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Supporting information for

Do Climate Models Support Claims of Volcanic Global Catastrophes?

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Text S1 | Technical description of the climate model simulations

PMIP4/*past1000* recommends a set of volcanic forcing inputs based on ice core sulfur estimates and scaling relationships, from the eVolv2k dataset (Toohey & Sigl, 2017) and Easy Volcanic Aerosol generator (EVA; Toohey et al., 2016), respectively. This recommendation was followed for the models INM-CM4.8, MIROC-ES2L, and MPI-ESM1.2-LR. For MRI-ESM2.0 gas release was simulated based on SO_2 emissions from the same dataset, then volcanic aerosol properties were calculated using interactive aerosol microphysics. We also examine the earlier 13-member CESM Last Millennium Ensemble (LME), which prescribes volcanic forcings according to an earlier dataset described in Gao et al (2008).

To examine distinct realizations of a very large eruption, we used two 5-member ensembles of GISS ModelE2.2 simulations from McGraw et al. (2024) that model the 1257 AD Mt. Samalas eruption as a 120 Tg SO_2 eruption of two different radiative forcing strengths. To alter forcing strength we varied the volcanic aerosol size prescribed into the simulations, scaling EVA output to represent volcanic aerosols with peak global mean effective radii of 0.55μm and 1.04μm for the *GISS A* and *GISS B* ensembles, respectively. *GISS A* has the stronger forcing because small particle size enhances the amount of sunlight aerosols reflect. The volcanic forcing in *GISS B* resembles the EVA-derived inputs for PMIP4, except that we manually scaled aerosol optical depth (AOD) to the mass of Samalas from EVA's replication of a 9 Tg Pinatubo-like eruption, whereas EVA is set up to match higher AOD estimates from Crowley & Unterman (2013). *GISS B* hence has a moderately weaker post-eruption TOA radiative flux imbalance than the PMIP4 models, while *GISS A* is in line with PMIP4 (see Fig. S1). We note that the TOA imbalance kicks in slightly earlier in the GISS simulations than in most PMIP4 models, indicating the GISS simulations erroneously simulated the eruption in June instead of the intended July timing.

In part of our examination, we repeat our analysis of the GISS eruption simulations but for an equivalent number of no-eruption control years. Each of the 5 eruption realizations in each ensemble was created by branching off of a different point in a single long control simulation. For each ensemble member, we based our control analysis on three years of the control run: the year of the control run in which the eruption is launched in the corresponding eruption realization, plus the following two years of the control run. This gives us 5 sets of simulated control years, each of which starts from exactly the same point as an eruption realization but continues as if no eruption had occurred.

Model Name	Source	Ensemble size	Volcanic Forcing	Additional Details
INM	PMIP4	1	Prescribed to eVolv2k forcing dataset	
MIROC	PMIP4	1	Prescribed to eVolv2k forcing dataset	
MPI	PMIP4	1	Prescribed to eVolv2k forcing dataset	
MRI	PMIP4	1	Calculated by interactive aerosol module using SO_2 emissions from eVolv2k	
CESM LME	Otto-Bliesner et al., 2016	13	Prescribed to Gao et al., 2008 forcing dataset	
GISS A	McGraw et al., 2024	5	120 Tg SO_2 eruption by rescaling EVA forcings of a 9 Tg S Pinatubo-like eruption. Aerosol size peaks at a global mean value of 1.04 µm	Samalas only
GISS B	McGraw et al., 2024	5	As directly above, but aerosol size is scaled to peak at a global mean value of 0.55 µm.	Samalas only

Table S1 | Description of model experiments used in our analysis.

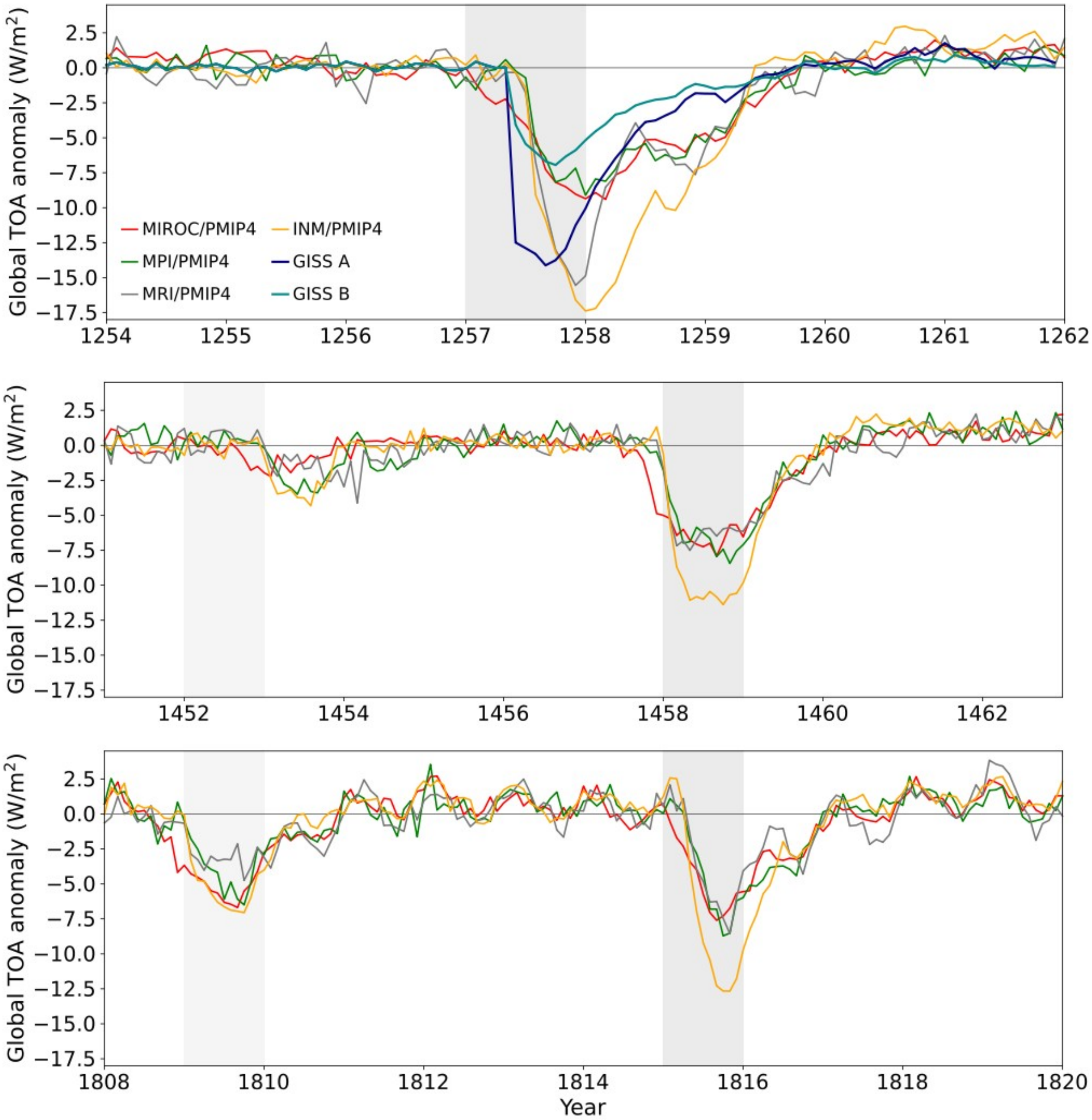

Fig. S1 | TOA flux anomalies in each assessed PMIP4/*past1000* simulation across the three largest eruption events of the millennium. We also show the ensemble-mean imbalances in the assessed GISS ensembles. The year of each major eruption is indicated as a medium grey shaded bar, while the year of smaller eruptions is shown in light grey.

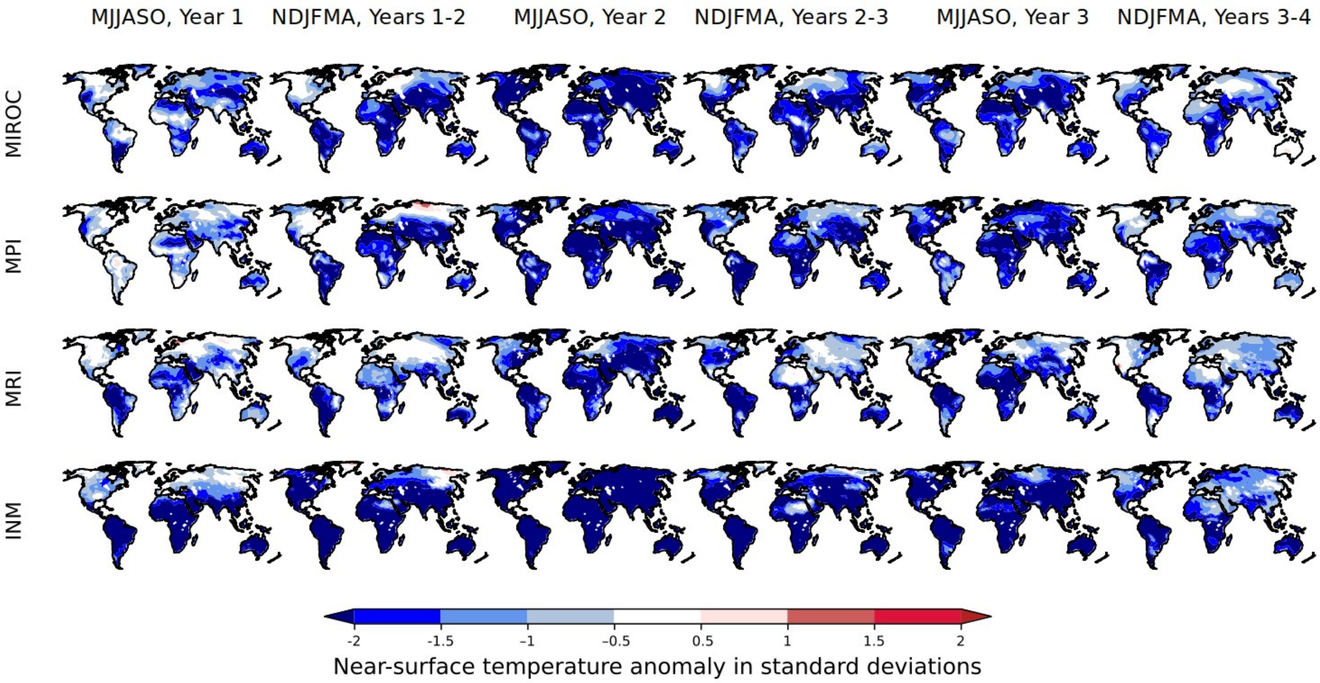

Fig. S2 | Post-eruption near-surface temperature anomalies in each PMIP4/*past1000* model, averaged over the 3 largest eruptions of the millennium (eruptions 1257, 1458, and 1815 AD) to remove internal variability from the analysis. Volcanic signals are shown as signal-to-noise ratio, being normalized by local standard deviations to convey how exceptional the signals are. For each eruption, anomalies are calculated as elsewhere in this study, with a 5-year pre-eruption mean subtracted from the signals, which is for the 1458 and 1815 AD eruptions shifted 6 years to avoid the influence of smaller 1452 and 1809 eruptions. Year 1 here is the year in which each eruption occurs.

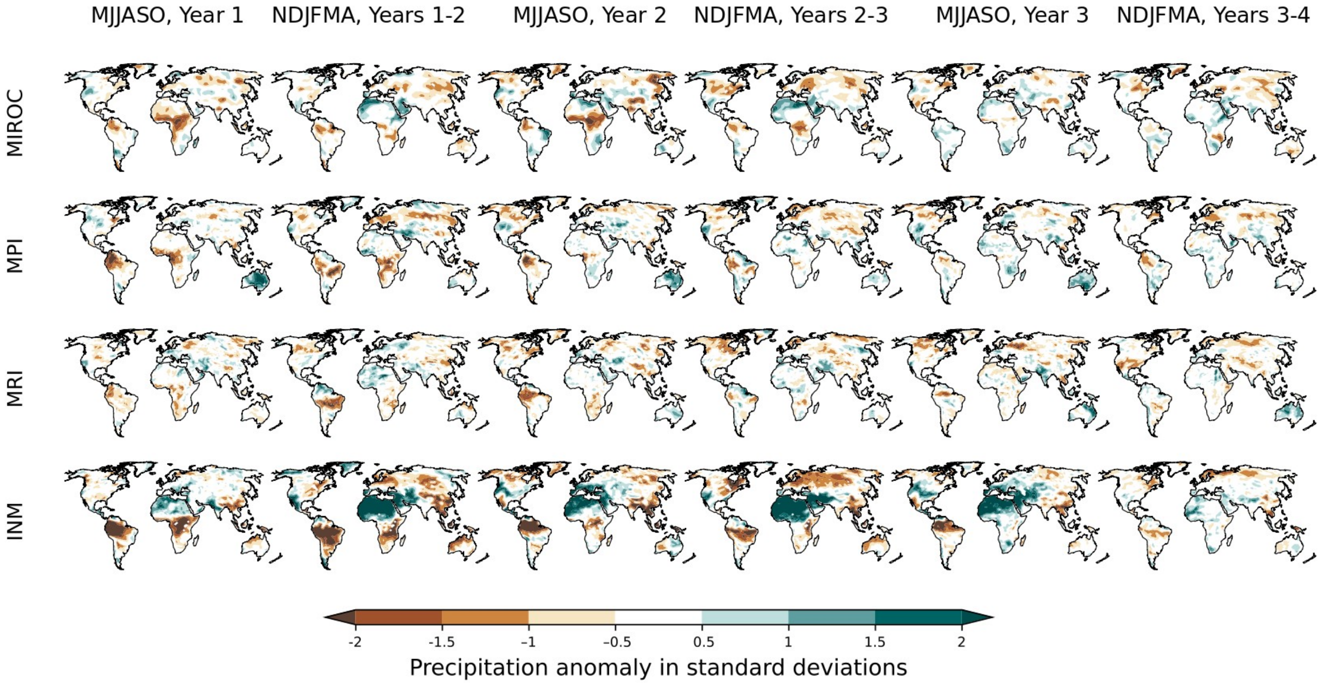

Fig S3 | Post-eruption precipitation anomalies in each PMIP4/*past1000* model, calculated as described in Fig. S2.