? It should be ‘the sensitivity of XX to sulphur injection is weaker’.

Page 19, lines 56-60: “Instead, we aim to highlight the physical mechanisms at play, especially when distinct between the two approaches (e.g., radiative balances and dynamic response).” I really don’t see what insightful physical mechanisms are highlighted in this study.

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