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Interactive comment on "The Model Intercomparison Project on the climatic response to Volcanic forcing (VolMIP): Experimental design and forcing input data" *by* Davide Zanchettin et al.

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We thank the anonymous reviewer for her/his comments on the VolMIP protocol and the manuscript. Below we respond to her/his specific comments (reported within quotation marks).

" The manuscript presents a protocol for investigations of the impact of volcanic eruptions on different time scales on climate in the framework of the Coupled Model Intercomparison project CMIP6 – The manuscript is well written, the background introduced in an adequate manner and the arguments carrying out the specific sensitivity studies are addressed properly. Also connections to other CMIP6 initiatives such as PMIP are outlined and interrelations are presented. However, some issues might be improved

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and/or extended, to improve the readability of the manuscript, especially for readers or modelling groups that are not in the core of the topic related to the volcanic impacts on climate. I recommend the final publication of the manuscript when the minor points below are addressed in the revised version of the manuscript.

Specific: Introduction The authors state in their paragraph on synergies with other CMIP6 activities the connection to “Clouds and atmospheric circulation” – I suggest including a paragraph on the potential impacts of volcanic eruptions on cloud formation (cf. suggested additional references) and the importance of the aerosol microphysical schemes implemented within the respective models (refs. 1–5).“

RESPONSE: We propose to modify the paragraph about “Clouds and atmospheric circulation” as follows, based on the suggestion by the reviewer: “[. . .], in particular through improved characterization of volcanic forcing and improved understanding of how the hydrological cycle and the large-scale circulation respond to volcanic forcing. Volcanic sulfate aerosols can affect clouds also by acting as cloud condensation nuclei (Graf et al., 1997; see also: Mather et al., 2004; Seifert et al., 2011; Schmidt et al., 2012; Meyer et al., 2015), thereby affecting regional precipitation (e.g., Zhao et al., 2012). Volcanic eruptions are among the natural aerosol sources producing the strongest simulated cloud albedo effect (Rap et al., 2013). Assessments of cloud responses to volcanic forcing in VolMIP must take into account that in all experiments only the radiative effects of volcanic aerosols are represented (see section 3). VolMIP further contributes to the initiative on leveraging the past record through planned experiments describing the climate response, in an idealized context, to historical eruptions that are not (or not sufficiently) covered by CMIP6-DECK, -historical or other MIPs.”

“A second issue relates to the (empirical) data side currently available for comparison with simulated response on past/historical volcanic eruptions – A paragraph addressing the data issues in terms of observations of volcanic eruptions can add the awareness that to date only the Pinatubo eruption is well documented based on satellite and meteorological observed data. For larger eruptions like Tambora or Samalas mostly proxy

reconstructions are available afflicted with non-climatic influences and limited spatial coverage (refs 6–10).“

RESPONSE: concerning the forcing, this issue was briefly addressed in lines 102-106 of the original manuscript. We plan to slightly expand the paragraph in the revised manuscript by modifying this sentence along the following lines: “As instrumental observations of volcanic eruptions are limited, with the 1991 eruption of Mt Pinatubo being the best documented event (e.g., Minnis et al., 1993), for eruptions that occurred prior to the instrumental period, forcing characteristics must often be reconstructed based on indirect evidence such as ice-core measurements (e.g., Devine et al., 1984; Sigl et al., 2014).”

Concerning the climatic response deduced from proxy-based reconstructions, discrepancies between reconstructed and simulated behavior were already addressed in lines 92-96 of the original manuscript. We plan to slightly expand the paragraph as follows: “Climate-proxy based reconstructions covering the last millennium are a major source of information about how the climate system responds to volcanic forcing (e.g., D’Arrigo et al., 2009; Corona et al. 2010; Gennaretti et al., 2014). Recent studies have explored new reconstruction methods applied on high-quality proxy records to produce more rigorous regional climate reconstructions and allow for an improved evaluation of climate models (e.g., Ortega et al., 2015; Luterbacher et al., 2016). However, discrepancies exist between simulated and reconstructed climate variability during periods of the last millennium characterized by strong volcanic activity, concerning, for instance, the magnitude of post-eruption surface cooling (e.g., Mann et al., 2012, 2013; Anchukaitis et al., 2012; Stoffel et al., 2015; Luterbacher et al., 2016) and the interdecadal response to volcanic clusters of tropical precipitation (Winter et al., 2015) and large-scale modes of atmospheric variability (Zanchettin et al., 2015a).”

“2. Experiments: rationale and general aspects: ll. 175 ff: The authors state that the VolcLong experiments should allow investigations on the response of the deep ocean – I wonder if a decade long simulation (“up to a decade time scale”) could allow for

such investigations. Therefore I suggest to increase the simulation time to at least 50 or better 100 years or to restrict the analysis to the mid- and upper oceanic response."

RESPONSE: The length of the simulations was defined based on the typical timescale of the response detected in the Atlantic meridional overturning circulation, in different climate models. We propose to change "into the deep ocean" to "into the subsurface ocean". Also note that an integration length of 20 years was chosen also in order to reduce the overall minimum computational resources required by VolMIP. As stated also in the original manuscript, we encourage modeling groups to perform simulations longer than the minimum length requested.

"2.1 VolcShort 2.1.2 VolcShort-Eq-surf and Volc-Short-Eq-strat ll 226. The authors state the DynVar diagnostics must be calculated. Some words on how this should be realized (with a link to the appendix) would be helpful as this experiment is labeled as Tier1 (mandatory) simulation and therefore it should be warranted that the information could be obtained via the VolMIP protocol outlined in this manuscript."

RESPONSE: DynVarMIP is described in a paper which will appear in the same issue of GMD (Gerber and Manzini, 2016, available here: http://www.geosci-model-dev-discuss.net/gmd-2016-80/gmd-2016-80.pdf). We agree that there should be no lack of information about the DynVar diagnostics to be used in VolMIP. However, Gerber and Manzini (2016) provide a clear and exhaustive description of the requested output, which we avoid reporting, necessarily only in part, here. Furthermore, as all variables requested by VolMIP, information about the format of DynVar diagnostics can be also retrieved through the Data Request available at: https://www.earthsystemcog.org/projects/wip/CMIP6DataRequest We propose to add the following text in the revised manuscript: "DynVarMIP defines requirements for diagnosing the atmospheric circulation and variability in the context of CMIP6. DynVar diagnostics include a refinement of the vertical resolution of standard variables archived as daily and monthly means, zonal mean diagnostics focused on the transport and exchange of momentum within the atmosphere and between the atmosphere

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and surface, and zonal mean diagnostics describing the interaction between radiation, moisture and the circulation. A detailed description of these diagnostics and the output format requested by DynVarMIP is provided by Gerber and Manzini (2016).“

“2.2 VolcLong 2.2.2. VolcLongSingle-HL An idea to complement the Northern Hemisphere eruption is to propose an additional (non-mandatory) experiment for a high latitude Southern Hemisphere eruption. Processes over the SH are more complex in terms of direct thermal response because of the vast oceanic areas – This kind of experiment would however allow comparison with eruptions of similar magnitude over the NH.“

RESPONSE: We agree to add a Southern Hemisphere high-latitude eruption experiment, following the suggestion of both reviewers. The experiment is given lowest priority and is only part of VolMIP. Both high-latitude experiments are described in section 2.2.2 of the revised manuscript.

“3. Forcing 3.3 VolcLong An extension to the proposed experiment is to carry out experiments with different amounts of sulfur ejected during the 1809 and 1815 eruptions (within certain empirically constrained ranges) – This would allow not only to test the sensitivity to the background conditions but also to get an idea how strong uncertainties of the simulated climatic response are due to the magnitude of the volcanic forcing. Both, the VolcLongSingle-HL for the high latitude southern hemisphere and the VolcLong-Cluster-Mill for different sulfate ejections of Tambora should be relatively easy to implement given the respective forcing data sets (one for an high latitude southern hemisphere eruption and possibly two additional Tambora [one larger 60 Tg, a second lower 60 Tg] are provided by the protocol.“

RESPONSE: Within the frame of CMIP6, VolMIP was built on a limited set of idealized eruptions (although defined based on historical events). The experiments were designed based on the primary goal of the MIP, i.e., the comparative assessment of simulated behaviors within a multi-model context. Nonetheless, we agree that the ex-

periments proposed by the reviewer are interesting within the broader framework of VolMIP. We would welcome modeling groups to perform such additional sensitivity experiments in a coordinated manner. We propose to discuss this in Section 4 of the revised manuscript along the following lines: "VolMIP is designed based on a limited number of idealized volcanic forcing experiments. We recognize that an eruption's characteristics are a major source of uncertainty for its climatic impacts. We encourage modeling groups interested in performing sensitivity experiments based on the experiments proposed here and concerning, e.g., the magnitude and the season of the eruption, to use of VolMIP as a platform for coordinating such efforts within a multi-model framework."

"4. Follow-up research and synergies with other modeling activities In this chapter a paragraph addressing experiments that were not proposed in the present VolMIP protocol could also stimulate further initiatives and experiments. This relates for instance to sensitivity studies in the context of the exact timing of the eruption within the seasonal cycle, direct (interactive) simulation with a more realistic point-source of the eruption, sensitivity studies related to aerosol microphysical schemes, and the potential impacts of future eruptions under anthropogenically changed background conditions (cf. also Short comment and proposal by I. Bethke) with volcanic eruptions trajectories constrained by historical eruptions."

RESPONSE: we agree to include the scenario cluster experiment proposed by I. Bethke in the VolMIP protocol, although not as part of CMIP6. Concerning the additional experiments, following our response to the previous comments, we will add a discussion about eruption's magnitude and season. Concerning uncertainties about the generation of the forcing, this is out of the focus of VolMIP. Scientific research to this regard is fruitfully coordinated by other initiatives, like SSiRC. We discussed this in lines 405-412 of the original manuscript and consider the discussion presented there sufficient to cover the matter.

"Minor comments: l 130: I suggest rephrasing the term "increase the SNR" to "assess

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the SNR". Especially in the context of comparisons between simulated and empirical data, noise is an integral part of the system."

RESPONSE: agreed

"ll 390ff: The authors mention a couple of related MIPs – one might include for theindividual MIPs links to their respective web pages to get an immediate overview."

RESPONSE: we prefer not to do that as the respective web pages may change in the future

"Additional references for introduction chapter: "

RESPONSE: we plan to include all suggested references in the revised manuscript

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