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Earth System Dynamics
Discussions

Interactive comment on "Climate System Response to Stratospheric Sulfate Aerosols: Sensitivity to Altitude of Aerosol Layer" *by* Krishnamohan Krishna-Pillai Sukumara-Pillai et al.

Anonymous Referee #2

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The authors simulate the solar radiation method (SRM) of stratospheric sulfate aerosols by prescribing a uniform layer of sulfate aerosol concentration. Assuming different altitudes of this layer, they determine the impact on different variables like radiative forcing, surface temperature, and humidity and temperature in the stratosphere.

The paper is very well written and includes an impressive literature review. I recommend publication after the authors addressed the following comments.

General comments

My main concern is related to the prescribed aerosol layer. Prescribing aerosols in a climate model is a widely used technique and can be used to be computationally more

efficient. However, the prescribed layer should be comparable to reality and preferable been calculated previously with a aerosol microphysical model. This study simplified the method by prescribing the aerosol concentration meridionally uniformly at a certain height (km) above sea level. This distribution is quite unrealistic. However, this may not have extremely strong impact on the main conclusion of the paper, the dependency of radiative forcing on altitude.

Stronger impact has the fact that the prescribed profiles do not include the changes caused by sedimentation. Sedimentation causes a vertical spread of the aerosols, the stronger the higher the injection altitude above the tropopause (e.g. (Tilmes et al. (2017)). This difference to a more realistic profile is not mentioned in the paper. As a consequence, heating of the aerosols will not occur in a small layer as shown in Figure 6a and 7. The heated layer extends to the tropopause. This has consequences for clouds and humidity transport. This aspect is not at all discussed in the paper.

I agree with the authors that a simplification is useful and can help to gain new insight. The dependency of the radiative forcing on the altitude of the SRM agent has been shown for three different SRM techniques by Niemeier et al (2013). Sulfur injection studies have shown that the resulting radiative forcing depends on the altitude of the injection. This has mostly been related to the vertical extension of the aerosol layer. This paper could give new insights by adding a simulation with more realistic sulfate profile. This would show whether the altitude of the injection or the vertical extension of the aerosol layer is the cause of an increased radiative forcing.

The limitation of the model, no aerosol microphysics, are well described. The more important limitation of the prescribed sulfate concentration are not prescribed. Please, add a figure of the prescribed sulfate layers in the main article. For a reader who is not familiar with stratospheric sulfate distribution it would be very helpful.

Specific comments

Page 3 Line 27: I don't understand this sentence.

Section 2.2:
How is the sulfate layer created? The global distribution in Nalam et al (2017) is unrealistic. Aerosols follow tropopause in a meridional cross section (e.g. Visioni et al. (2017) or Dhomse et al. (2014)).

Add figures of sulfate distribution.

It remains unclear how the sulfate is distributed vertically. I assume you only change the height of the prescribed layer.

Page 4 Line 22: 20 Mt SO4? Change unit to Tg (SI unit)

Page 6 Line16: Thus, CO2 reduction would be most effective. This would be a good statement in the conclusion.

Page 7 Line 16 - 26: Results of Kuebbeler et al (2012) should be taken into account.

Page 8 Line 30: See also Liepert and Prevedi (2009) and Kravitz et al (2013).

Page 8 Line 27pp: This is a very short summary of this topic.

Page 9 Stratospheric dynamics: The vertical resolution of you model is very limited. Good results of stratospheric dynamics need a higher resolution, even in a model that is still not capable to generate a QBO. You should mention the QBO in the first paragraph and not only cite the two papers.

Page 9 Line 27: You show significance for the temperature. How about the zonal wind? Your differences are very small. Please add a figure with significance of the zonal wind.

Page 9 Line 29: Higher temperature in the tropics because of more solar radiation. The aerosols cannot absorb as much radiation during polar winter then during summer.

Page 10 Line 3: Significant?

Page 10 Line 4 to 10: Your vertical profile of aerosols is unrealistic. As a consequence the vertical profile of temperature anomaly and humidity anomaly are unrealistic. You

have to say this and the consequences for your results.

Page 12 Line 5 to 6: I don't understand this sentence? What would be the relation between microphysics and global mean surface temperature?

Page 12 Line 15-16: This is not a new result and can be found in many previous studies. I don't think there is a tendency to include radiation to aerosol coupling for SW only in the models, at least not in general.

Page 12 Line 25 Many studies show that higher altitude of injection causes stronger forcing. Most studies relate this to the thicker aerosol layer. Niemeier et al. (2013) have show that for different SRM methods the forcing depends on the altitude of the forcing agent. Thus, your result is not new. It remains open, whether the top level of the aerosols or the vertical extension of the sulfate layer is more important. Your study would gain a lot if you could answer this by adding a simulation with a more realistic vertical profile.

Page 13 Line 15 to 25: As stated above, the main limitation is the profile itself. The profile changes when injecting at higher altitude and the particle sediment. This has to be reflected in your profile and would change e.g. vertical humidity transport.

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