Supplementary Information

Figure S1. The geographic distribution of sulfate aerosol emission during (a) 1980s and (b) 2020s. (c)(e) The fast and slow responses to sudden removal of the aerosol forcing in the experiment using the sulfate aerosol emission during 1980s. (d)(f) The fast and slow responses in the experiment using the sulfate aerosol emission during 2020s.
Figure S2. Similar panels to the Figure 3 but for the fast response (year 1-3 minus control) in the idealized aerosol experiments using tropical sulfate aerosol emission. The tropical-only aerosol experiment, containing 15 ensemble members, involved a time invariant sulfate aerosol emission between 10°S–10°N at 1980s condition, which is suddenly introduced in the beginning of the experiment.
Figure S3. The meridional depth-profile of (top) fast and (bottom) slow potential temperature responses over Pacific in the idealized aerosol experiment. From the left to the right panels, we show the potential temperature anomalies (shaded) at 160°E, 160°W, and 120°W. The light grey lines denote the isopycnals of the control simulation, and the black lines represent the $\sigma_0 = 24$–$27$ kg/m$^3$ isopycnals.
Figure S4. 0–400m heat budget. Temporally integrated, anomalous heat convergence of the top 0–400m in equatorial Pacific region (2°S–2°N, 160°E–90°W) during years 1–10. Bars from the right include: the tendency term (total), heat convergence from the vertical direction, surface flux, heat convergence from the meridional direction, and the residual. The heat convergence from the meridional convergence is further decomposed into contributions of anomalous temperature, velocity, and a nonlinear term. Detailed derivation of the heat budget can be found in Eq. 2.2-2.6 in Tseng et al. 2023 (reference 42). In brief, the anomalous temperature (relative to control) at year 10 (the first bar on the left) can be attributed to the contributions from the four bars on the right.
Figure S5. Evolution of (a) the globally averaged sulfate aerosol emission in CESM LE (plotted in black, molecule/cm²/s) and its time differential (plotted in red, molecule/cm²/s²), and the pattern correlation between the 20-year running trend of tropical Pacific SST in (b) ALL minus XAERindus (c) ALL (d) HadISST (observation) and the fast response (plotted in red) and the slow response (plotted in black) in the idealized experiment (the patterns plotted in Figure 3). The light black and red lines in (b)-(d) denote the time that the 20-year SST running trends are not statistically significant over more than 70% of the tropical Pacific region.
Figure S6. Zonal and meridional mean anomalous potential temperature in the equatorial Pacific (5°S–5°N; Pacific basin) in (a) CESM LE ALL minus XAERindus, (b) CESM LE ALL, and (c) ORAS5 (Ocean Reanalysis System 5 by the European Center for Medium-Range Weather Forecasts, reference 49). (d) The averaged anomalous potential temperature in the subsurface equatorial Pacific (5°S–5°N; Pacific basin; 200–400m). The anomalies in CESM LE are computed using the multi-century control simulation with preindustrial condition. The anomalies in ORAS5 are calculated with the base period 1958–1978, a spin-up period treated as a backward extension in ORAS5 system. All of the anomalies are smoothed by a 5-year running mean in CESM AER (All minus XAERindus) and CESM LE, and by 3-year running mean in ORAS5.

Reference