Response to reviewer 1

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.

“The authors discuss the climate impact of stratospheric volcanic aerosols, how their large scale distribution may be affected by stratospheric transport oscillations (QBO) and how their size distribution may change as a function of the injected SO2. A paragraph should be added, addressing the potential impact of the aerosol radiative interactions on some features of stratospheric dynamics and transport, as age of air and strat-trop exchange of trace species. Recent studies which may be relevant from this point of view, are those by Ray et al. (2014), Pitari et al. (2016a), Diallo et al. (2017). A brief paragraph on this aspect would make even stronger the need for the proposed MIP. This paragraph could probably be inserted in the Introduction or at the end of Subsection 3.3.2.”

As the reviewer suggested we have included a couple of sentences on stratospheric aerosol and dynamics in the introduction and we also discuss uncertainties in mean age of air at the end of section 3.3.2.

Page 2, lines 57-65: “The consequent heating of the stratospheric aerosol layer strongly influences stratospheric dynamics amplifying the Brewer-Dobson circulation (BDC) and modifying the equator-to-pole temperature gradient. These two primary drivers cause changes to geostrophic zonal winds and the propagation of atmospheric waves (e.g. Bittner et al., 2016; Toohey et al., 2014) and lead to a strengthening of the polar vortex (e.g. Charlton-Perez et al., 2013). The heating from continued SO_2 injection to the stratosphere may further disturb or even “shut down” the quasi biennial oscillation (QBO) (e.g. Aquila et al., 2014; Niemeier and Schmidt, 2017). These composition-dynamics interactions also influence the transport and residence time of other long-lived species (N_2O, CH_4) (Pitari et al., 2016a; Visioni et al., 2017). The enhanced stratospheric aerosol layer after large volcanic eruptions causes also large mean age of air variations on time scales of several years (e.g. Ray et al., 2014; Muthers et al., 2016, Garfinkel et al., 2017).”

Page3, lines 78-81: “…..counteracted the warming due to increased greenhouse gases over that period (e.g. Solomon et al., 2011; Ridley et al., 2014; Santer et al., 2015). Small to moderate volcanic eruptions after 2008 also show an impact on the stratospheric circulation in the Northern Hemisphere, in particular on the pattern of decadal mean age variability and its trends during 2002–2011 (Diallo et al., 2017).”

Page 14, lines 487-497: “Analysing how the vertical profile of the enhanced stratospheric aerosol layer evolves during global dispersion and decay, will provide a key indicator for why the models differ, and what are the key driving mechanisms. Furthermore, the actual response of the BDC and mean age of air to Pinatubo is poorly constrained by existing reanalysis data (Garfinkel et al., 2017). While some modeling studies reported a decreasing mean age of air following volcanic eruptions throughout the stratosphere (Garcia et al., 2011; Garfinkel et al., 2017), show other studies an increase in mean age (Diallo et al., 2017). Moreover, Muthers et al. (2016) found decreasing age of air in the middle and upper stratosphere and increasing mean age below, while Pitari et al. (2016a) found decreasing mean age at higher levels of 30 hPa in the tropics and 10 hPa in the middle latitudes after the Pinatubo eruption. The HerSEA experiment in combination with a passive volcanic tracer might therefore help to better constrain the response of the BDC to volcanic eruptions using observations and help to clarify the uncertainties in age of air changes after the Pinatubo eruption. For all three major eruptions, we have identified key observational datasets (Table 7) that will provide benchmark tests to evaluate the vertical profile, covering a range of different aerosol metrics.”

“References to new studies on volcanic aerosols may be added. The QBO impact on aerosol dispersal and e-folding time has been discussed in Pitari et al. (2016b) and could be cited at

page 5 line 181. A re-examination of the initial SO2 cloud lifetime was made in Mills et al. (2017) and could be cited at page 2 line 51".

To take into account new developments/studies we have included a couple of recent published papers (indicated in blue) in the field:

Page 2, lines 59-52: "Major volcanic eruptions inject vast amounts of SO_2 into the stratosphere, which is converted into sulphuric acid aerosol with an e-folding time of about a month, which might be prolonged due to OH depletion within the dense SO_2 cloud in the first weeks following a large volcanic eruption (Mills et al., 2017)".

Page 3, lines 90- 93: "For example, we now have a 2002-2012 long record of global altitude-resolved SO_2 ,and carbonyl sulphide (OCS) and aerosol volume density measurements provided by the Michelson Interferometer for Passive Atmospheric Sounding Environmental Satellite (MIPAS Envisat, Höpfner et al., 2013; 2015; Glatthor et al., 2015, Günther et al., 2018)."

Page 6, lines 193-196: "Internal variability associated with the QBO alters the isolation of the tropical stratosphere and subsequently the poleward transport of tropical stratospheric aerosol, thereby modulating its global dispersal, particle size distribution, and residence time (e.g. Trepte and Hitchmann, 1992; Hommel et al., 2015, Pitari et al., 2016b,)."

See also further new references included in the answers to other points by the reviewer.

"At page 7 lines 271-273 the authors write: "Modelling groups are encouraged to include a set of passive tracers to diagnose the atmospheric transport independently from emissions mostly following the CCMI recommendations (Eyring et al., 2013). These tracers are listed in Table S3 in the supplementary material." It should be specified that in case modelling groups had already run these experiments, results produced and uploaded for CCMI may also be used for ISA-MIP, taking them directly from the CCMI data repository. I would also suggest to provide a link (as made in Eyring et al., 2013) where gridded input data may be available for download (S fluxes etc.)."

Thank you very much for your suggestion. This is a good point. We agree it will be valuable to compare the temporal variations in the ISA-MIP experiments (in particular the transient TAR and HErSEA experiments) with those from the CCMI REF-C1 and REF-C1SD simulations, which include the full fix of external forcing variations. Although we do not feel there is a need to specify this in the paper we will certainly encourage the leads for those two ISA-MIP experiments to consider this, and approach the relevant CCMI coordinators accordingly. In particular, there may still be time to double-check whether any extra diagnostics should be added to the ISA-MIP simulations as most groups will still be finalizing the final set-up for their integrations.

Forcings and other data sets will be made available on the ISA-MIP website: http://www.isamip.eu and through specific links, which will be included in the revised manuscript.

"At the beginning of Section 2 (page 5 lines 15-155) the following sentence sounds odd: "However, the focus of the ISA-MIP experiments described here is on comparing to measurements of the overall optical and physical properties of the stratospheric aerosol

layer, which is manly determined by stratospheric aerosol". Maybe the final "aerosol" should be substituted with sulfate."

We have corrected the sentence to:

Page 5, lines 167-169: "However, the focus of the ISA-MIP experiments described here is on comparing to measurements of the overall optical and physical properties of the stratospheric aerosol layer, which is mainly determined by stratospheric aerosol sulphate."

"The discussion at the end of Section 2 (page 7 lines 210-219) could probably be made even more robust with reference to sulfate geoengineering studies. Some of these have highlighted differences in what the authors themselves call "a crucial point", i.e., the different degree of isolation of the tropical pipe and the meridional transport of sulfate aerosols through the subtropical barrier. See for example Tilmes et al. (2015) and Visioni et al. (2018)."

We have added a sentence to refer to sulphate geoengineering studies

Page 7, lines 233-237: "Sulphate geoengineering studies confirm the importance of the model dependent meridional transport through the subtropical barrier (e.g. Niemeier and Timmreck, 2015; Visoni et al., 2018; Kleinschmitt et al., 2018). Reasons for these differences need to be understood with a multi-model comparison study, as suggested for example by Tilmes et al., (2015)."

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