Supplementary Information for:

Critical role of biomass burning aerosols in enhanced historical Indian Ocean warming

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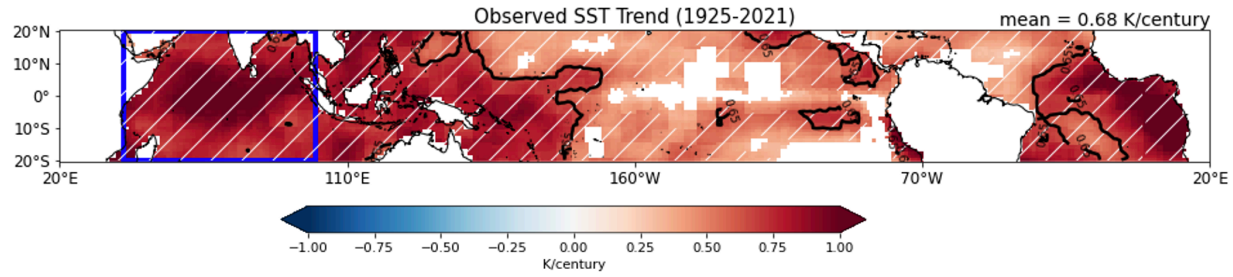
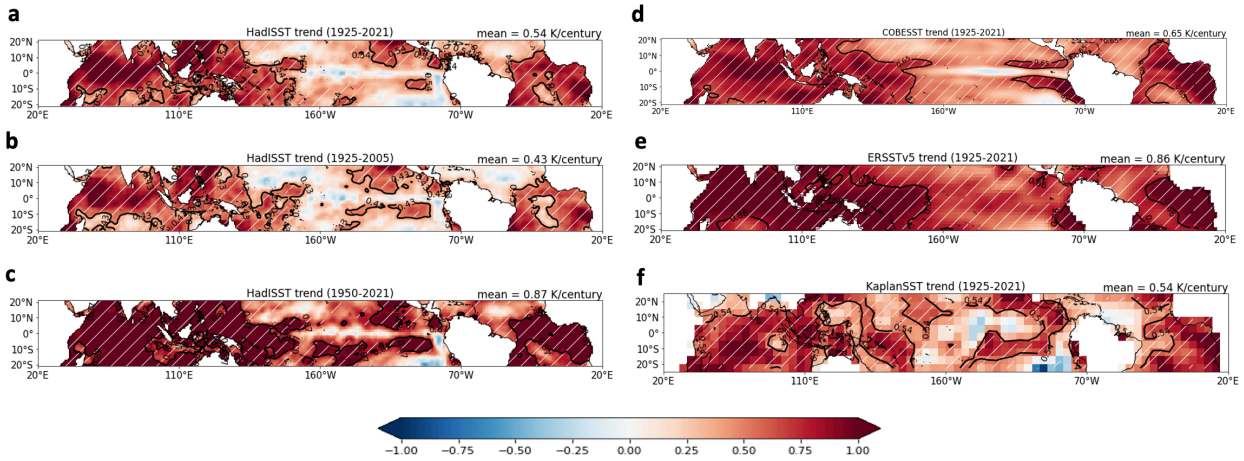
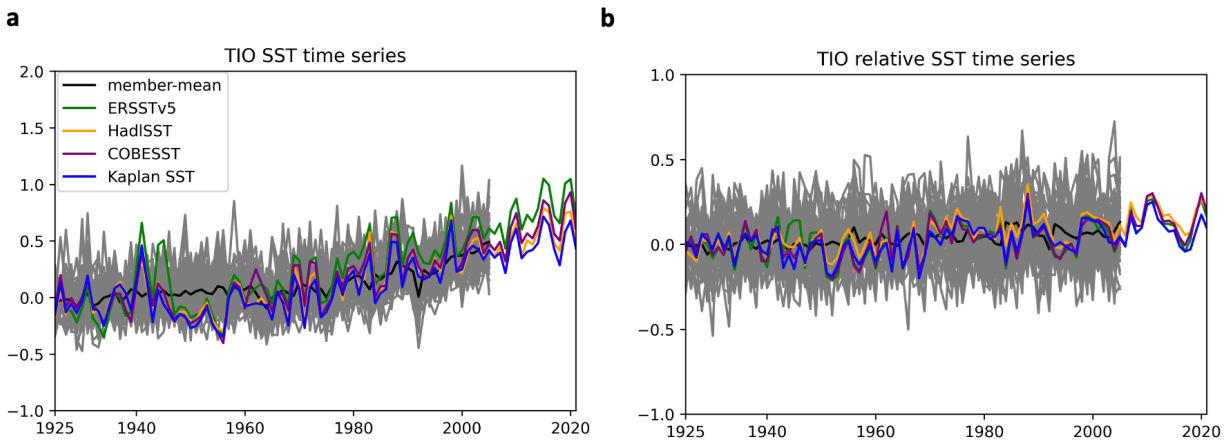


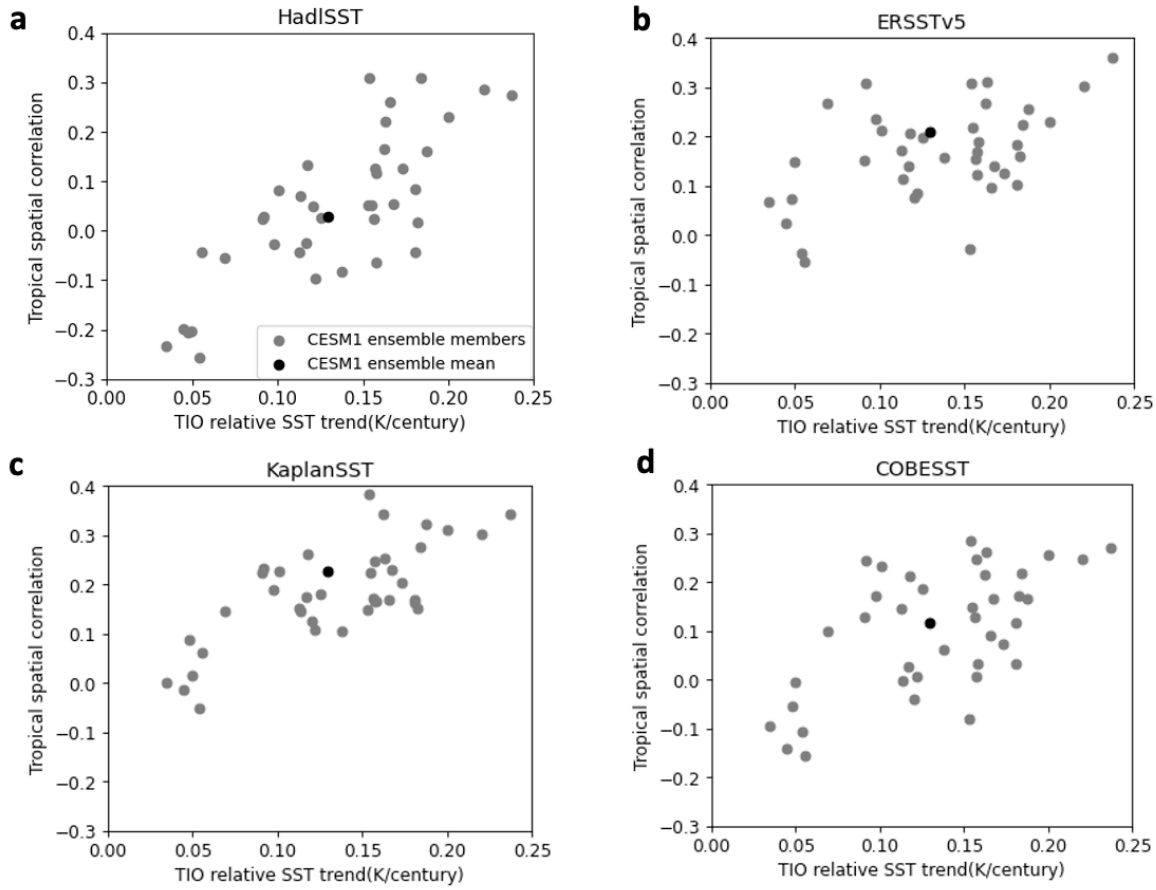
Supplementary Figure 1 | Observed tropical SST trends since 1925. Observed tropical SST trends (K/century) during 1925-2021, averaged across four SST datasets (ERSSTv5, HadISST, COBE-SST, Kaplan SST). The black contour line represents the isopleth of the tropical-mean SST trend (value shown on the top-right corner). This figure is the same as Fig. 1a but with only the regions where all four datasets agree on the sign of the SST trend being shown. White hatches represent the regions that are 99% significant based on a t-test.



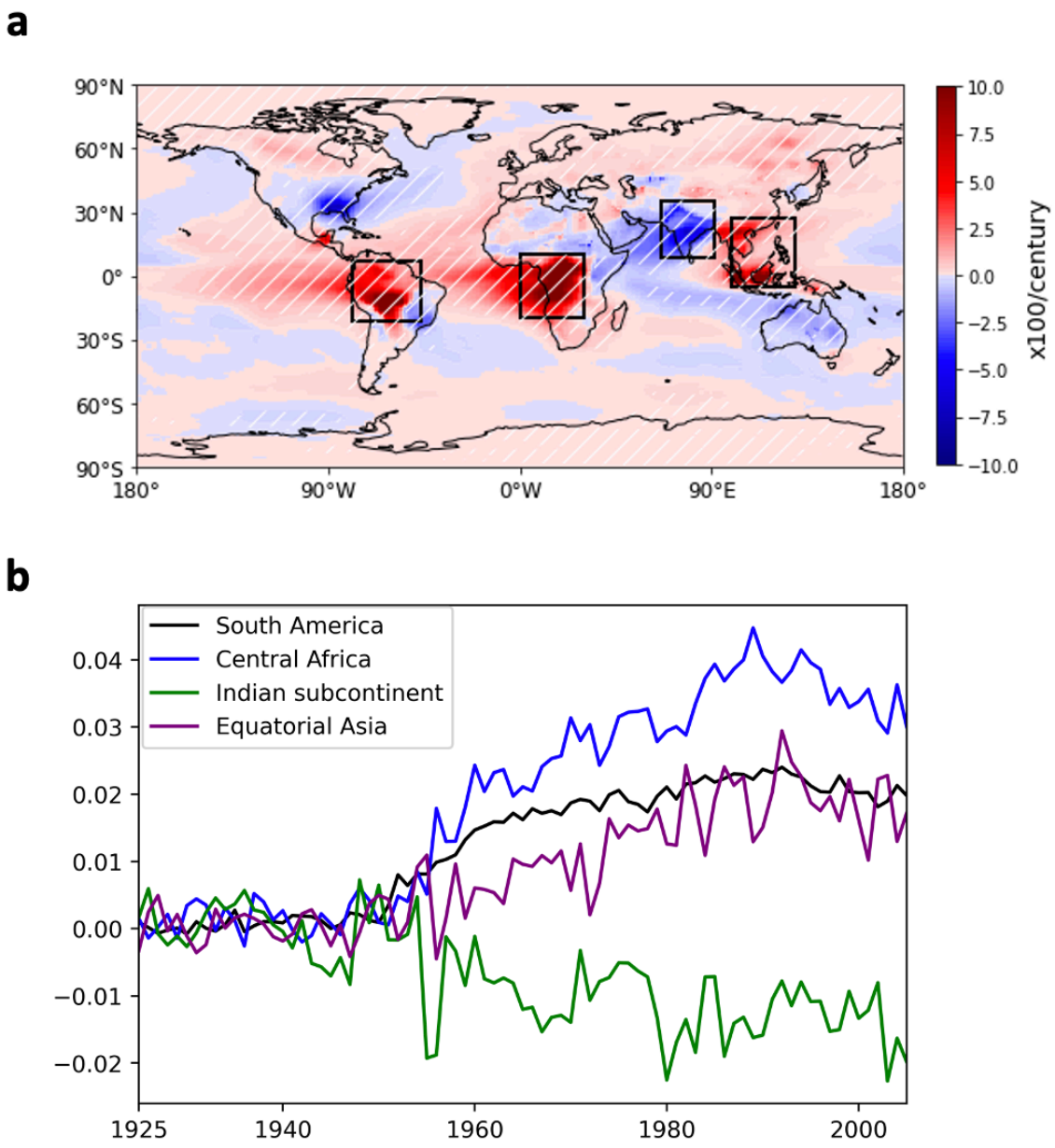
Supplementary Figure 2 | Observed tropical SST trends in different datasets. a-c, SST trends in HadISST during the periods of **a** 1925-2021, **b** 1925-2005, and **c** 1950-2021. **d-f,** SST trends during 1925-2021 for **d** ERSST v5, **e** COBE-SST, and **f** Kaplan SST v2. The black contour line represents the isopleth of the tropical-mean SST trend (value shown on the top-right corner). White hatches in **a-f** represent the regions that are 99% significant based on a t-test.



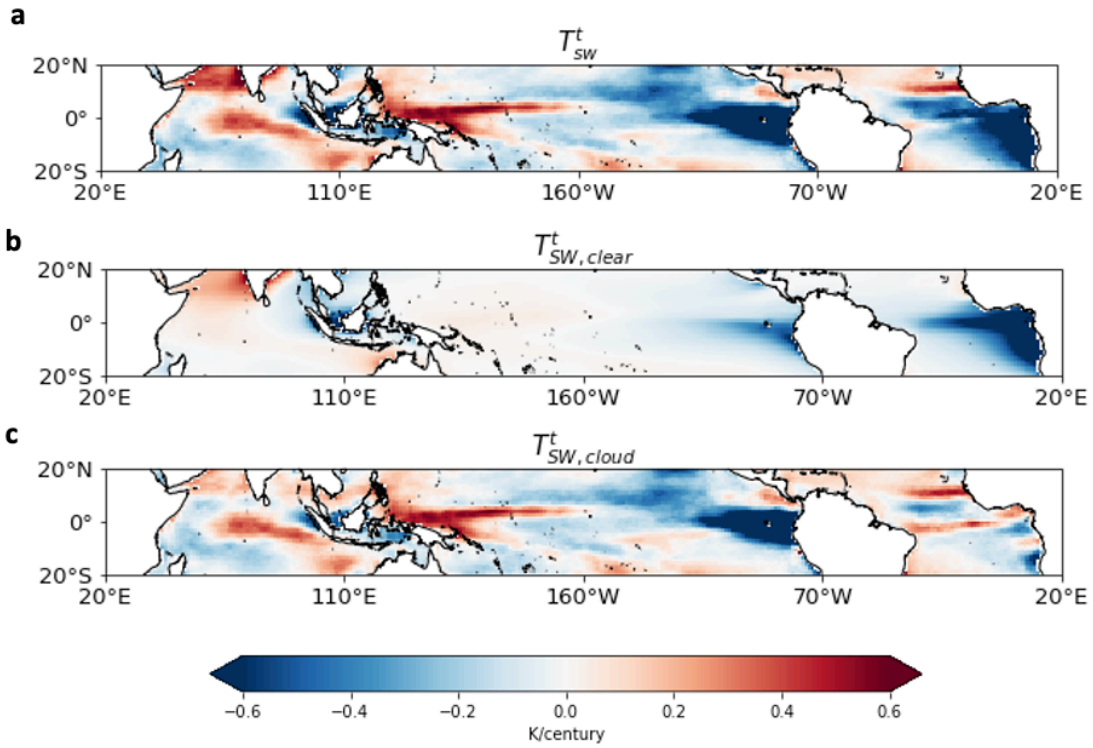
Supplementary Figure 3 | Observed and model simulated variations in annual-mean TIO SST since 1925. a, TIO absolute SST (K) and **b,** TIO relative SST (K) with respect to the reference period 1925-1944. In both panels, the grey lines are for each CESM1-LE all-forcing ensemble member and the black line is for ensemble-mean in the all-forcing experiments, and the colored lines are for different observational SST datasets. Relative SST is defined as absolute SST minus tropical-mean SST.



Supplementary Figure 4| Model simulated tropical SST trend pattern against observations. In all panels, the horizontal axis is for TIO relative SST trends during 1925-2005, and the vertical axis is for the pattern correlation of tropical SST trends within 20°S-20°N between an individual ensemble member (grey) or ensemble-mean (black) of CESM1 LE all-forcing experiments and observations. The only difference among the four panels is the observational dataset. **a,** HadISST. **b,** ERSSTv5. **c**, Kaplan SST v2. **d**, COBESST V2. Relative SST is defined as absolute SST minus tropical-mean SST.



Supplementary Figure 5 | BMB aerosol changes in the historical period. a, Aerosol optical depth (AOD) trends during 1925-2005 associated with BMB aerosol changes. **b,** AOD variations in specific regions associated with BMB aerosol changes. Boxes used for averaging AOD are shown in **a**. White hatches in **a** represent the regions that are 99% significant based on a t-test.



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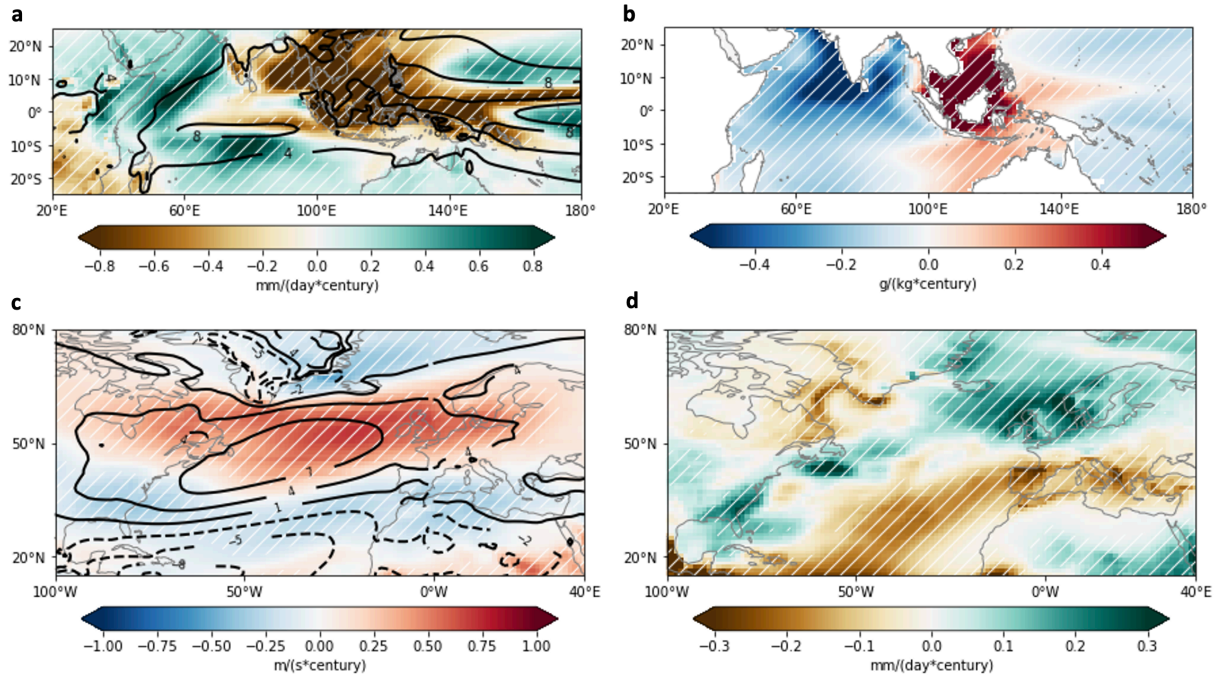
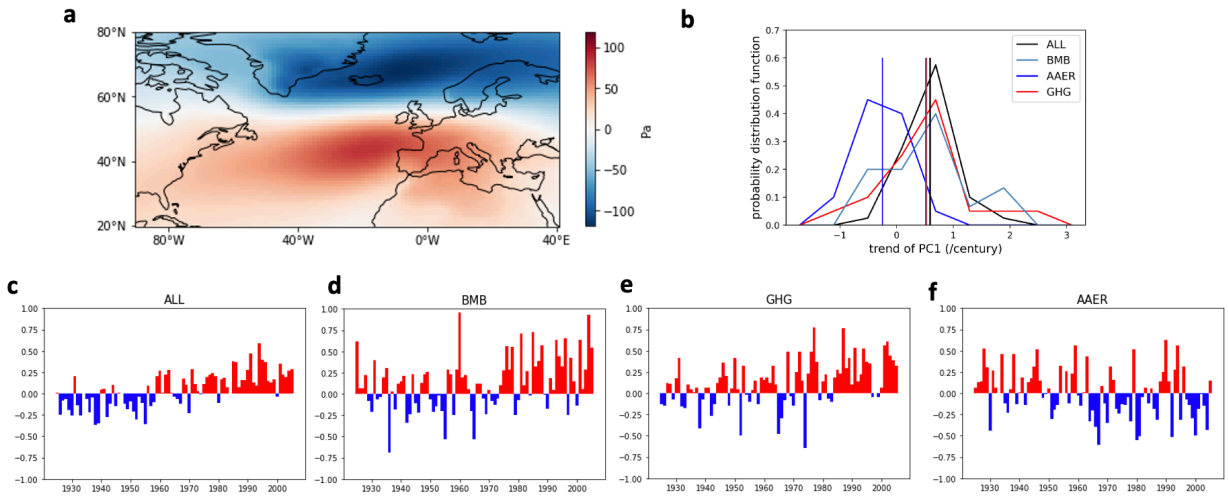
63 **Supplementary Figure 6 | BMB-induced tropical SST trends.** BMB-induced tropical SST

64 trends (K/century) during 1925-2005 associated with **a** total (T^t_{SW}), **b** clear-sky ($T^t_{SW,clear}$), and **c**

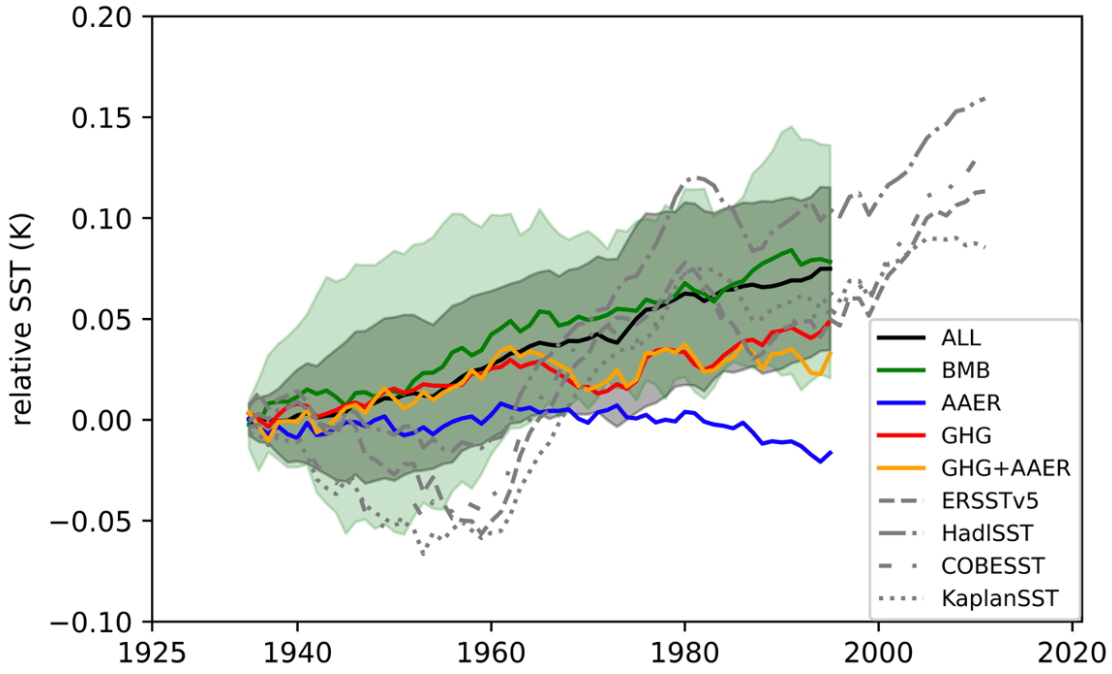
65 cloud ($T^t_{SW,cloud}$) shortwave radiative flux changes.



Supplementary Figure 7 | Climate changes simulated by CESM1 LE all-forcing experiments. a, Ensemble-mean rainfall trends (colors; mm/d/century) overlaid by climatological rainfall (contours; mm/d) and **b**, Ensemble-mean ocean salinity trends (g/kg/century) during 1925-2005. **c**, Ensemble-mean 850 mb zonal wind trends (colors; m/s/century) overlaid by climatological 850 mb zonal wind (contours; m/s) and **d**, Ensemble-mean rainfall trends (mm/d/century) during 1925-2005. White hatches in **a-d** represent the regions that are 99% significant based on a t-test.



Supplementary Figure 8 | NAO changes in the single-forcing CESM1 LE. a, Sea level pressure anomalies associated with the positive phase of NAO. **b**, Probability distribution functions of NAO trends across all the members in each set with vertical lines highlighting the ensemble averages. **c-f**, Ensemble-mean NAO series in ALL, BMB, GHG, and AAER, respectively.



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81 **Supplementary Figure 9 | Observed and model simulated TIO relative SST series. a**, 21-
82 year running mean for TIO relative SST variations (°C) since 1920 for observations (grey lines)
83 and ensemble means from the single-forcing CESM1 LE. The grey and green shadings are one
84 standard deviation among ensemble members for ALL and BMB, respectively.