

Interactive comment on “Radiative and climate effects of stratospheric sulfur geoengineering using seasonally varying injection areas” by Anton Laakso et al.

Anonymous Referee #3

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General Comments:

This study aims to investigate how different sulfate injection strategies (from different locations) would affect the changes of radiative forcing, temperature and precipitation using ECHAM-HAMMOZ and MPI-ESM. This type of study is a good fit for ACP GeoMIP special issue. However, more clarifications and analysis are needed.

More detailed model description and the experiment design are needed. It is not clear whether the model has chemistry involved, how the experiments are set up, e.g. whether the injection is continuously over the year or just couple individual injections in different seasons? What is the amount for each individual injection?

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The set-up of this experiment (separating the aerosol model and the climate circulation model) limits the soundness of the conclusion. The offline calculation of radiative properties of stratospheric aerosol will prohibit the feedback between the stratospheric circulation change (e.g. Brewer Dobson Circulation) and the aerosol transport. There should more discussion on this.

More analysis are needed on the aerosol micro-physics (e.g. the aerosol size distribution change, how long it takes for SO₂ changing to H₂SO₄?), aerosol chemistry (e.g. OH map in different seasons? whether the model includes ozone chemistry in the stratosphere?), and the trajectory (e.g. stream function of the stratospheric circulation to indicate how sulfate aerosol is transported under different injection strategies? The transport of SO₂ and H₂SO₄?)

Specific comments:

Page 1:

-Lines 11-12: “In geoengineering studies these injections are ... the solar radiation is highest”. This sentence sounds like the only reason of tropical injection is because of the highest solar radiation. But actually, there is another important reason: the strong upwelling in the tropics brings sulfate aerosols polar-ward through Brewer Dobson Circulation.

-Lines 12-13: “However, it may not be the most optimal ... the meridional temperature gradient”. What is ‘optimal’? Why do we need to keep the meridional temperature gradient as the same as before geoengineering?

-Line 20: should it be “the reduction of shortwave radiative forcing decreased by 27% ... and increased by 15% ...”? As shown in Figure 3.

-Lines 21-23: “Compared to the continuous ... hemispheres respectively”. This sentence is confusing. In summer months, radiative forcing increase in both hemispheres when comparing p2 to EQ? But figure 4 shows different results.

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-Line 23: How to qualify “significant changes in temperatures”?

-Lines 23-25: Please rewrite “Based on ESM . . . scenarios studies here.” It is not clear which scenarios are compared here

Page 3:

-Lines 7-16: Are injections in EQ, NH, NHH once a year? If so, when?

-Lines 18-24: Are injections in p0, p2, p4, p6 and p2w continuous? If so, what is the flux? If not, what is the amount for one injection? The location is changing in what time step? Monthly or seasonally? Figure 2 shows very smooth change of the locations.

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-Line 8: Add citation for HAM. And add couple sentence to evaluate

-Lines 15-19: Does MPI-ESM include atmospheric chemistry, such as ozone chemistry? Does the land model and the ocean model (as well as the ocean biochemistry model) fully coupled or just data model?

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-Line 17: not just because “in these two scenarios sulfur is injected to an area where solar intensity is on average weaker”, but also the transport of sulfate aerosol in NH and NHH is not as efficient as in EQ. It would be very helpful to look at how the aerosol transport evolves in difference scenarios.

-Line 25: It would be helpful to look at the size distribution in different scenarios.

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-Line 12: Is OH specified in the model, or there is interaction with the UV and water vapor change?

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-Lines 5-14: There should be sentences discussing this sulfur distribution doesn't include the changes in stratospheric dynamics induced by the sulfate injection geoengineering.

Page 9 - 10:

-Lines 29 (p9)-5(p10): Does this model include water vapor radiation? In sulfate injection scenarios, temperature reduction would reduce the water vapor content in the atmosphere, which reduces water vapor greenhouse effect as well.

-Line 16-19: Please reorganize this sentence "climate was clearly over cooled before SRM was suspended compared to years before SRM when G4 tempters has been kept same"

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-Line 2-17: Since the goal of the experiment design is to reduce the tropic-polar temperature gradient change due to sulfate aerosol injection, it would be better to plot Figure 7 in a different way. Instead of using EQ as the base line, it might be better to use RCP4.5. In that way, we could see how EQ changes the temperature gradient as well as other scenarios. Also it might be better to calculate the tropic-polar temperature gradient and plot the time series change under different scenarios.

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Summary and conclusion: This part has too many repeating from the method and results sections. It would be better to add more discussion on the uncertainty of this work.

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