

Supplements

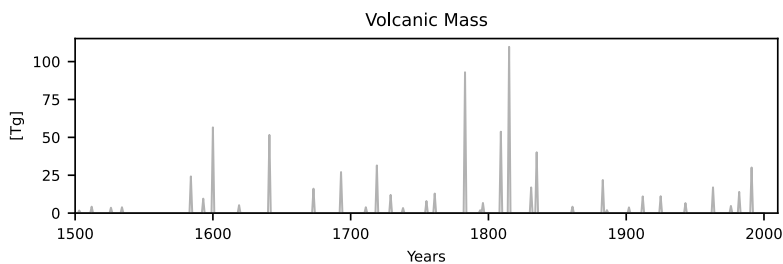


Figure S1. Volcanic forcing from 1500 to 2010.

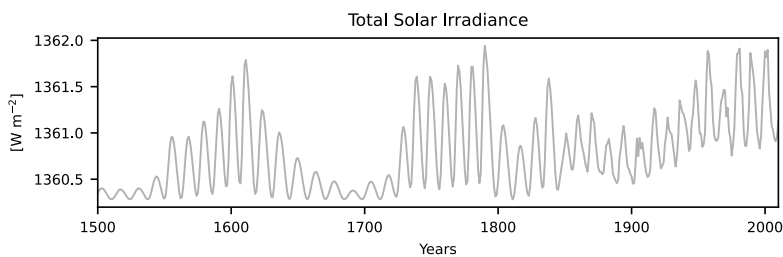


Figure S2. Total Solar Irradiance from 1500 to 2010.

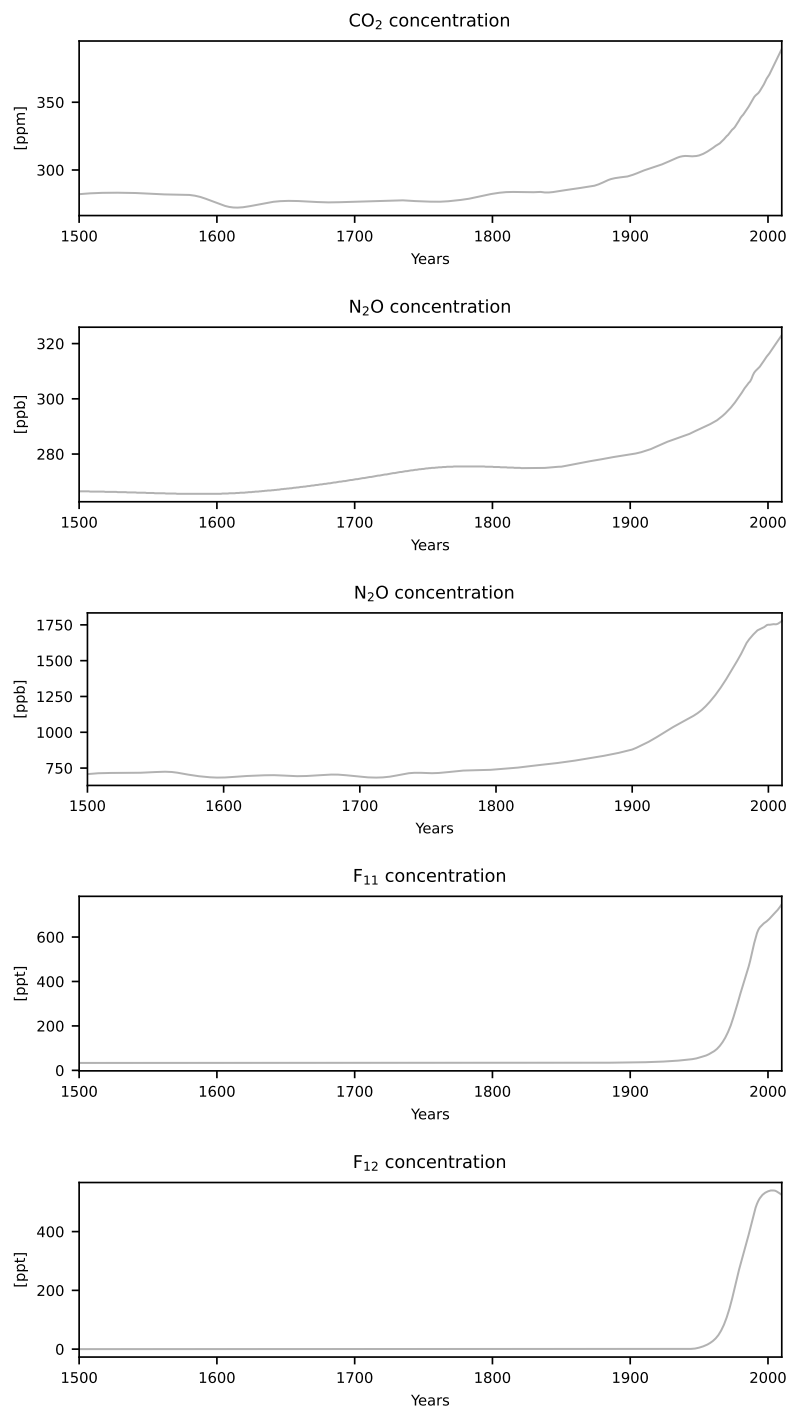


Figure S3. Greenhouse gas forcing from the five agents from 1500 to 2010.

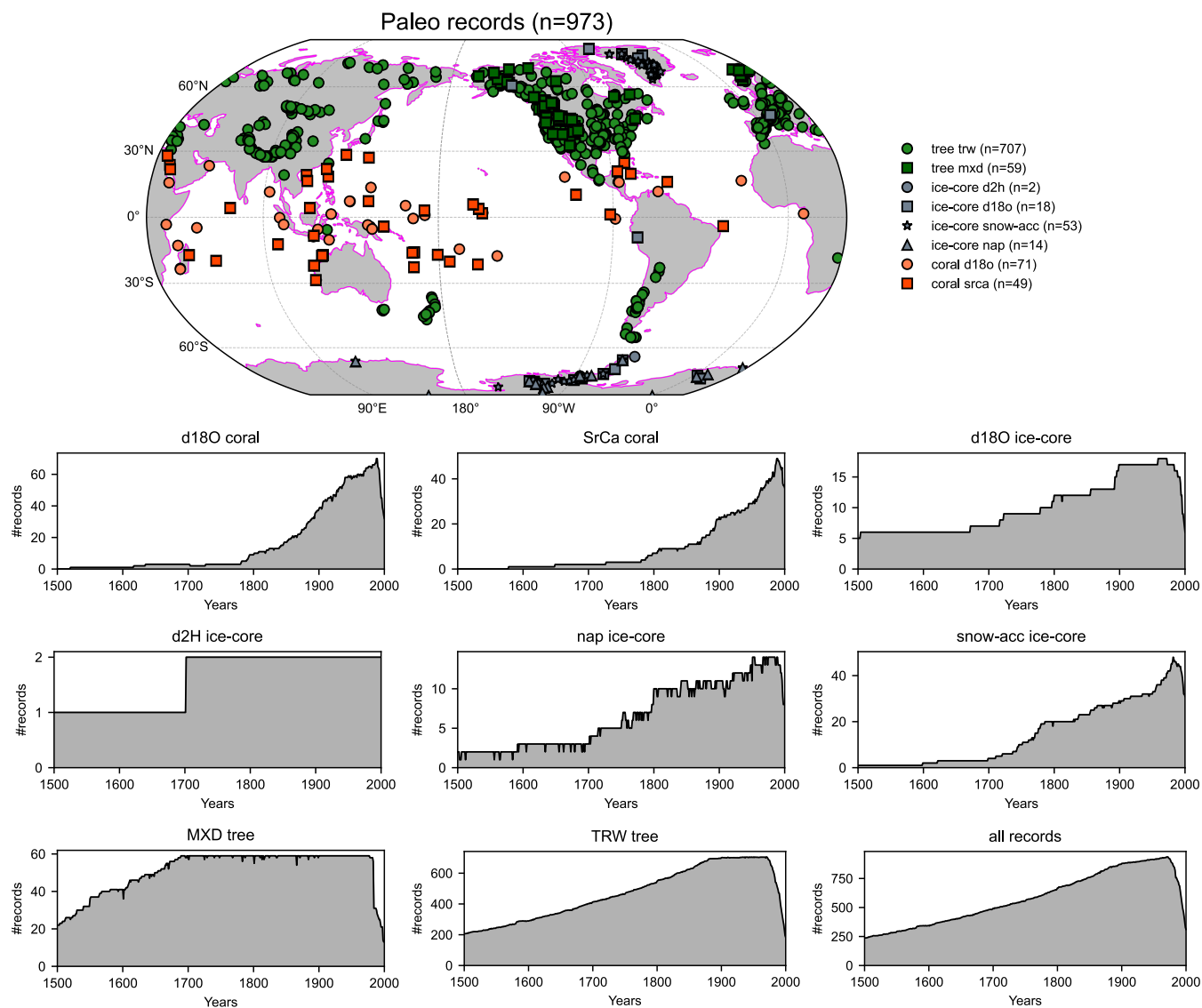


Figure S4. Geographical locations of screened paleo records along with the temporal availability for the different types of records.

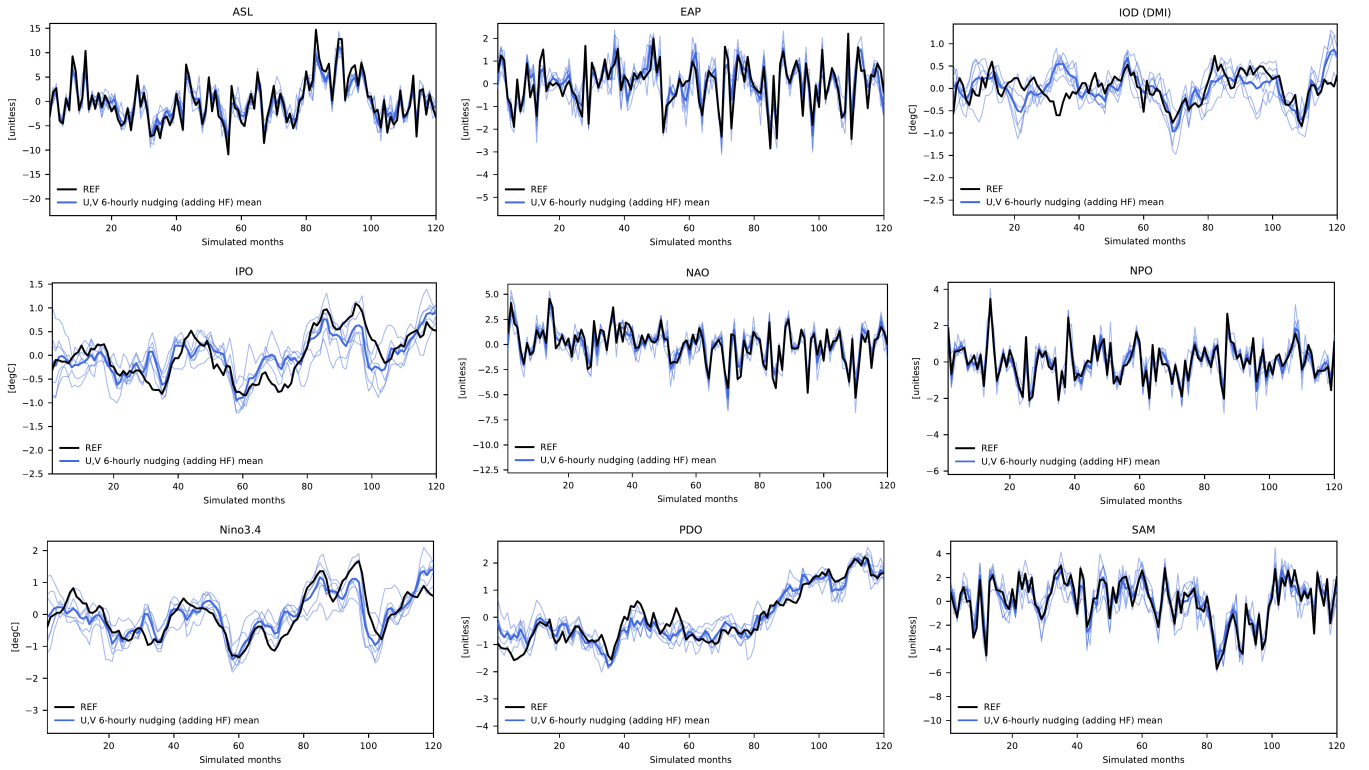


Figure S5. Monthly time-series of the Amundsen Sea Low (ASL), East Atlantic Pattern (EAP), Indian Ocean Dipole Mode Index (DMI), Interdecadal Pacific Oscillation (IPO), North Atlantic Oscillation (NAO), North Pacific Oscillation (NPO), Niño-3.4 index, Pacific Decadal Oscillation (PDO), and Southern Annular Mode (SAM) over a 10-year twin experiment. The reference (target) simulation is shown in black, the ensemble mean of the six wind-nudging simulations is shown as a thick blue line, and the individual ensemble members are shown as thin blue lines. All the simulations started from different oceanic conditions. All time series are expressed as anomalies relative to the monthly climatology over the simulation period.

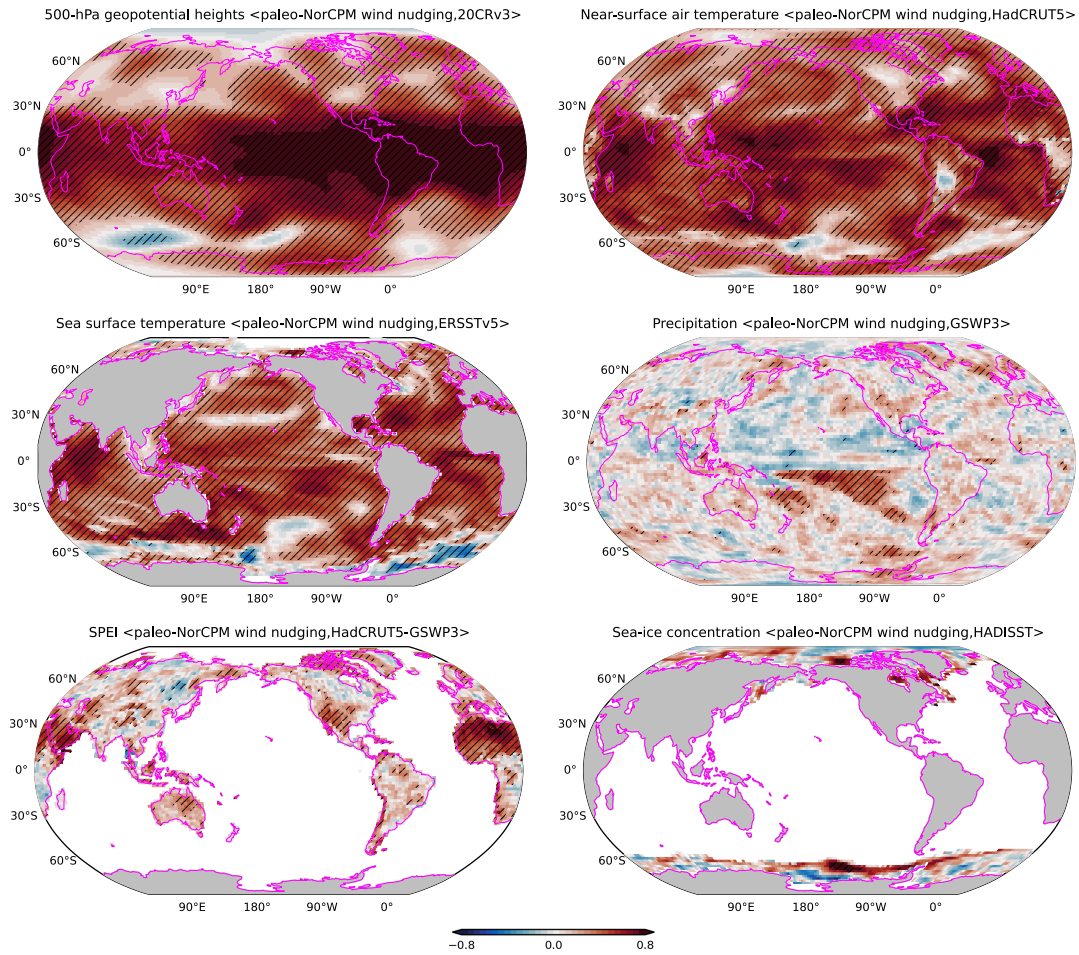


Figure S6. Maps of the correlation coefficients for the paleo-NorCPM1 wind nudging (ensemble mean), evaluated against reference datasets for six variables: 500-hPa geopotential height from the 20th Century Reanalysis version 3 (20CRv3; Slivinski et al., 2021); near-surface air temperature from the Met Office Hadley Centre/Climatic Research Unit global surface temperature dataset (HadCRUT5; Morice et al., 2021); SST from the NOAA Extended Reconstructed SST version 5 (ERSSTv5; Huang et al., 2017); precipitation from the Global Soil Wetness Project phase 3 dataset (GSWP3) (Lange et al., 2021); SPEI derived from HadCRUT5 temperature and GSWP3 precipitation; and sea-ice concentration from HadISST4 (Kennedy et al., 2019). Correlations are computed using annual time-series and over the 20th century, except for sea-ice concentration, which is evaluated over 1979–2000. Stippling indicates statistically significant correlations at the 95% confidence level (taking into account the False Discovery Rate; FDR).

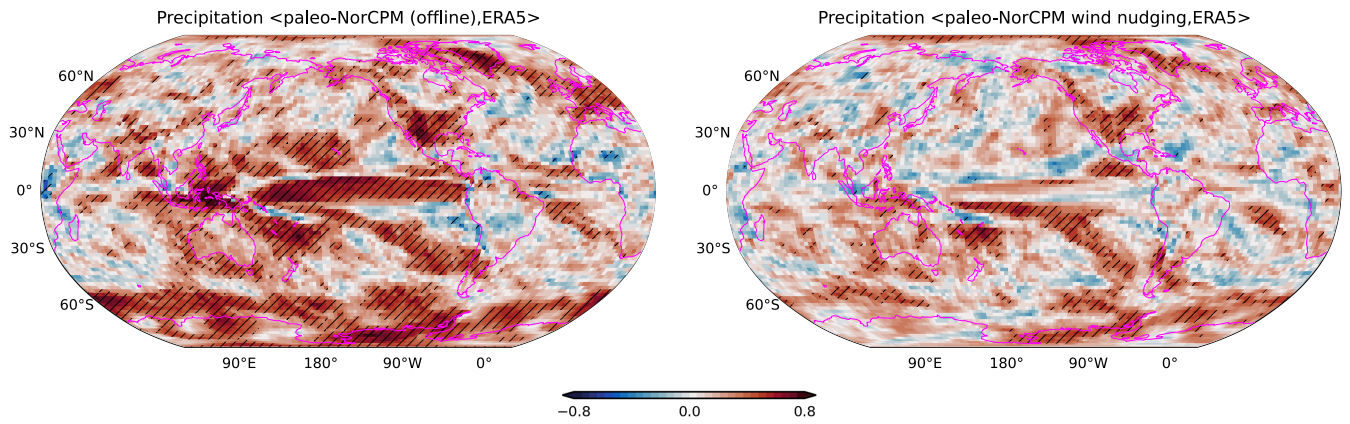


Figure S7. Maps of the correlation coefficients for paleo-NorCPM1 offline and wind nudging (ensemble mean), evaluated against ERA5 for precipitation. Correlations are computed using annual time-series and over the 1950–2000 period. Stippling indicates statistically significant correlations at the 95% confidence level (taking into account the False Discovery Rate; FDR).

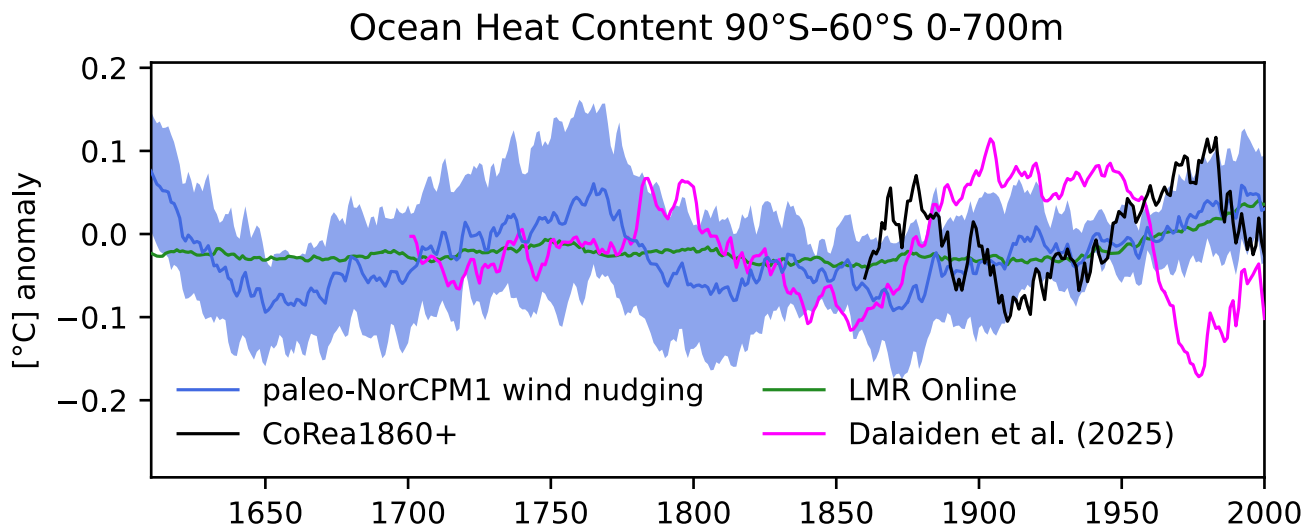


Figure S8. Temporal evolution of the anomalies of Southern Heat Content (below 60°South) integrated over the top 700 m from 1700 to 2000 (expressed in °C). Anomalies are calculated from the 20th century mean.

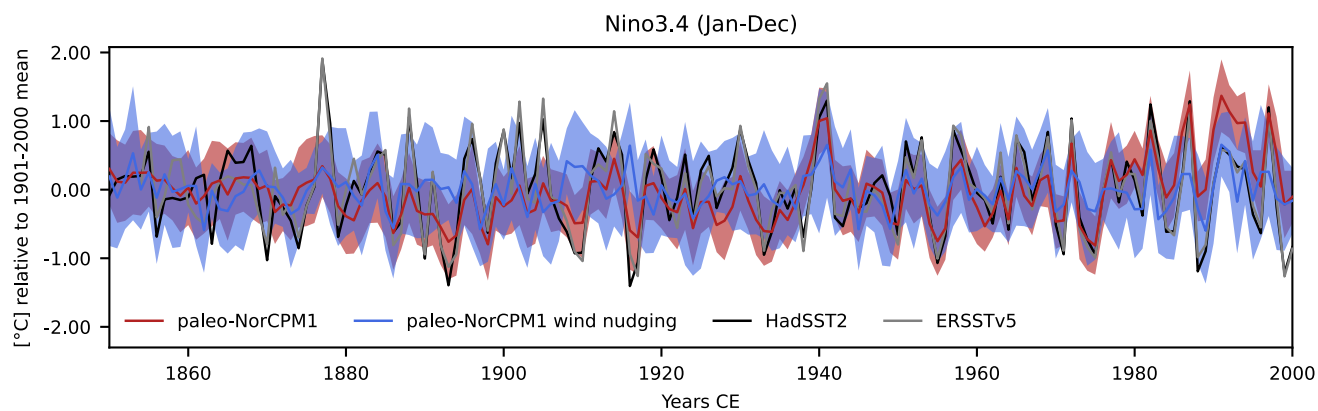


Figure S9. Temporal evolution Nino3.4 index over the period 1850–2000, for paleo-NorCPM1 offline, paleo-NorCPM1 wind nudging, HadSST2, and ERSSTv5. Anomalies are expressed relative to the 20th-century mean. The 31-year high-pass filter has been applied on all time-series.

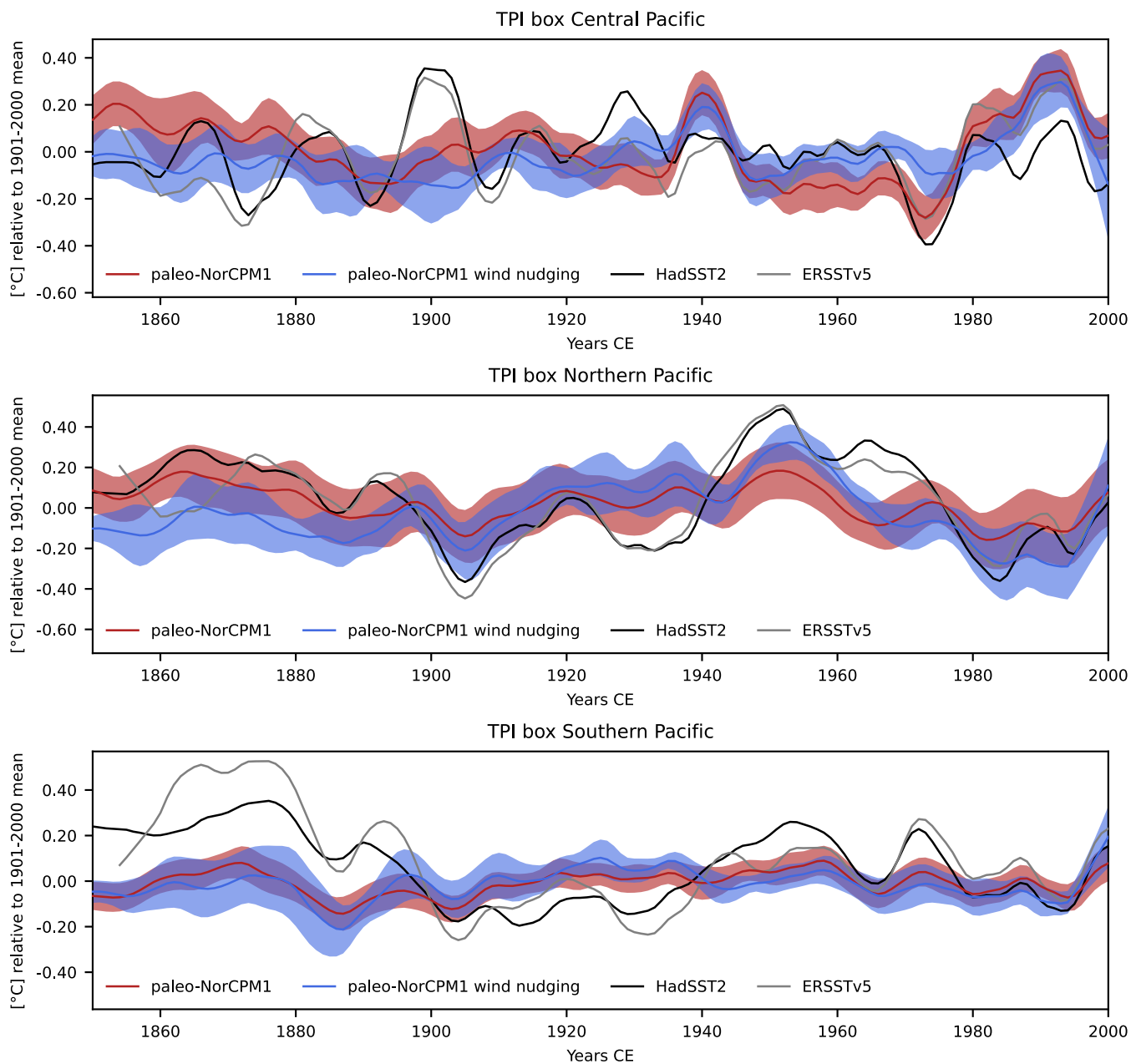


Figure S10. Temporal evolution of SST anomalies in the three Pacific regions used to compute the IPO Tripole Index over the period 1850–2000, for paleo-NorCPM1 offline, paleo-NorCPM1 wind nudging, HadSST2, and ERSSTv5. Anomalies are expressed relative to the 20th-century mean.

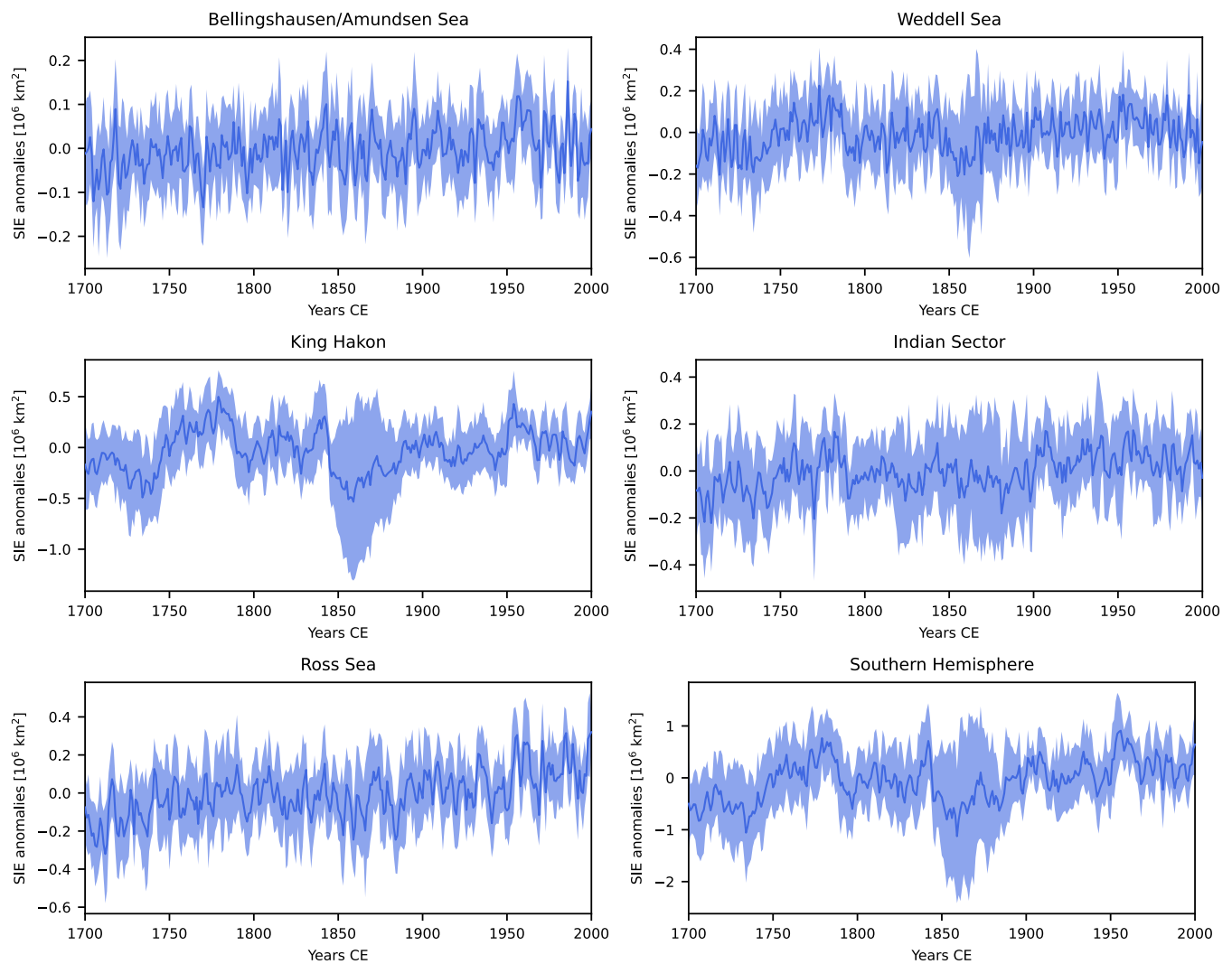


Figure S11. Time series of annual regional sea-ice extent anomalies for main five Antarctic regions along with the Southern Ocean from paleo-NorCPM1 wind nudging. Anomalies are computed relative to the entire period. The five Antarctic sectors analyzed are Amundsen–Bellingshausen Seas (110°W – 70°W), Weddell Sea (70°W – 15°W), King Håkon sector (15°W – 70°E), Indian sector (70°E – 165°E), and Ross Sea (165°E – 110°W).

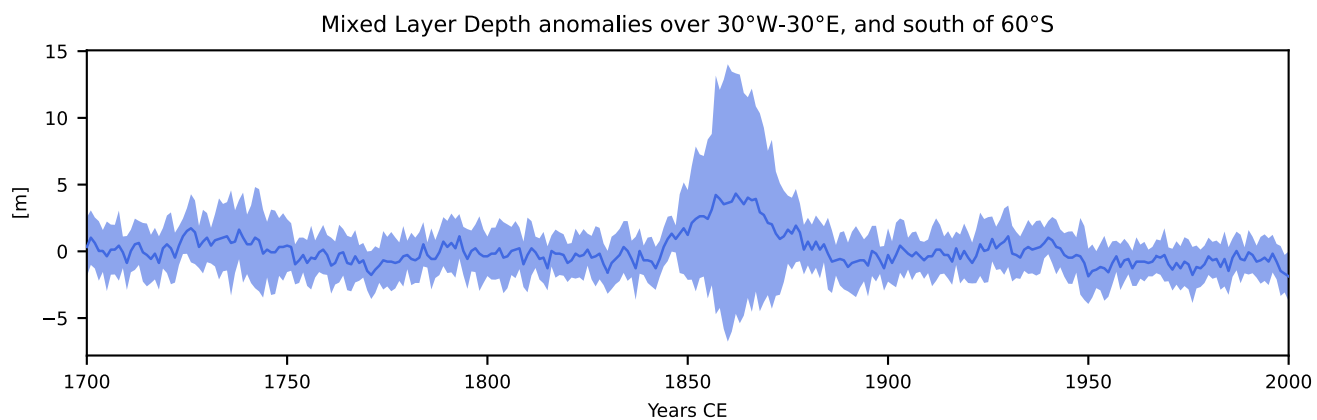


Figure S12. Time series of the annual mixed layer depth in the South Atlantic (30°W–30°E, south of 60°S) from paleo-NorCPM1 wind nudging. Anomalies are computed relative to the entire period

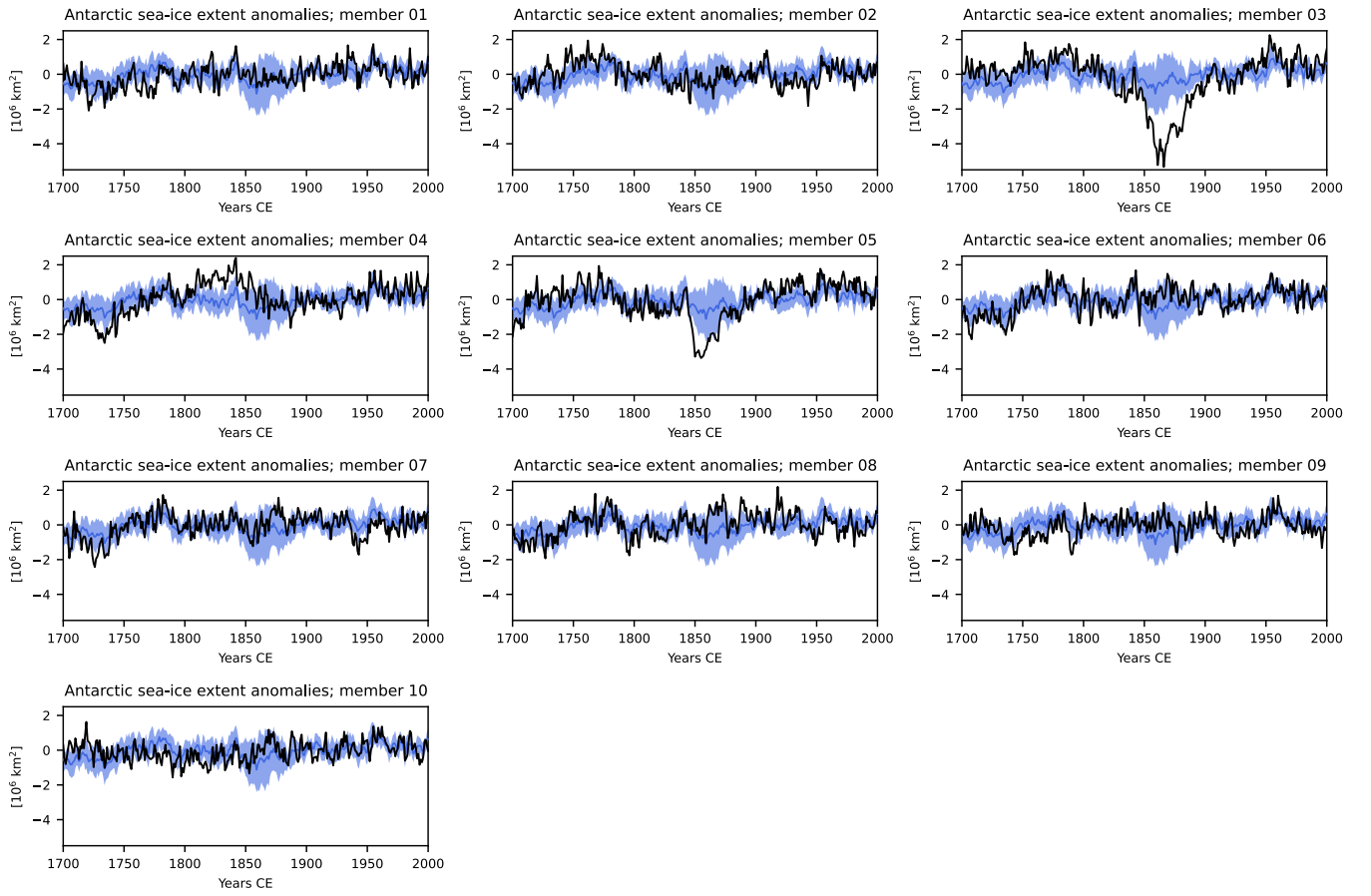


Figure S13. Time series of the annual Antarctic sea-ice extent from paleo-NorCPM1 wind nudging, including each single member. The ensemble mean is represented by the thick blue line while the envelope corresponds to the ensemble spread (one standard deviation). Each single member is shown by the thick black line. Anomalies are computed relative to the entire period.