Application for a Model Intercomparison Project on the climatic response to Volcanic forcing (VolMIP) as CMIP6-Endorsed MIP

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VolMIP

Name of MIP:

Model Intercomparison Project on the climatic response to Volcanic forcing (**VolMIP**)

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Link to website (if available):

WCRP webpage:
http://www.wcrp-climate.org/index.php/modelling-wgcm-mip-catalogue/modelling-wgcm-mips/505-modelling-wgcm-volmip
Official webpage: under construction

Goal of the MIP and a brief overview

VolMIP is central to the three broad CMIP questions:

- How does the Earth system respond to external forcing?
- What are the origins and consequences of systematic model biases?
- How can we assess future climate changes given climate variability, predictability and uncertainties in scenarios?

VolMIP is motivated by the large uncertainties regarding the climatic responses to strong volcanic eruptions identified in CMIP5 simulations with respect to, e.g., the Northern Hemisphere's winter response (e.g., Driscoll et al., 2012, Charlton-Perez et al., 2013) and the response of the oceanic thermohaline circulation (Ding et al., 2014), and by the apparent mismatch between simulated and reconstructed post-eruption surface cooling for volcanic eruptions during the last millennium (Mann et al., 2012, 2013; Anchukaitis et al., 2012; D'Arrigo et al., 2013; Schurer et al., 2013). Therefore, VolMIP will assess to what extent responses of the coupled ocean-atmosphere system to strong volcanic forcing are robustly simulated across state-of-the-art coupled climate models and identify the causes that limit robust simulated behavior, especially differences in their treatment of physical processes.

VolMIP is closely linked to the WCRP Grand Challenge on:

- "Clouds, circulation and climate sensitivity," 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. VolMIP further contributes to the initiative on leveraging the past record through planned experiments describing the climate response to historical eruptions that are not (or not sufficiently) covered by CMIP6-DECK or other MIPs. VolMIP will contribute towards more reliable models through improved understanding of how model biases affect the response to volcanic forcing.
- "Climate extremes" and "Regional climate information," in particular through a more systematical assessment of regional climate variability – and associated predictability and prediction - during periods of strong volcanic forcing at both intraseasonal-to-seasonal (e.g., post-eruption Northern Hemisphere's winter warming) and interannual-to-decadal (e.g., post-eruption delayed winter warming) time scales.

- “Water Availability,” in particular through the assessment of how strong volcanic eruptions affect the monsoon systems and the occurrence of extensive and prolonged droughts.

VolMIP addresses specific questions related to:

- The apparent mismatch between simulated and reconstructed post-eruption surface cooling for volcanic eruptions during the last millennium (Mann et al., 2012; Anchukaitis et al., 2012; D’Arrigo et al., 2013; Schurer et al., 2013). A possible reason for the mismatch are the large uncertainties in the volcanic forcing for eruptions that occurred during the pre-instrumental period and for which no direct observations are available. Therefore, VolMIP will provide new consensus forcing input data and related coupled climate simulations for some of the major volcanic eruptions that occurred during the pre-industrial period of the last millennium. Forcing data will be in the form of best estimates with uncertainties or of a range of estimates if a best estimate is not feasible with the given uncertainties.
- The mismatch between observed and modeled seasonal to interannual dynamical responses to volcanic eruptions during the instrumental period. Observations suggest that volcanic eruptions are followed by an anomalously strong Northern Hemisphere’s winter polar vortex, and significant positive anomalies in the North Atlantic Oscillation and Northern Annular Mode, but CMIP5 models do not robustly reproduce this behavior (e.g., Driscoll et al., 2012, Charlton-Perez et al., 2013). Observed volcanic events are, however, few and of limited magnitude, and their associated dynamical climate response is very noisy (e.g., Hegerl et al., 2011). The short-term dynamical response is now known to be sensitive to the particular structure of the applied forcing (Toohey et al., 2014). Using carefully constructed forcing fields and a sufficient number of realizations, VolMIP will investigate the inter-model robustness of the short-term dynamical response to volcanic forcing, and elucidate the mechanisms through which volcanic forcing leads to changes in surface dynamics.
- The large uncertainties in the interannual and decadal dynamical climatic responses to strong historical volcanic eruptions. As described above, coupled climate simulations produce a considerable range of atmospheric and oceanic dynamical responses to volcanic forcing, which likely depend on various aspects of model formulation, on the simulated background internal climate variability (e.g., Zanchettin et al, 2013), and also on eruption details including magnitude, latitude and season (e.g., Timmreck, 2012). VolMIP will help to identify the origins and consequences of systematic model biases affecting the dynamical climate response to volcanic forcing and to clarify how regional responses to volcanic forcing are affected by the background climate state, especially the phase of dominant modes of internal climate variability. As a consequence, VolMIP will improve our confidence in the attribution and dynamical interpretation of reconstructed post-eruption regional features and provide insights into regional climate predictability during periods of strong volcanic forcing.
- The large uncertainties in the multidecadal and longer-term climate repercussions of prolonged periods of strong volcanic activity (e.g., Miller et al., 2012; Schleussner and Feulner, 2013; Zanchettin et al., 2013). VolMIP proposes an experiment describing the climate response to the close succession of strong volcanic eruptions that affected the early 19th century, whose long-term repercussions may be relevant for the initialization of CMIP6-Nucleus *historical* simulations.

In summary, VolMIP will contribute towards advancing our understanding of the dominant mechanisms behind simulated post-eruption climate evolution, but also more generally of climate dynamics and decadal variability. Volcanic eruptions offer the opportunity to assess the climate system’s dynamical response to changes in radiative forcing, a major uncertainty in future climate projections. Careful sampling of initial climate conditions and the possibility to consider volcanic eruptions of different strengths (e.g., Fröhlicher et al., 2012; Muthers et al., 2014a,b; Zanchettin et al., 2014b) will allow a better understanding of the relative role of internal and externally-forced climate variability during periods of strong volcanic activity, hence improving the evaluation of climate models and enhancing our ability to accurately simulate past, as well as future, climates.

For these purposes, VolMIP defines a common protocol to improve comparability of results across different Earth system models and coupled general circulation models, and accordingly subjects them to the same set of idealized volcanic perturbations under similar background climate conditions (Zanchettin et al., in prep, 2014a).

VolMIP experiments will be designed based on a twofold strategy.

- A first set of experiments is designed to systematically investigate inter-model differences in the long-term (up to the decadal time scale) dynamical climate response to idealized volcanic eruptions that are characterized by a high signal-to-noise ratio in the response of global-average surface temperature. The main goal of these experiments is to assess the signal propagation pathways of volcanic perturbations within the simulated climates, the associated determinant processes and their representation across models.
- A second set of experiments will be used to systematically investigate inter-model differences in the short-term dynamical response to volcanic eruptions characterized by a low signal-to-noise ratio in the response of global-average surface temperature. The main goal of these experiments is to quantify the uncertainty in the short-term climate response to a 1991 Pinatubo-like eruption and discriminate the parts that are due to internal variability and to model characteristics. The proposed set of experiments will include idealized sensitivity experiments designed to determine the different contributions to such uncertainty that are due to the direct radiative (i.e., surface cooling) and to the dynamical (i.e., stratospheric warming) response.

Generation of forcing input data for both types of experiments is an integral part of VolMIP. Some of the participating modeling groups are currently testing the proposed methodologies through coordinated activities within VolMIP and in cooperation with other MIPs.

An overview of the proposed experiments

An overview of the proposed experiments is provided in Tables 1, 2 and 3, where they are summarized according to their prioritization. VolMIP experiments are divided into two main branches: long-term volcanic forcing experiments and short-term volcanic forcing experiments.

Long-term volcanic forcing experiments

Experiments based on coupled climate simulations to assess inter-model differences in the climate response to *very strong* volcanic eruptions up to the decadal time scale.

- *VolLongS100EQ:* This Tier 1 experiment is designed to realistically reproduce the radiative forcing resulting from the 1815 eruption of Mt. Tambora, Indonesia. The experiment will not account for the actual climate conditions when the real event occurred (e.g., presence and strength of additional forcing factors). Instead, the experiment is designed to span very different initial climate states to systematically assess uncertainties in the post-eruption behavior that are related to background climate conditions.
- *VolLongS100HL:* An additional, non-mandatory experiment which applies the same approach as *VolLongS100EQ* and extends the investigation to the most relevant historical high-latitude volcanic eruption (1783-1784 Laki, Iceland). The unique eruption style (large SO_2 mass releases: 100 Tg SO_2, and close temporal spacing: 5 active phases within 5 months) will substantially contribute to outstanding questions about the magnitude of the climatic impact of high-latitude eruptions. Results of this experiment may have implications for sulfate aerosol geo-engineering.
- *VolLongC19th*: A “volcanic cluster” experiment to investigate the climate response to a close succession of strong volcanic eruptions. The proposed experiment is designed to realistically reproduce the volcanic forcing generated by the early 19th century volcanic cluster (including the 1809 eruption of unknown location and the 1815 Tambora and 1835 Cosigüina eruptions). The early 19th century is the coldest period in the past 500 years (Cole-Dai et al., 2009) and therefore of special interest for mutidecadal variability. In addition long-term repercussions may be relevant for the initialization of CMIP6-Nucleus *historical* simulations.

Short-term volcanic forcing experiments

Experiments based on coupled climate simulations to assess uncertainty and inter-model differences in the seasonal-to-interannual climate response to volcanic eruptions characterized by a rather low signal-to-noise ratio in the response of global-average surface temperature.

- *VolShort20EQfull*: This Tier 1 experiment uses the same volcanic forcing recommended for the 1991 Pinatubo eruption which is used in the CMIP6-Nucleus *historical* simulation, but produces a large ensemble of short-term simulations in order to accurately estimate simulated responses to volcanic forcing which may be small compared to the internal variability.
- *VolShort20EQsurf/strat:* Additional non-mandatory simulations, which are aimed at investigating the mechanism(s) connecting volcanic forcing and short-term climate anomalies. Specifically, these experiments will aim to disentangle dynamical responses to the two primary thermodynamic consequences of aerosol forcing: stratospheric heating and surface cooling.
- *VolShort20EQslab:* Non-mandatory slab-ocean experiment, which is proposed to clarify the role of coupled atmosphere-ocean processes (most prominently linked to the El Niño-Southern Oscillation) in determining the dynamical response.
- *VolShort20EQini:* Non-mandatory experiment to address the impact of volcanic forcing on seasonal and decadal climate predictability and predictions. The experiment will address the climate implication of a future Pinatubo-like eruption.

Experimental set-up:

Length of integration

- *LongS*: for each simulation: at least 20 years (mandatory), but preferably longer (30-40 years) to cover the multi-decadal oceanic response;
- *LongC*: at least 50 years to cover the multi-decadal oceanic response and to assess stationarity of post-cluster climate;
- *Short*: for each simulation: 3 years, since the experiment focuses on the short-term responses;
- *Short.ini:* 10 years for each initialized run (hindcast, forecast).

Initial conditions:

- *LongS*: predefined states describing different states of dominant modes of variability (see "ensemble size") sampled from an unperturbed control integration, under common constant boundary forcing across the different models (*PiControl* simulations from DECK). The VolMIP experiments should maintain the same constant boundary forcing as the control integration, except for the volcanic forcing;
- *LongC*: as *LongS,* but inclusion of background volcanic forcing and a dedicated spin-up procedure for this experiment are currently under discussion to account for possible implications of volcanic forcing on ocean heat content in long transient simulations (e.g., Gregory, 2010);
- *Short*:
- *Short.ini*: initialized on 1 January 2014.

Ensemble size:

- *LongS*: should be large to systematically account for the range of variability depicted by the dominant processes influencing interannual and decadal climate variability. VolMIP will accordingly identify a set of desired initial conditions. Nine simulations are planned for the Tier 1 experiment, which would allow spanning warm/cold/neutral and strong/weak/neutral states of El Niño-Southern Oscillation (ENSO) and of the Atlantic Meridional Overturning Circulation (AMOC), respectively;
- *LongC*: at least an ensemble of 3 simulations;
- *Short*: same rationale as for *LongS*, but further taking into account additional phenomena primarily contributing to internal atmospheric variability, such as the Quasi Biennial Oscillation (QBO), the characteristics of the polar vortex and the North Atlantic Oscillation (NAO). A core of 25 simulations is requested for the Tier 1 experiment, but a larger ensemble size is recommended;
- *Short.ini:* at least 5-member ensembles, but preferably 10-member ensembles.

Forcing input:

Forcing data should be consistent across the participating models for all events included in the protocol. Therefore, VolMIP will provide a self-consistent set of forcing parameters that can be used by all models, in order to ensure the best possible consistency between models in the resulting radiative forcing. Depending on the number of participating coupled climate models including modules for interactive stratospheric chemistry and aerosols microphysics, VolMIP may pose an additional focus on the simulated climatic response to given SO_2 emissions beyond the proposed CMIP6 simulations. In this stage, VolMIP will benefit from global aerosol model studies conducted within the framework of the Stratospheric Sulfur and its Role in Climate (SSiRC) initiative.

- *Long:* The forcing input data will be in the form of aerosol optical properties (e.g., aerosol optical depth, effective radius, single scattering albedo, asymmetry factor), which will allow the applied forcing in the different models to be constrained. Coupled climate models including modules for stratospheric chemistry and aerosol microphysics will be selected and used to generate the forcing input. Ongoing coordinated activities mainly involving MPI-M and IPSL are currently devoted to testing the methodology. If ad-hoc forcing inputs cannot be generated for an event through the proposed methodology, VolMIP will indicate reference forcing data sets to be used that are already available to the community.
- *Short*: The mandatory Tier1 experiment will use the volcanic forcing for the 1991 Pinatubo eruption which is recommended for the CMIP-Nucleus *historical* simulation (assumed: Sage_4λ[1]). The additional mechanistic forcing experiments that are aimed at dissecting the contributions from direct radiative and dynamical responses will make use of prescribed surface radiative flux anomalies and of heating rates in the stratosphere. To generate such input data, specific diagnostics from the Tier-1 experiments are required (if these are not made available, the VolMIP protocol will provide reference input data to the community).

  The observation-based volcanic-forcing to be used in the CMIP *historical* and VolMIP *VolShort20EQfull* experiments contains information about the real-world structure of the stratospheric circulation at the time of the eruptions, which does not necessarily match the states of individual free-running model realizations. To further investigate the impact of the forcing structure on the dynamical response, VolMIP will support the development of an idealized Pinatubo volcanic forcing dataset, where the spatial structure of the forcing is much more uniform than observation-based forcings. This work shares parallels with the WCRP Grand Challenge initiative “Easy Aerosol”, and we envision cooperation in the future months between the two groups. Additional dedicated sensitivity experiments will be carried out by individual model Centers to contribute to this activity.

An overview of the proposed evaluation/analysis of the CMIP DECK and CMIP6 experiments

VolMIP experiments will provide context to CMIP6-DECK (AMIP) and -Nucleus simulations where volcanic forcing is among the dominant sources of climate variability and uncertainty.

Proposed timing

2014 November	High-latitude volcano workshop in Stockholm: definition of pre-studies on high-latitude

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[1] VolMIP experiments will be designed in a way that any recommended CMIP6 volcanic data set is applicable. The indications provided so far by the CMIP6 panel about the recommend volcanic forcing data for the CMIP6-Nucleus experiments are not definitive (email V. Eyring, 27.11.2014). It is assumed that the recommended volcanic forcing dataset for the CMIP6 *historical* simulations is based on the SAGE_4λ dataset (Arfeuille et al., 2013), since Larry Thomason is the designed responsible for volcanic forcing (page 10 ofCMIP6FinalDesign_WGCMMeeting_141110_Sent.pdf).

	volcanic eruptions
2014 November	Revised version submitted to CMIP6 panel
2014-2015	Experimental design phase and definition of consensus volcanic forcing input
2015 January	Experiment and variable list sent to CMIP6 panel
2015 February	MiKlip/SPECS workshop in Offenbach. Experimental set-up for volcanic prediction runs (DCPP, VolMIP)
2015 April	VolMIP splinter meeting at Tambora conference in Bern (Switzerland)
2015	GMD Paper documenting detailed experimental design
2015 -2016	Work on idealized volcanic forcing fields
2016	Execution of Tier1 experiments
2017- 2019	Execution of Tier2 (Tier3) experiments
2017	Public sharing and analysis of model output

Possible synergies with other MIPs:

VolMIP is closely linked to and will co-operate with the following ongoing modeling activities and MIPs:

- **PMIP** (https://pmip3.lsce.ipsl.fr/) – PMIP and VolMIP provide complementary perspectives on one of the most important and less understood factors affecting climate variability during the last millennium. VolMIP systematically assesses uncertainties in the climatic response to volcanic forcing associated with initial conditions and structural model differences. In contrast, the PMIP last-millennium experiments, i.e., the *past1000* simulations, describe the climatic response to volcanic forcing in long transient simulations where related uncertainties are due to the reconstruction of past volcanic forcing, the implementation of volcanic forcing within the models, initial conditions, the presence and strength of additional forcings, and structural model differences. VolMIP and PMIP are expected to tighten cooperation in the upcoming months to strengthen the synergies between the two MIPs.
- **GeoMIP** (http://climate.envsci.rutgers.edu/GeoMIP/) – GeoMIP and VolMIP share interest on the climatic effects of massive stratospheric aerosol loadings. The closest association between proposed experiments is between VolMIP *Long* and GeoMIP G6sulfate simulations.
- **RFMIP** (Radiative Forcing MIP) – Precise quantification of the forcing to which models are subject is central for both RFMIP and VolMIP. RFMIP has encouraged other MIPs to standardize as far as possible to the RFMIP methodology for computing radiative forcings. RFMIP has planned transient volcanic and solar forcing experiments with fixed preindustrial SST to diagnose volcanic and solar effective forcing, instantaneous forcing and adjustments, which seems to be complementary to the *Short* experiments for VolMIP.
- **DAMIP** (Detection and Attribution MIP) – DAMIP and VolMIP share the common interest of assessing the relevance of volcanic forcing over the historical past. In particular, VolMIP can address the substantial uncertainty associated with the effects of volcanism on the historical periods. DAMIP's histALL, histNAT, histVLC and histALL_aerconc can provide context to the *Short* set of VolMIP simulations, since they include the 1991 Pinatubo eruption within transient climate situations.
- **DCPP** (Decadal climate prediction panel) - VolMIP and DCPP are closely working together on the impact of future volcanic eruptions on seasonal and decadal predictions, with a common experiment. The proposed VolMIP's *Short* experiment including 1991 Pinatubo-like volcanic forcing in decadal prediction

runs *(Short20EQini)* and the DCPP experiment C2.1 are identical and will be jointly prepared/discussed in a meeting planned for February 2015 in Offenbach (Germany).

- **SPARC DYNVAR (**http://www.sparcdynvar.org/) – The SPARC DynVar group aims to assess the impact of uncertainty in atmospheric dynamics on climate projections and is therefore deeply involved in the setup and analysis of VolMIP's *Short* experiments.
- VolMIP is closely linked to with the ongoing modeling activities within **SPARC-SSiRC** (http://www.sparc-ssirc.org/). The Stratospheric Sulfur and its Role in Climate Initiative (SSiRC) model intercomparison uses global aerosol models to understand the radiative forcing of stratospheric aerosols (background, volcanic) and to assess related parameter uncertainties. The SSiRC study "Pinatubo Emulation in Multiple models" (PoEMs) will inter-compare and evaluate Pinatubo perturbation to stratospheric aerosol properties and radiative forcings across AGCMs with prognostic stratospheric aerosol modules.

Potential benefits of the experiment to (A) climate modeling community, (B) Integrated Assessment Modelling (IAM) community, (C) Impacts Adaptation and Vulnerability (IAV) community, and (D) policy makers.

A. VolMIP will contribute towards identifying the causes that limit robust simulated behavior under strong volcanic forcing conditions. Uncertainty in simulated estimates of clear-sky radiative forcing is largest around strong volcanic eruptions, which poses VolMIP at the core of CMIP6. VolMIP will also clarify more general aspects of the dynamical climatic response to strong external forcing, especially differences in the models' treatment of physical processes. VolMIP will further evaluate the possibility of robustly identifying key climate feedbacks in coupled climate simulations following well-observed eruptions (e.g., Soden et al., 2002), and assess the role of model biases for simulations-observations discrepancies.

B. VolMIP will contribute towards advancing our understanding of the dominant mechanisms behind simulated post-eruption climate evolution, but also more generally of climate dynamics, decadal variability and of past transitions between different multi-centennial climate states, such as the transition between the so-called Medieval Climate Anomaly and Little Ice Age. Careful and systematic sampling of initial climate conditions and consideration of volcanic eruptions of different strength will help in better understanding the relative role of internal and externally-forced climate variability during periods of strong volcanic activity, hence improving the evaluation of climate models and advancing our understanding of past climates.

C. VolMIP will identify regions that are most robustly significantly affected by strong volcanic eruptions, and it will provide a framework for assessing the immediate as well as decadal climate repercussions of future volcanic events.

D. VolMIP will contribute towards advancing our understanding of the relative role of internal and volcanically-forced climate variability, therefore providing relevant information to policy makers concerning how the latter may contribute to the spread of future climate scenarios (where volcanic forcing is presently not accounted for).

All model output archived by CMIP6-Endorsed MIPs is expected to be made available under the same terms as CMIP output. Most modeling groups currently release their CMIP data for unrestricted use. If you object to open access to the output from your experiments, please explain the rationale.

No objection

List of output and process diagnostics for the CMIP DECK/CMIP6 data request:

VolMIP output is planned to be converted into the standard format using the CMOR package, following the same criteria adopted for *past1000* and *historical* simulations. Additional output is needed for *Short* experiments, in particular for the DYNVAR diagnostic tool, which includes key diagnostics of parameterized and resolved wave forcings, radiative and latent heating rates. A daily temporal resolution of output data for the stratosphere is desirable.

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Table 1 – Tier 1 VolMIP experiments

Name	**Description**	**Start year**	**Configuration**	**Ens. Size**	**Years per simulation (minimum)**	**Total years**	**Connection with other MIPs**	**Gaps of knowledge being addressed with this experiment**
VolLongS100EQ	Idealized equatorial eruption corresponding to an initial emission of 100 Tg of SO_2. This eruption has a magnitude roughly corresponding to the 1815 Tambora eruption, the largest historical tropical eruption, which was linked to the so-called "year without a summer" in 1816	PID (from *PiControl*)	AOGCM/ESM	9	20	180	PMIP	Uncertainty in the climate response to strong volcanic eruptions, with focus on coupled ocean -atmosphere feedbacks and interannual to decadal global as well as regional responses. The mismatch between reconstructed and simulated climate responses to historical strong volcanic eruptions, with focus on the role of simulated background internal climate variability.
VolShort20EQfull	1991 Pinatubo forcing as used in the CMIP6 *historical* simulations. Requires special diagnostics of parameterized and resolved wave forcings, radiative and latent heating rates. A large number of ensemble members is required to address internal atmospheric variability	PID	AOGCM/ESM	25	3	75	DYNVAR DCPP	Uncertainty in the climate response to strong volcanic eruptions with focus on short-term response. Robustness of volcanic imprints on Northern Hemisphere's winter climate and of associated dynamics.

Vol = Volcano, Long = long-term simulation, Short = short-term simulation, S = Single (XXX = approx. amount of Tg of SO_2 release), C = Cluster (XXX = approx. period of the cluster), HL = high latitude, EQ = equator, full = full-forcing simulation, surf = short-wave forcing only, strato = stratospheric thermal (long-wave) forcing only, slab = slab ocean simulation, ini = simulation initialized for decadal prediction

Table 2 – Tier 2 VolMIP experiments

Name	**Description**	**Start year**	**Configuration**	**Ens. Size**	**Years per simulation**	**Total years**	**Connection with other MIPs**	**Gaps of knowledge being addressed with this experiment**
VolLongS100HL	Idealized high-latitude (60°N) eruption emitting 100 Tg of SO_2 over five months. The eruption's strength and length roughly correspond to that of the 1783-84 Laki eruption.	PID	AOGCM/ESM	9	20	180	PMIP, GeoMIP	Uncertainty in climate response to strong high-latitude volcanic eruptions (focus on coupled ocean-atmosphere). Laki has a unique eruption style (large SO_2 mass releases occurred at short temporal intervals). Outstanding questions about the magnitude of the climatic impact of high-latitude eruptions.
VolLongC19thC	Early 19th century cluster of strong tropical volcanic eruptions, including the 1809 event of unknown location, and the 1815 Tambora and 1835 Cosigüina eruptions.	PID (integration starts on year 1809)	AOGCM/ESM	3	50	150	PMIP, GeoMIP	Uncertainty in the multi-decadal climate response to strong volcanic eruptions (focus on long-term climatic implications). Contribution of volcanic forcing to the climate of the early 19th century, the coldest period in the past 500 years. Discrepancies between simulated and reconstructed climates of the early 19th century.
VolShort20EQsurf	As VolShort20EQfull, but with prescribed surface cooling patterns or net surface flux changes	PID	AOGCM/ESM	25	3	75	DYNVAR DCPP	Mechanism(s) underlying the dynamical atmospheric response to large volcanic eruptions, in particular in Northern Hemisphere's winters. The experiment considers only the effect of volcanically induced surface cooling. Complimentary experiment to VolShort20EQstrat.
VolShort20EQstrat	As VolShort20EQfull, but with prescribed aerosol heating in the stratosphere	PID	AOGCM/ESM	25	3	75	DYNVAR DCPP	Mechanism(s) underlying the dynamical atmospheric response to large volcanic eruptions, in particular in Northern Hemisphere's winter. The experiment considers only the effect of volcanically-induced stratospheric heating. Complimentary experiment to VolShort20EQstrat.

Vol = Volcano, Long = long-term simulation, Short = short-term simulation, S = Single (XXX = approx. amount of Tg of SO_2 release), C = Cluster (XXX = approx. period of the cluster), HL = high latitude, EQ = equator, full = full-forcing simulation, surf = short-wave forcing only, strato = stratospheric thermal (long-wave) forcing only, slab = slab ocean simulation, ini = simulation initialized for decadal prediction

Table 3 – Tier 3 VolMIP experiments

Name	**Description**	**Start year**	**Configuration**	**Ens. Size**	**Years per simulation**	**Total years**	**Connection with other MIPs**	**Gaps of knowledge being addressed with this experiment**
VolShort20EQslab	As VolShort20EQfull, but with a slab ocean	PID	AOGCM/ESM	25	3	75	ENSOMIP DCPP	Effects of volcanic eruptions on ENSO dynamics.
VolShort20EQini/ DCPP C2.1	As VolShort20EQfull, but as decadal prediction runs joint experiment with DCPP	PID	AOGCM/ESM	10(5)	10		DCPP	Influence of large volcanic eruptions in future climate. Influence of large volcanic eruptions on seasonal and decadal climate predictability

Vol = Volcano, Long = long-term simulation, Short = short-term simulation, S = Single (XXX = approx. amount of Tg of SO_2 release), C = Cluster (XXX = approx. period of the cluster), HL = high latitude, EQ = equator, full = full-forcing simulation, surf = short-wave forcing only, strato = stratospheric thermal (long-wave) forcing only, slab = slab ocean simulation, ini = simulation initialized for decadal prediction