

Response to Reviewer 1 of manuscript
“Climate impact of volcanic eruptions: the sensitivity to eruption season and latitude in MPI-ESM ensemble experiments” by Zhihong Zhuo et al.

We are very grateful to Daniele Visioni for your kind efforts and thoughtful comments, which are very helpful for enhancing the clarity and quality of the manuscript. We have revised the manuscript carefully according to the comments. The list of the reviewer’s questions and comments (*in italic*) as well as our responses are listed below. Text added to the manuscript is in red. Text removed is in red and struck through.

Daniele Visioni (Referee)

In this work the author analyze the climatic response to tropical and extratropical idealized volcanic eruption, simulating injections at three latitudes and two seasons, and describing the changes at the surface, focusing in particular on surface temperature, precipitation (with a focus on ITCZ shifts and Indian monsoon and cloud cover. The paper is scientifically sound, even if it has a tendency in places to repeat the same, somewhat obvious concept multiple times (like the fact that higher cooling is produced where the aerosols are localized), but it is overall interesting, and the size of the ensembles used allow for some interesting, robust observation. So I think the work can be published on ACP, but the text (and the quality of some figures) needs to be improved in places to make reading it easier. I have offered some suggestions below.

Thanks for the positive feedback and comments regarding the study. We have revised the text according to the comments and checked carefully before the final submission. The quality of figures will be ensured. They are in PDF format and will be separately uploaded for the final submission.

Abstract *Using parenthesis that way makes the abstract unreadable. Better to use two phrases. Please see Robock, 2010 as to why <https://eos.org/opinions/parentheses-are-not-for-references-and-clarification-saving-space>. The same is valid for the whole text in multiple places!*

Thanks for the comment and the reference. We have removed all the parentheses.

L 18: “emphasizes”

Revised.

Introduction

L 39: “have been thought” -> “are considered to be”

L 60: aims “to answer”, no capital letter for “How”

Revised.

Method

(add an s to “Methods”)

Revised.

Add information on chemistry used: I assume it’s prescribed, but better to specify.

We added this sentence:

Chemical processes are not explicitly simulated, and background tropospheric and stratospheric aerosols, as part of the forcing data, are represented by their aerosol optical properties (Giorgetta et al., 2013).

Line 93: which longitude? It's not specified here.

In this study, the volcanic forcing is generated with the EVA module and then the forcing file is read in when running model simulation with MPI-ESM. This is different from other model simulations with an interactive aerosol module. EVA is a simplified module with emulated time evolution of sulfate mass base in a chemical box model framework in the troposphere and three-boxes in the stratosphere. Each eruption is treated as an instantaneous injection of SO₂ into one of the three boxes, with the injection region based on the latitude of the volcano (Toohey et al., 2016). Thus, we can only specify the eruption latitude in the EVA module.

Line 102: "remains an unsolved question"

Revised.

Line 113: maybe add "IVT = " to the equation?

Added as suggested.

Results

Line 127: see my comment in the Abstract about that use of parenthesis

We have removed the parentheses that were misused for shortening the sentences.

Line 130: if the scale in Fig. 2 was a bit narrower (no point in plotting AOD after 1994), one could maybe tell how many months was the "several" said here? Or just specify the e-folding time of the plume.

Here, "several" is "six", as it reached the maximum in December 1991 (June 1991) for the summer (winter) eruptions" as shown in line 130 in the preprint manuscript. We revised the sentence to:
and is reached after ~~several~~six months, i.e. in December 1991 and ~~(June 1991)~~ for the summer and ~~(winter)~~ eruptions, respectively.

Line 135: it depends on the specific of the stratospheric circulation, yes, which are dependent on the season. For instance, see Tilmes et al. (2017) and Vioni et al. (2019) where we tested injections of SO₂ in all season at various latitudes in a systematic way with CESM1(WACCM) and the different transport paths are evident.

We revised the general description of "atmospheric circulation in the tropical stratosphere" to more specified description:

This indicates that the transport of volcanic aerosols from equatorial eruptions to high latitudes depends on the eruption season, which is related to the ~~atmospheric circulation in the tropical stratosphere~~ large-scale transport of the Brewer Dobson circulation (Hamill et al., 1997).

We also added discussion on the seasonal distribution of stratospheric aerosols in the discussion part, as shown in the following sentences:

~~These may be the potential reason that the climate response is not sensitive to the eruption season in our study, as the aerosol distribution in the stratosphere depends on the injection season (Aquila et al., 2012; Tilmes et al., 2017; Vioni et al., 2019).~~

Line 154: I'm not sure what this confirms, other than the obvious observation that there is less solar radiation at high latitudes during winter?

Since "confirm" may be misunderstanding, we changed it to "reflect":

This ~~confirm~~reflects the role of the seasonal change of the incoming solar radiation in the two hemispheres.

Line 156: SR is not reflected at the TOA. We see it at the TOA (the model diagnoses it as such) but the SR is reflected in the stratosphere by the volcanic aerosols, thus decreasing SR reaching the surface and cooling the surface.

We revised the sentence to:

SR ~~at top of the atmosphere~~ is reflected by the volcanic aerosols ~~in the stratosphere~~.

Line 204: aims to explain

Revised.

Line 214-217: this entire phrase makes very little sense. Please rephrase. In which case does “the temperature difference between the hemispheres increases slightly”?

We meant the SH case. As suggested, to make it clearer, we rephrased the sentence to:

Similar results are found in the winter NH and EQ eruption cases, ~~except for that in the SH case~~, while the temperature difference between the hemispheres increases slightly ~~in the SH case~~, indicating a larger cooling in the southern hemisphere than in the northern hemisphere after the winter SH volcanic eruption (Fig. 7b).

Line 220: how is the ITCZ calculated? There are various ways to do so. Is it the precipitation centroid? Global, or between certain latitudes? Or is it calculated with the position of the Hadley Cell? Please explain.

In our study, the ITCZ is indicated by the JJA mean zonal mean precipitation between 20° N and 20° S. This was only described in figure 7. To make it clearer, we added the description at the beginning of the Analysis methods section:

~~The position of the ITCZ is indicated by the latitude of the maximum zonal mean precipitation between 20°N and 20°S.~~

Section 3.5.2 and 3.5.3 are completely unreadable due to all those parenthesis.

Sorry for this. We have removed all those parentheses and rephrased the sentences.

Conclusions

Line 355: “Because of this, extratropical eruptions in the northern (the southern) hemisphere (NH and SH cases) cause larger cooling over the northern (southern) hemisphere continents compared to the equatorial eruption (EQ case)” I Have really no idea how to read this phrase: which one is the parenthesis that is supposed to be read first?

We have revised the sentences to:

Because of this, extratropical eruptions in the northern ~~(the southern)~~ hemisphere (NH ~~and SH~~ cases) cause larger cooling over the northern ~~(southern)~~ hemisphere continents, ~~while SH cases cause larger cooling over the southern hemisphere continents~~, compared to the equatorial eruptions (EQ cases).

Figures

Some figures (2-3-4) are incredibly low resolution, and they’re very hard to understand because of it. Make sure they are higher quality before resubmitting.

The problem occurred after we merged the pdf figures into the word file. Sorry for the inconvenience, we should have noticed and dealt with the problem. The figures should be clear when separately submitted in pdf format for the final submission.

Figure 9 would benefit from being more specific in the titles for panels b-d that it is a difference with CTR, and not the full field, even if it says in the caption.

We pointed out that these are anomalies in Line 118 in the preprint manuscript. And as the referee said, it's clear from the caption. The different scale of color bar should also give a hint. Because all the other figures with EQ, NH, SH in the title also show anomalies, we think it is better to keep it simple and consistent throughout the manuscript.

References

S., Tilmes, H., Richter J., J., Mills M., B., Kravitz, G., MacMartin D., F., Vitt,... F., Lamarque J.â (2017). Sensitivity of aerosol distribution and climate response to stratospheric SO₂ injection locations. *Journal of Geophysical Research: Atmospheres*, 122, 12,591– 12,615. <https://doi.org/10.1002/2017JD026888>

Visioni, D., MacMartin, D. G., Kravitz, B., Tilmes, S., Mills, M. J., Richter, J. H., & Boudreau, M. P. (2019). Seasonal injection strategies for stratospheric aerosol geoengineering. *Geophysical Research Letters*, 46, 7790– 7799. <https://doi.org/10.1029/2019GL083680>

Thanks for the references.