Read this file first.

Here we describe the other files posted to this repository in TXT (.txt) and NETCDF (.nc) format. These data were generated during the simulations listed in the table below using the Community Earth Systems Model (CESM1). If you use or refer to these data, please acknowledge the source as:

Black, BA, Neely III, R, Lamarque, JF et al. "Systemic swings in end-Permian climate from Siberian Traps carbon and sulfur outgassing."

Our modeling approach has been adapted from that of [1-3]. The Community Earth System Model (CESM1) is a global climate model that tracks the coupled interactions between the Earth's atmosphere, ocean, land, and sea ice to yield a comprehensive view of coupled Earth systems [4, 5]. In order to combine detailed microphysical simulations with long atmosphere-ocean coupled simulations, we use two configurations: the Community Atmosphere Model (CAM4) with the Community Aerosol and Radiation Model for Atmospheres (CARMA), and CAM4 with interactive ocean. We describe the model components in more detail below.

CARMA

Robust aerosol size distributions are critical to accurate assessment of radiative effects, and such size distributions can vary significantly for different styles of eruption [6, 7]. We therefore employ the Community Aerosol and Radiation Model for Atmospheres (CARMA, a sectional aerosol microphysical model [8] that includes processes such as nucleation, growth and settling [8-10]. In our work, CARMA has been configured with 35 aerosol size bins, from 0.003 microns to 7 microns, and has been coupled to CESM1(CAM4) to permit the simulation of the aerosol plume in three dimensions through time [8, 11, 12]. All size bins are included as tracers within CESM1(CAM4). Heating of sulfates from tropical eruptions can influence the dispersal of the sulfates [13, 14], a process that is not accounted for in our simulations. The expected consequences of aerosol heating might include self-lofting, slower removal of stratospheric aerosols, and increased transport into the southern hemisphere. Therefore the climate effects we consider are representative, though conservative, given the assumptions involved.

CESM1(CAM4)

The configuration of CESM1(CAM4) used in this study has 26 vertical levels that extend to ~40 km altitude with 1.9° × 2.5° horizontal resolution. CESM1(CAM4) handles the representation of dynamics, physics, atmospheric chemistry, and coupling to the land and prescribed SSTs within CESM while CARMA simulates only the sulfate aerosol microphysics. We use a version of CAM4 with extended sulfur chemistry to allow for the accurate transformation of the volcanic SO_2 plume into sulfate. Appropriate boundary conditions and paleogeography for the latest Permian were used to force the simulations.

Prescription of CARMA results in CESM1(CAM4) under end-Permian conditions

In our simulations with interactive ocean circulation, an atmospheric model with a horizontal resolution of 3.75° × 3.75° was used. The radiative properties of the sulfate aerosol plume calculated by CARMA were coupled to CESM1(CAM4) by calculating the optical properties of the plume from the output of WACCM-CARMA simulations. To accomplish this, we first calculate the wet aerosol mass and size from the dry sulfate radius and mass output by CARMA by accounting for temperature and water activity [8, 15]. Mie calculations are performed using this information to determine the radiative properties of the plume required by CESM1(CAM4) [16]. CESM1(CAM4) uses this input and the CAM-RT *(71)* radiative transfer scheme to determine the full radiative effects of the sulfate aerosol distributions in four dimensions (space and time) during fully coupled simulations with latest Permian paleogeography [1].

Ocean model

We use prescribed SSTs based on a climatology derived from our equilibrium simulations with CESM1(CAM4) in our CESM1(CAM4)-CARMA simulations. All other simulations include the fully interactive Parallel Ocean Program (POP2) model [4, 17], with bathymetry from Kiehl and Shields [1].

	Run	Filenames	Output fields
4	**[CO_2 only]** a. 710 ppm CO_2 (500 years) to b. 2800 ppm CO_2 (2000 years) to c. 5600 ppm CO_2 (2000 years)	Global annual mean: 4a_710ppmCO2_globalTS.txt Annual mean: 4a_710ppmCO2_ANN.nc Ocean zonal annual mean: 4a_710ppmCO2_ocn_ANN_ZONAL.nc Global annual mean: 4b_2800ppmCO2_globalTS.txt Ocean zonal annual mean: 4b_2800ppmCO2_ocn_ANN_ZONAL.nc Global annual mean: 4c_5600ppmCO2_globalTS.txt Annual mean: 4c_5600ppmCO2_ANN.nc Ocean zonal annual mean: 4c_5600ppmCO2_ocn_ANN_ZONAL.nc	Model year, surface temperature TS, PRECT TEMP, SALT, ROFF_F, MOC Model year, surface temperature TEMP, SALT, ROFF_F, MOC Model year, surface temperature TS, PRECT TEMP, SALT, ROFF_F, MOC
5	**[SO_2 + CO_2]** Starting from run 4a: 710 ppm CO_2 (500 years) to b. 2800 ppm CO_2 + 2000 Tg SO_2/year (200 years) to c. 2800 ppm CO_2 + 20 Tg SO_2/year (1800 years) to d. 5600 ppm CO_2 + 2000 Tg SO_2/year (200 years) to e. 5600 ppm CO_2 + 20 Tg SO_2/year (1800 years)	Global annual mean: 5b_2800ppmCO2_2000TgSO2_globalTS.txt Annual mean: 5b_2800ppmCO2_2000TgSO2_ANN.nc Ocean zonal annual mean: 5b_2800ppmCO2_2000TgSO2_ocn_ANN_ZONAL.nc Global annual mean: 5c_2800ppmCO2_20TgSO2_globalTS.txt Annual mean: 5c_2800ppmCO2_20TgSO2_ANN.nc Ocean zonal annual mean: 5c_2800ppmCO2_20TgSO2_ocn_ANN_ZONAL.nc Global annual mean: 5d_5600ppmCO2_2000TgSO2_globalTS.txt Annual mean: 5d_5600ppmCO2_2000TgSO2_ANN.nc Ocean zonal annual mean: 5d_5600ppmCO2_2000TgSO2_ocn_ANN_ZONAL.nc Global annual mean: 5e_5600ppmCO2_20TgSO2_globalTS.txt Annual mean: 5e_5600ppmCO2_20TgSO2_ANN.nc Ocean zonal annual mean: 5e_5600ppmCO2_20TgSO2_ocn_ANN_ZONAL.nc	Model year, surface temperature TS, PRECT TEMP, SALT, ROFF_F, MOC Model year, surface temperature TS, PRECT TEMP, SALT, ROFF_F, MOC Model year, surface temperature TS, PRECT TEMP, SALT, ROFF_F, MOC Model year, surface temperature TS, PRECT TEMP, SALT, ROFF_F, MOC
6	**[SO_2 only]** 710 ppm CO_2 + 2000 Tg SO_2/year (years 150-250)	Annual mean: 6_710ppmCO2_2000TgSO2_ANN_years150-250.nc	TS, PRECT

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