

## ***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 Christoph Raible for reviewing the VolMIP protocol and the manuscript. Below we respond to his specific comments (also reported below in between quotation marks, before our point-by-point replies).

"General Comments The paper is generally well written and structured. The important steps are described in a sufficient way, so that the participants of VolMIP can start their contributions. The topic itself is highly relevant as major model uncertainties still exist with respect to the climate response to volcanic forcing. Calling for a coordinated approach to tackle these challenges. Therefore, the presented study delivers the necessary background and I recommend to publish this study after minor

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revision, detailed below. Minor Comments Concerning the selected experimental design, I wonder why only a northern latitude volcanic eruption is selected and not also a southern hemispheric one. The reason why I suggest to include such an experiment (forcing like in Fig.4 but for the Southern Hemisphere) is that the climate is different, less land-sea contrast, more zonal flow patterns, etc. which could be of interest to assess. Additionally, it would complement the comparison suggested for the northern latitude simulation."

RESPONSE: we agree that an experiment focusing on a high-latitude eruption in the Southern Hemisphere would be a valuable addition to the protocol. Our choice not to include such an experiment in VolMIP was mainly due to the necessity of limiting the number of proposed experiments. Following the reviewer's suggestion, seconded by Reviewer #2, and if there are no further contrarian comments to this regard, we propose to add this experiment in the list with the lowest priority (Tier 3) and as part of VolMIP but not CMIP6. For the sake of model inter-comparability (maximizing the number of models used for the same experiment), we therefore recommend that modeling groups interested in performing a high-latitude volcanic eruption experiment give priority to the Northern Hemisphere case.

"Another more general point is that only the forcing for the Tambora-like eruption and the northern latitude eruption is shown (Figs. 3 and 4) and not the one for Pinatubo. Maybe this could be included."

RESPONSE: We will add a curve for Pinatubo in the revised version of Figure 3a. However, we would prefer not to add the Pinatubo forcing in Figure 4a as it compares idealized volcanic forcing data created with the same tool (EVA), which are therefore easily intercomparable. The Pinatubo forcing data used in the "short" experiments are, instead, the same that are to be used for the historical experiment and derived from instrumental measurements. Adding them to Figure 4a would require some explanation that goes beyond the illustrative purpose of the figure.

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"L39-40: Please change to: ' : : the applied forcing. It defines : : :'" RESPONSE: agreed

"L96: The authors are correct that there are discrepancies between the simulated response of modes of variability to volcanic forcing. Still, reconstructions show at least for the NAO some common response which needs to be mentioned here. A possible relevant publication is: Ortega, P., F. Lehner, D. Swingedouw, V. Masson-Delmotte, C. C. Raible, M. Casado and P. Yiou 2015: A multi-proxy model-tested NAO reconstruction for the last millennium. *Nature*, 523 71-75." RESPONSE: The point we wanted to make here concerns discrepancies between simulations and reconstructions, for the same events, not robust responses detected in reconstructions. Concerning the NAO response to volcanic forcing, the suggested paper does not provide a detailed simulations-reconstructions analysis, and rather refer to a few citations. Nonetheless, we propose to cite the suggested paper in a more general statement about proxy-based reconstructions we will add in the revised manuscript.

"L112: Maybe the authors could add the following publication as they also show the dependence on the mean state. Muthers, S., F. Arfeuille, C. C. Raible, and E. Rozanov 2015: The impact of volcanic aerosols on stratospheric ozone and the Northern Hemisphere polar vortex: Separating radiative from chemical effects. *Atmos. Chem. Phys.*, 15, 11461-11476." RESPONSE: agreed. We propose to add also the following citation by the same authors, which seems to be relevant: Muthers, S. and co-authors (2014) Northern hemispheric winter warming pattern after tropical volcanic eruptions: Sensitivity to the ozone climatology. *J. Geophys. Res. Atmos.*, 119, 1340–1355, doi:10.1002/2013JD020138

"L119: The Tambora eruption is newly described in a review publication in *Wiley Climate Change* and could be added here: Raible, C. C., S. Broennimann, R. Auchmann, P. Brohan, T. L. Froelicher, H. F. Graf, P. Jones, J. Luterbacher, S. Muthers, R. Neukom, A. Robock, S. Self, A. Sudrajat, C. Timmreck, and M. Wegmann, 2016: Tambora 1815 as a test case for high impact volcanic eruptions: Earth system effects. *Wiley Interdis-*

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*ciplinary Reviews: Climate Change*, in press." RESPONSE: We propose to include the suggested reference as follows: "A recent review paper describes this volcanic eruption as a test case for high impacts on the Earth system (Raible et al., 2016)."

"L180: Maybe add the modes here so the reader knows which modes will be considered." RESPONSE: since we state in the same sentence that these modes "are specifically defined for each experiment", we prefer to avoid providing more information at that point.

"L219-221: The authors suggest to use an EOF analysis to define the NAO, which is commonly used. Still if a model has deficiencies in simulated the NAO as the leading mode (sometimes EOF1 and EOF2 are exchanged) models can falsely select the wrong mode. Also the pattern can change from one to another model simulation. To avoid this a 'station-based' index definition might be superior. At least the authors need to request that the EOF pattern shows a north-south dipole." RESPONSE: we agree with the reviewer that an EOF-based index may be slightly problematic. We propose therefore to change the definition using the two-box NAO index by Stephenson et al. 2006, which was also recently used by Zanchettin et al. (2015a)

"L232: There are multiple ways (and complexities) of a slab ocean model. A very simple parameter is e.g. the mixed layer depth which may vary from model center to model center. I am not sure whether this needs to be defined in more detail to increase the comparability between the different model." RESPONSE: we agree on the fact that the rather general design of this experiment could lead to some heterogeneities across results from different models. However, as for the Tier 1 "mechanistic" experiments, we slightly shift focus away from the multi-model framework in order to better understand the behavior of individual models. We therefore propose to add the following sentence in the revised version of the manuscript to allow comparability between the coupled model results: "A reference simulation shall be set up using the mixed layer depth climatology of the coupled model."

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"L241: It is not clear why the date should be flexible. I suggest to fix the date to either Nov. 1st 2015 again to avoid problems when comparing the simulations." RESPONSE: For the decadal prediction experiment we have to follow the general DCPD set up. The start dates are not fixed for the DCPD experiments as stated in the DCPD protocol: "Start date on or before 31 Dec of the year preceding the forecast period (start dates on or before Nov 15 allow for DJF seasonal forecast results and are recommended)" (Boer et al., 2016). So all participating models will be initialized before 1st of January 1991 six months prior to the eruption.

"L263: Please change 'should' to 'shall'." RESPONSE: we used "should" as this refers to a first-order expectation. In fact, there are differences between the two forcings, which we highlighted later on in the same sentence by introducing a cautionary statement ("but see Section 3.3").

"L265: Please change 'outstanding' to 'open'." RESPONSE: agreed

"L276: Please start with 'The non-mandatory experiment VolcLong-Cluster-Ctrl investigates the climate response : : :'" RESPONSE: We propose to change the sentence to: "This non-mandatory experiment investigates the climatic response to a close succession of strong volcanic eruptions, so-called "volcanic cluster" (Table 2)"

"L287: Please change 'should' to 'shall'." RESPONSE: agreed

"L295: Avoid space for 'Mill'. " RESPONSE: agreed

"L315: Please change 'created' to 'generated'." RESPONSE: agreed

"L334: Please introduce here the acronym ToA as it is used in the tables." RESPONSE: agreed

"L338: What is meant with 'mechanistic experiments'?" RESPONSE: "mechanistic" was used to describe the two experiments used to disentangle the two main contributions to the general mechanism driving the short-term response to volcanic eruptions. We agree that this adjective is not very clear, and will avoid its use in the revised version

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of the manuscript.

"L363-364: Please change to ': : : from a given eruption : : : and latitude with an idealized spatial : : :'" RESPONSE: agreed

"L381-382: Please change to 'Differences occur mainly due to : : :'" RESPONSE: agreed

"L415-416: Please change 'diagnostic s should : : : and would be useful : : :' to 'diagnostics shall : : : and will be useful : : :'" RESPONSE: agreed

"L449: This sentence is not well connected to its surrounding." RESPONSE: we propose to merge this sentence with the following one. The text would read as follows: "Follow-up research must take also into account that the design of the simulations reflects necessary constraints on the overall resources required to perform the whole set of mandatory experiments."

"L463-464: ': : : records. Additionally, observations-simulations assessments need to include the identification : : :' reads better." RESPONSE: we will modify the sentence as suggested

"L485: : : Maybe not so important but at which temporal resolution needs the data be provided." RESPONSE: This paragraph provides general information about data availability and follows the guidelines provided by the CMIP panel. The temporal and spatial resolution of the simulation output depends on the variable of interest. Details to this regard can be found in the data request at: <https://www.earthsystemcog.org/projects/wip/CMIP6DataRequest> (mentioned in the manuscript on line 330).

"Page 18-24: There are a lot of errors in the publications so please revised them." RESPONSE: we will revise the references and correct errors to our best.

"Fig. 2 The labels at the 'y-axis' shall be in upper cases." RESPONSE: We will modify the figure so that we only use upper cases for all text

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"Fig.3 and Fig. 4: Comparing the magenta dashed line in Fig.3a with the black in Fig.4a I wonder why these are not the same." RESPONSE: They are not the same because they refer to quantities averaged over different spatial domains (global for magenta line in Figure 3a, northern-hemisphere for the black line in Figure 4a). The aim of Figure 4a is to compare hemispheric-average AOD estimates for a equatorial eruption and a high-latitude eruption with half SO<sub>2</sub> emission than the equatorial one.

"Table 1: Second column second row: The largest eruption with respect to which period?" RESPONSE: We propose to change "the largest historical tropical eruption" to "the largest tropical eruption of the last five centuries"

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