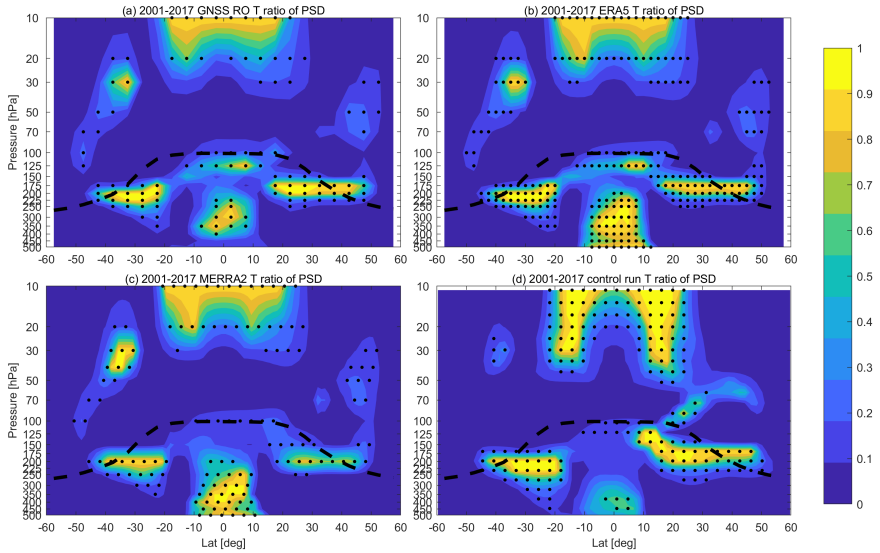

Figure S1: The ratio between SAO and annual cycle PSD based on COSMIC-1 (2007-2017) (a), ERA5 (2007-2017) (b), MERRA2 (2007-2017) (c) and model simulation (2007-2017) (d). The dots mark the significant area at 95% level.The dashed black lines mark the tropopause height calculated with GNSS RO data.

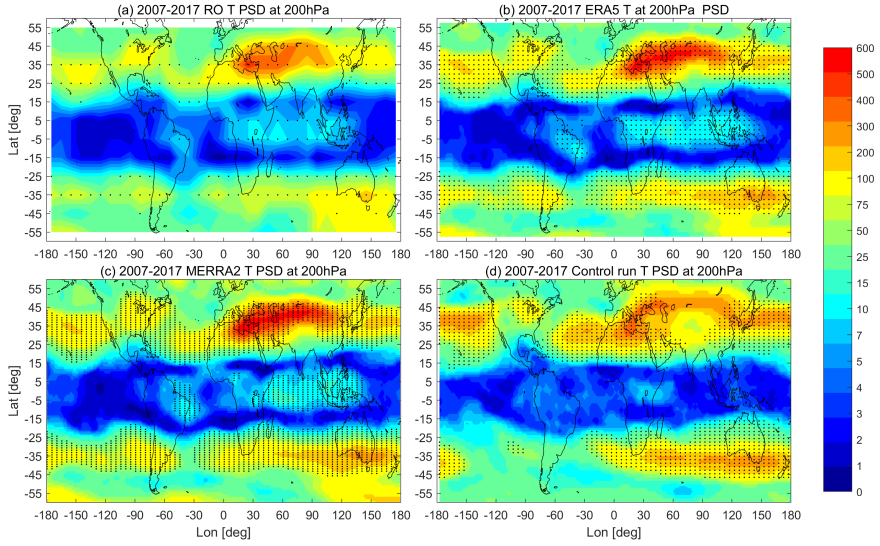

Figure S2: The PSD of SAO based on COSMIC-1 (2007-2017) (a), ERA5 (2007-2017) (b), MERRA2 (2007-2017) (c) and model simulation (2007-2017) (d) at 200hPa. The dots mark the significant area at 95% level.

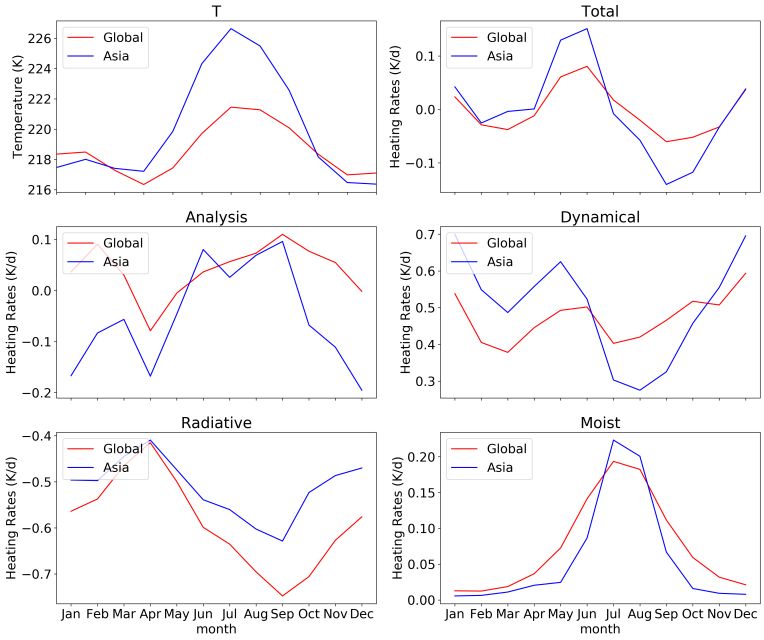

Figure S3: Annual cycle of the zonal mean temperature (T), total heating rates (Total), analyzed heating rates (ANA), dynamical heating rates (Dynamical), radiative heating rates (Radiative), and moist heating rates (Moist) at 200hPa averaged around the Asia region with blue lines (25°N-45°N, 20°E-100°E) and global region with red lines (25°N-45°N) using MERRA2 data. The total heating rates equal the sum of analyzed, dynamical, radiative, and moist heating rates.

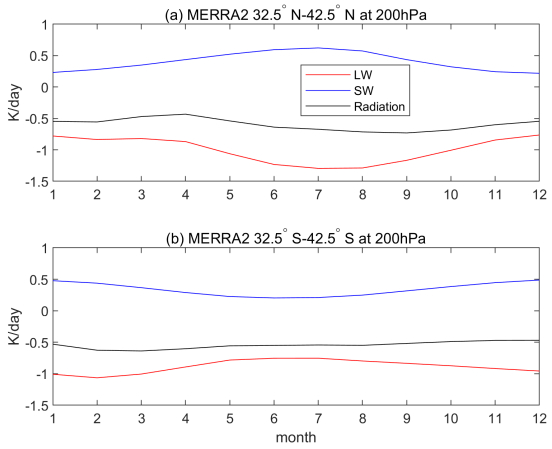

Figure S4: MERRA2 annual cycle of radiation heating rates at 200 averaged around the Northern Hemisphere Mid-latitudes (NHM) 32.5°N-42.5°N (a) and the Southern Hemisphere Mid-latitudes (SHM) 32.5°S-42.5°S (b). The red, blue and black lines indicate the heating rates related to long-wave, short-wave and radiation terms.

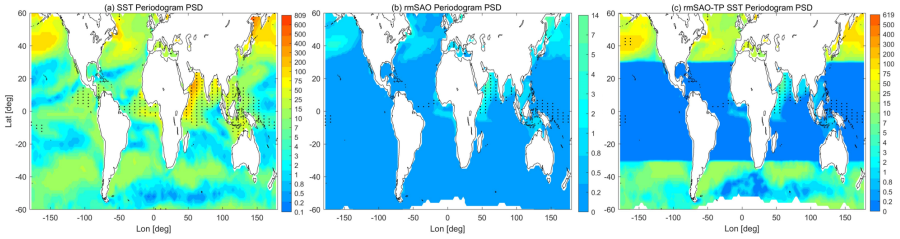

Figure S5: SAO power spectrum of SSTs in the Control, rmSAO and rmSAO-TP simulations. The dots indicate where the SAO power spectrum is significant.

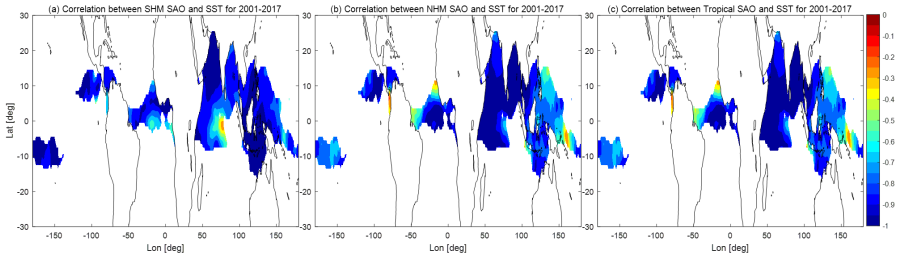

Figure S6: Correlation between ERA5 temperature SAO signal at 200 hPa averaged around the SM (32.5°S-45°S, 20°E-100°E) (a), NM (32.5°N-45°N, 20°E-100°E) (b), Tropical SAO (5°S-5°N, 20°E-100°E)),and SST-SAO.