Response to reviewer 2

Thank you very much, for your very helpful comments and suggestions (indicated in bold and italic). You will find our point-by-point reply to them below.

"My only comment regarding the protocol concerns the TAR experiment "db1". This is a mandatory (Tier 1) experiment that uses preferably tabulated point sources or, optionally, 3D data. However, the latter option is given an own identification in the protocol and a different priority (Tier 3). There may thus be a conflict, as a mandatory experiment is optionally bypassed by performing a low-priority experiment. If the two experiments are equivalent alternatives, they should be given the same priority, or even appear as the same experiment with the selected option to be reported in the metadata.

I recommend some clarification."

We accept the original description of the TAR experiment may have been confusing. To ensure comparability between all of the three data sets we agreed on point sources for the volcanic emission in the mandatory (TIER1) experiments. For clarification we have changed the following sentence:

Page 11, lines 379-380: "If modelling groups prefer not to use point sources, we additionally offer VolcDB1_3D which provides a series of discrete 3D gridded SO_2 injections at specified times."

to

Page l1, lines 37-382: "To test the effect of the implementation strategy (point source vs cloud) an additional non-mandatory experiment has been set up: tar_db1_sub with VolcDB1_3D as corresponding data set which provides a series of discrete 3D gridded SO_2 injections at specified times. "

To clarify, we also changed slightly the text:

Page 12, lines 401-402: "The optionally provided VolcDB1_3D data set, contains volume mixing ratio distributions of the injected SO_2 on a T42 Gaussian grid with 90 levels.

to

Page 12, lines 401-404: "The VolcDB1_3D data set, for the optional experiment tar_db1_3D contains volume mixing ratio distributions of the injected SO_2 cloud on a T42 Gaussian grid with 90 levels. The integral SO_2 mass for each injection is the same."

"As a general note, an expanded description about potential synergies and links with other ongoing MIPs would better highlight the value of ISA-MIP for the broader climate modelling community."

We have included in the summary the following sentences:

Pages 18-19, lines 632-649: "For example, the CMIP6 Geoengineering Model Intercomparison Project (GeoMIP, Kravitz et al., 2015) investigates common ways in which climate models treat various geoengineering scenarios some of them via sulphate aerosols (e.g. Tilmes et al., 2015). However, there is a large inter model spread for the cooling efficiency of sulphate aerosol, i.e. the normalized cooling rate per injected unit of sulphur (Moriyama et al., 2016). ISA-MIP is therefore of special importance for GeoMIP as it could help to understand the reason for these uncertainties, to better constrain the forcing efficiency and to improve future scenarios. Furthermore it is so far not clear whether the large inter-model spread of the CMIP5 models in the simulated post-volcanic climate response mostly depends on uncertainties in the imposed volcanic forcing or on an insufficient representation of climate processes. To discriminate the individual uncertainty factors it is useful to develop standardized experiments/model activities that systematically address specific uncertainty factors. Hence ISA-MIP, which covers the uncertainties in the pathway from the eruption source to the volcanic radiative forcing, will complement the CMIP6 VolMIP project (Zanchettin et al., 2016) which addresses the pathway from the forcing to the climate response and the feedback, by studying the uncertainties in the post-volcanic climate response to a well-defined volcanic forcing. ISA-MIP also complements the chemistry climate model initiative CCMI (Eyring et al., 2013) and the Aerosol Comparison (AeroCom) initiative (Schulz et al., 2006) as well as the Aerosol Chemistry Model Intercomparison Project (AerChemMIP, Collins et al., 2017) as it concentrates on stratospheric aerosol which is not in the focus of all these activities."

Specific comments on the manuscript:

Line 78: please check, the acronym OCS seems to be only introduced in line 164

We have included the explanation of OCS now earlier in the manuscript.

Page 3, lines 90-91: "we now have a 2002-2012 long record of global altitude-resolved SO_2, and carbonyl sulphide (OCS) and aerosol …"

Line 186: "compared to moderate eruptions"

We have revised the sentence accordingly to:

Page 6, lines 200-201: "… and predict a reduced cooling efficiency compared to moderate eruptions with moderate sulphur injections (e.g. Timmreck et al., 2010; English et al., 2013).

"Line 295: Across?"

We have revised the sentence to:

Page 9, line 313: "although new in situ measurements indicate that the cross-tropopause-SO2-flux is neglible over Mexico and central America (Rollins et al., 2017)."

"Line 321: the nudging period for the QBO is 1980-2000 (21 years) but the experiment only consists of 20 years. It seems that to include the year 2000 at the end of the simulation, the nudging period should start in 1981."

We have revised this accordingly:

Page 10, lines 329-340: .Modelling groups should run this simulation with varying QBO, either internally generated or nudged to the 1980-2000 period.

"Paragraph 3.3.3: It appears from Tables 5 and 6 that "VolcDB*" identify the datasets, whereas the experiment names are "TAR_db*/TAR_sub". It seems that the text in this paragraph mixes the two (for instance in lines 374-376)."

Thank you very much for this hint. We have revised the sentences to

Page 12, lines 394-397: "Summarising the number of experiments to be conducted within TAR: four are mandatory (TAR_base with no volcanic emission, Tar_db1/2/3), one additional is recommended (TAR-sub) and two others are optional (TAR_db4 and TAR_db1_3D; see Table 5 for an overview)."

Lines 432-438: this is certainly an interesting goal, but in this short description this appears at the edge or even slightly out of the scope of ISA-MIP itself. Can you expand on this?

Whilst we agree with the reviewer that there is no specific experiment aiming to understand the relationship between the ice core sulphate deposition and the stratospheric aerosol layer enhancements that drives the radiative cooling, the idea was to suggest that there is the potential for a systematic multi-model analysis of those 2 metrics (based on the HErSEA results) and seek to identify how uncertain historic volcanic forcings derived from ice core sulphate deposition may be.
We have added the following sentence to the revised manuscript stating that:

Page 13-14, lines, 440-463:"Although HErSEA has no specific experiment to understand the relationship between the ice core sulphate deposition and the stratospheric aerosol layer enhancements that drive the surface cooling, there is the potential for a systematic inter-model study (e.g. similar to Marshall et al., 2018) to identify how uncertain historic volcanic forcings derived from ice core sulphate deposition may be."

"Table 1: some of the information provided is not clearly described. For instance, are the numbers in parentheses in the "Total years" column the recommended integration years? This seems not to hold for the PoEMS where the numbers seem to refer to the number of perturbed parameters. The description of the number of specific experiments for PoEMS also seems to lack clarity."

There was a mistake in the Table provided in the Discussions version of this article which we agree was confusing. In the revised manuscript we have changed Table 1 to be as shown below. We have also re-iterated (in the section 3.4.2 of the text, and in Table 1) the important requirement (currently only explained in the caption to Table 11) that the PoEMS parameter-scalings must only be applied in gridboxes with "volcanically-enhanced airmasses" (determined either by total-sulphur-vmr-threshold or the "passive Volc tracer".

Page 17, lines 592-597: "When imposing the parameter-scalings, the models must only enact that change in grid boxes with volcanically-enhanced air masses. This can be determined either via total sulphur volume mixing ratio threshold suitable for the particular model, or via the "passive tracer Volc" recommended in section 3.3.3. Restricting the perturbation to the Pinatubo sulphur will leave pre-eruption conditions and tropospheric aerosol properties unchanged. ensuring a clean "uncertainty pdf" for the volcanic forcing."

Experiment	**Focus**	**Number of specific experiments**	**Years per experiment**	**Total years** [A]	**Knowledge-gap to be addressed**
....	....	......	.....	.....	....
Pinatubo Emulation in Multiple Models [PoEMS][B]	Perturbed parameter ensemble of runs to quantify uncertainty in each model's predictions	7 experiments per parameter , where the number of parameters refers to the minimum (3), reduced (5) or standard (8) parameter set (see also Table 10)	3 per experiment[c]	63, 105 or 168	Intercompare Pinatubo perturbation to strat- aerosol properties with full uncertainty analysis over PPE run by each model. Quantify sensitivity of predicted Pinatubo perturbation stratospheric aerosol properties and radiative effects to uncertainties in injection settings and model processes Quantify and intercompare sources of uncertainty in simulated Pinatubo radiative forcing for the different complexity models.

[A] Each model will need to include an appropriate initialization and spin-up time for each ensemble member (~3-6 years depending on model configuration).

[B] As explained in the caption to Table 11 and section 3.4, models will need to restrict the PoEMS parameter-scaling to volcanically-enhanced air masses (either via total-sulphur-vmr threshold or passive volcanic SO_2 tracer)

[C] Although the Pinatubo enhancement to the stratospheric aerosol layer remained apparent until 1997 (e.g. Wilson et al., 2008), whereas the HErSEA experiments will continue longer, the PoEMS analysis will require only 3 post-eruption years to be run, as this gives sufficient time after the peak aerosol to characterize decay timescales robustly (e.g. ASAP2006, chapter5)

Table 1 General overview of the SSIRC ISA-MIP experiments

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