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Earth System Dynamics
Discussions

Interactive comment on "The response of terrestrial ecosystem carbon cycling under different aerosol-based radiation management geoengineering" *by* Hanna Lee et al.

Anonymous Referee #2

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This manuscript studied how vegetation carbon and soil carbon changes under three solar radiation management: sulfate aerosol injection, marine cloud brightening and cirrus cloud thinning. The three SRM strategies result different responses of terrestrial carbon pools. Based on analysis of temperature and precipitation changes, they concluded that precipitation is the factor to determine the terrestrial carbon storage under SRM scenarios comparing with RCP8.5. They also concluded that CO2 concentration and land surface usage play a more important role than climate changes under SRM. There are only a few works on SRM impacts on vegetation and terrestrial carbon cycle, and more research are needed to further understand vegetation and carbon cycle responses to climate changes from SRM. Therefore, this study is filling the gap

in SRM impact study and is the first to compare three SRM methods. However, some improvements are needed in writing and analysis.

General Comments:

This manuscript only analyzed temperature and precipitation as biome average and concluded precipitation is the determine factor for plant NPP. However, the relation between precipitation and NPP may not be cause and effect. (1) other climate factors important to vegetation and soil respiration are ignored. Diffuse and direct radiation have only be looked at as land average. CO2 fertilization effect might be different under different combination of T&P. Comparing to precipitating, soil moisture is more important to plant growth. (2) within one biome, is NPP change homogeneous? What about temperature and precipitation? What is the fundamental phenology to explain the relationship between precipitation and NPP/soil respiration? In addition, please don't repeat the same sentences in abstract, introduction and conclusion.

Specific Comments:

1. Line 2: please change "and at the same time help reach" to "by reaching"

2. Line 4-6: Please change the sentence to something like "Here we assess the changes of ecosystem carbon exchange and storage among different terrestrial biomes under three aerosol based radiation management (RM) methods with the baseline of RCP8.5 using an Earth System Model (NorESM1-ME)."

3. Line 7 and in the whole manuscript: please change "marine sky brightening" to "marine cloud brightening", "MSB" to "MCB"

4. Line 8: please add "reach" before "that of the RCP4.5 scenario"

5. Line 8: please delete "different" after "three". Please change "exhibit" to "show"

6. Line 9: please delete "due to the methodological differences in how the aerosols are applied"

7. Line 10-11: please change the sentence to “Precipitation differences from the three RM methods result large variability in global vegetation carbon uptake and storage”

8. Line 11: add some explanation, why “these consequences should be taken into account in future climate policies”

9. Line 14-17: rephrase the two sentences “We find that changes in vegetation . . .in the tropics. Hence. . .”

10. Line 21: please change “Reaching global climate target of 1.5-2 oC” to “This temperature target”

11. Line 22: please change “but also” to “and also”

12. Line 23-26: please rephrase the two sentences. They are the same as in the abstract.

13. Line 34-35: What is the reason of using RM instead of SRM? SRM is a much more used term in the field. Originally, I thought the reason of using RM is because CCT is included, which is management of longwave radiation instead of solar radiation. But now I am confused.

14. Line 44: please rephrase “unless atmospheric CO2 concentrations are not dealt with during such a RM deployment period”

15. Line 47: please add references: Xia et al., 2016, Yang et al., 2020

Xia, Lili, Alan Robock, Simone Tilmes, and Ryan R. Neely III, 2016: Stratospheric sulfate geoengineering could enhance the terrestrial photosynthesis rate. Atmos. Chem. Phys., 16, 1479-1489, doi:10.5194/acp-16-1479-2016.

Yang et al., (2020) Assessing terrestrial biogeochemical feedbacks in a strategically geoengineered climate, Environmental Research Letters, https://doi.org/10.1088/1748-9326/abacf7

16. Line 53: please correct this sentence “The mechanism how different methods stabilize the climate are slightly different.” The mechanism of the three methods are quite different. SAI and MCB are managing shortwave radiation, and CCT is modifying terrestrial radiation.

17. Line 59-60: please clarify the two sentences: is the precipitation the main reason for the different responses in global average and high latitude NPP? That isn’t cause and effect. The difference of NPP in global mean and high latitude is due to many reasons, such as regional changes, different combination of temperature/precipitation. In addition, I don’t understand why comparing global mean and high latitude? Or maybe the author tries to say there are different NPP responses in climate models? In that case, precipitation is not the main reason. The different land models and how they represent C-N cycle are the main reason.

18. Line 79-89: more introductions on land model: how carbon pools are calculated, how soil carbon and nitrogen is affected by climate changes, how photosynthesis is represented. . . Also, since land model is adopted from CLM4, if comparing with CLM5, what are the advantages and disadvantages?

19. Line 104: Tilmes et al. (2015) is to reduce radiative forcing from RCP6.0 to RCP4.5. To clarify, maybe add something like “based on the approach of Tilmes et al., (2015), although different reference cases are used.”

20. Figure 1 and Line 137-141: It is better to show the temperature response or the radiative forcing change TOA first. Then describe details of direct and diffuse radiation. CO2 concentration change should be the last, after all interactions with the terrestrial system and ocean.

21. Figure 1: (1) please use the full names for subtitles (and please do this for all figures); (2) CO2 in subtitle should be CO2; (3) please indicate what is “-60 to 70°N”; (4) please change the line thickness of plots’ boundaries thinner (please do this for all figures); (4) please show the radiation at TOA first; (5) why are temperature reduction in

three methods similar, but soil respiration changes are different? (6) Why does RCP4.5 show much lower soil respiration than three RM scenarios?

22. Line 146: please explain why CCT has precipitation higher than RCP8.5 here instead of saying the reason is in Muri et al., 2018. You can explain it here, and then cite Muri et al., 2018 to support.

23. Line 148: please cite Figure 2 for precipitation pattern changes.

24. Line 153: please change “largeo” to “large”. The increase is compared to which period?

25. Line 156-159: please break this long sentence into two or three sentences.

26. Line 160: please add reference Xia et al., 2016. Did you look at photosynthesis changes under those scenarios? Although there is no significant change in NPP, there might be changes in photosynthesis rate and GPP, but respiration changes may play an important role in NPP.

27. Line 163-166: the description of precipitation pattern change under three scenarios are not accurate. Middle latitude over Northern Hemisphere are important in term of NPP and agriculture. And all methods show precipitation reduction over east Asia.

28. Line 167: please rephrase this sentence.

29. Line 171-172: “In all biomes, SAI application results in the largest decrease in precipitation followed by MSB, and CCT relative to RCP8.5 scenario.” Is not accurate, since CCT results more precipitation than in RCP8.5 in some biomes.

30. Line 179: precipitation in SAI does get less than RCP4.5 even averaging only land (Figure 1).

31. Line 181-186: it might be better to describe the overall pattern of NPP change in three scenarios (reduction over the high latitude and spread responses over the mid-low latitudes), and explain why, then get into details of how precipitation difference

might control NPP responses over sub-tropic and tropic regions.

32. Line 181-182: why showing the correlation between precipitation and NPP? This cannot support NPP changes in RM scenarios are due to precipitation changes.

33. Supplementary information 3: please change figure caption. This is average of biomes not -60 to 70°N land. Please use RCP8.5, RCP4.5 in the legend instead of R8.5 and R4.5 (also in all other figures in supplementary materials).

34. Line 202-206, please rephrase this sentence.

35. Line 209-213: Based on Figure 3 and 4, NPP and soil respiration show similar changes as precipitation in temperate forest and grass-shrubland biomes as well. In Figure 5, temperate forest and grass-shrubland should show similar pattern as NPP under three RM scenarios (as they all use the same land surface data as in RCP8.5). The changes are not obvious in Figure 5 is because of the scale and the accumulative C.

36. Figure 4, please use the same scale.

37. Figure 4: unit is wrong, should be gC m-2 yr-1

38. Figure 4: why does soil respiration show similar patterns as in precipitation? Isn’t soil respiration strongly affected by temperature? How does soil moisture change?

39. Figure 4: why does NPP under RCP8.5-SAI show a jump after termination, especially in temperate forest and grass-shrubland.

40. Line 214: “This likely due to increased respiration rate overshadowing the increase in NPP”, this sentence is incorrect. NPP is GPP minus plant respiration already. If you mean soil respiration, then this respiration has nothing to do with vegetation C.

41. Supplementary information 5: how did soil carbon anomalies calculated? Geo scenarios minus transient RCP8.5? What is the pattern of soil carbon change under RCP8.5?

42. Line 222: please compare with the work from Yang et al., (2020) Assessing terrestrial biogeochemical feedbacks in a strategically geoengineered climate, Environmental Research Letters, https://doi.org/10.1088/1748-9326/abacf7

43. Line 231: what does “the rate of carbon uptake” mean here? NPP or net ecosystem carbon flux?

44. Line 235: could you please estimate how much CO2 concentration change will be based on this 170 PgC difference. Under RCP4.5 and RCP8.5, the anthropogenic CO2 emission difference will cause different CO2 concentration. But what will be CO2 concentration different resulting from the land surface usage difference?

45. Line 239: NPP changes under three RM scenarios do have similar patterns with precipitation changes, but that doesn’t mean precipitation change is the reason of NPP changes. Soil respiration is also showing similar pattern. Could the NPP changes due to nitrogen limitation from organic matter decomposition?

46. Line 240-242: This might be incorrect: (1) studies show that cooling over tropics has positive impact on crops comparing with global warming; (2) agriculture will have irrigation, which will be different than natural vegetation.

47. Line 251-252: why is there an increase of soil carbon under RCP4.5? what about RCP8.5?

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