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Atmospheric Chemistry and Physics Discussions

Interactive comment on "What is the limit of stratospheric sulfur climate engineering?" *by* U. Niemeier and C. Timmreck

Anonymous Referee #1

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General Comments

Generally, this is a well presented modelling study of climate engineering by stratospheric SO2 injection. It examines and for the most part clearly explains some of the impacts of variations in injection strategy and how microphysical and dynamical effects interact to produce these impacts.

However, in its current form it fails to adequately answer the question posed in its title (see Specific Comment 5). I've assigned this paper to "Minor Revisions", but this particular section (arguably the culmination of the study) really needs "Major Revisions". However, if this and the other comments below are addressed, then I think it should certainly be published.

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Specific Comments

1. Page 10943, lines 5-14: A few words describing how atmospheric oxidants are handled would be useful, i.e. whether they're prescribed or modelled interactively.

2. Page 10946, lines 18-20: Aerosol number in the coarse mode also appears to increase more rapidly than that in the accumulation mode (the lines in Fig. 1 are more widely separated in the coarse mode when compared with the accumulation mode), which might be worth mentioning.

3. Page 10952, line 21: It would help if it was made clear which of the seven lines in E12's Fig. 9 were used and how they were "estimated and simplified". Was there any scaling of the 525nm AOD in E12's Fig. 9 to the 550nm AOD used here?

4. Page 10945, lines 7-11; Page 10953, lines 13-15; Page 10955, lines 1-4: Throughout the paper (I've just selected certain points where the issue is addressed) it needs to be emphasised that the values obtained in this study are for the specific injection altitude chosen. The authors mention (p.10945) that increasing the injection height also increases the efficiency, but there is no quantitative analysis of this effect. This point needs to be made again later in the paper in Sections 4 and 5 where a specific forcing value or values are discussed - these only apply for the altitude chosen. Some quantitative estimate of the range of how the forcing and efficiency might vary with injection height is desirable.

5. Page 10953, lines 17-24: This Section is the biggest problem with the manuscript. After careful explanation and analysis up to this point the paper loses its way here. Specifically:

(a) What is the source of the "flight emissions" data? Are the emissions comparable to the geoengineering levels under discussion? (line 17).

(b) I can't make sense of the phrase "injection efficiency given per achieved reduction of TOA forcing in Wm-2" (line 18).

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(c) The efficiency of SO2 injection was defined previously (page 10945, lines 20-21) as "the ratio of the top of atmosphere (TOA) forcing to injection strength", which is quite clear. Here, however, it's defined differently as "the amount of sulfur per Wm-2 which is needed to get a certain TOA forcing" (lines 19-20), which I don't follow.

(d) Then (line 20) there's a reference to "These data" - which data?

(e) Then follows (lines 20-22 and more in the next paragraph) some numerical values which appear out of nowhere with no explanation of their source. Neither do I understand what they mean. In lines 20-22 it says "to obtain a reduction of -1 Wm-2 an injection of 4.5 Tg(S)/yr per Wm-2 is necessary, while -7 Wm-2 TOA forcing requires an injection of almost 10Tg(S) per Wm-2". Where do these numbers come from? What does it mean to describe an injection in units of "Tg(S)/yr per Wm-2"? To me, an injection rate is an amount of substance per unit time, so I don't understand what it means to describe an injection in terms of mass per unit time per Wm-2.

This section, where the central question of the paper's title is finally addressed, needs to be thoroughly revised. As it stands it makes no sense to this reviewer.

Minor Comments/Technical Corrections

1. Page 10941, lines 17-18: Change "counteract" to "reduce".

2. Page 10942, line2 21-22: Change "applied model version" to "model version used".

3. Page 10943, lines 25-26: Change "calculated aerosol concentrations in the tropics were six months after the eruption lower than observed" to "calculated aerosol concentrations in the tropics were lower than observed six months after the eruption".

4. Page 10946, line 7: Change "extends" to "extrapolates".

5. Page 10947, line 25: Change "forms continuously" to "continuously forms".

6. Page 10948, line 3: Change "are larger particles in accumulation and coarse mode" to "larger particles in the accumulation and coarse modes are".

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7. Page 10948, line 9: Change "are large and fine particle sizes" to "large and fine particle sizes are".

8. Page 10950, line 17: "injectiona" should be "injection".

9. Page 10951, line 19: I think "GEO1-10" should be "Geo10".

10. Page 10953, line 10: "switching of" should be "switching off".

11. Page 10961, caption to Table 1: Include a few words to make it clear that "Geo10", which occurs a lot in the text but is not in the Table, is just the 10 Tg(S)/yr version of simulation "Geo".

12. Page 10963, Figure 1 (Left): Remove the crosses from the part of the curve for injection rate values greater than 100 Tg(S)/yr: having them on the plot implies that simulations were done for these rates (at about 120, 140, 160, 180 and 200 Tg(S)/yr) but the text suggests that this is just an extrapolation of the fit.

13. Page 10964, Figure 2: A colourblind person is likely to find this plot difficult to interpret - I suggest either changing to a "colourblind accessible" set of colours or taking a different approach to this plot.

14. Page 10967, caption to Figure 5: The phrase "with different injection rates of 10 Tg(S)/yr" doesn't really mean anything. If they're all injecting at 10 Tg(S)/yr then the rates are not different. I think you mean that they all inject at the same rate but have different injection strategies or implementations.

Interactive comment on Atmos. Chem. Phys. Discuss., 15, 10939, 2015.