Supplementary information for
Record low Antarctic sea ice coverage indicates a new sea ice state

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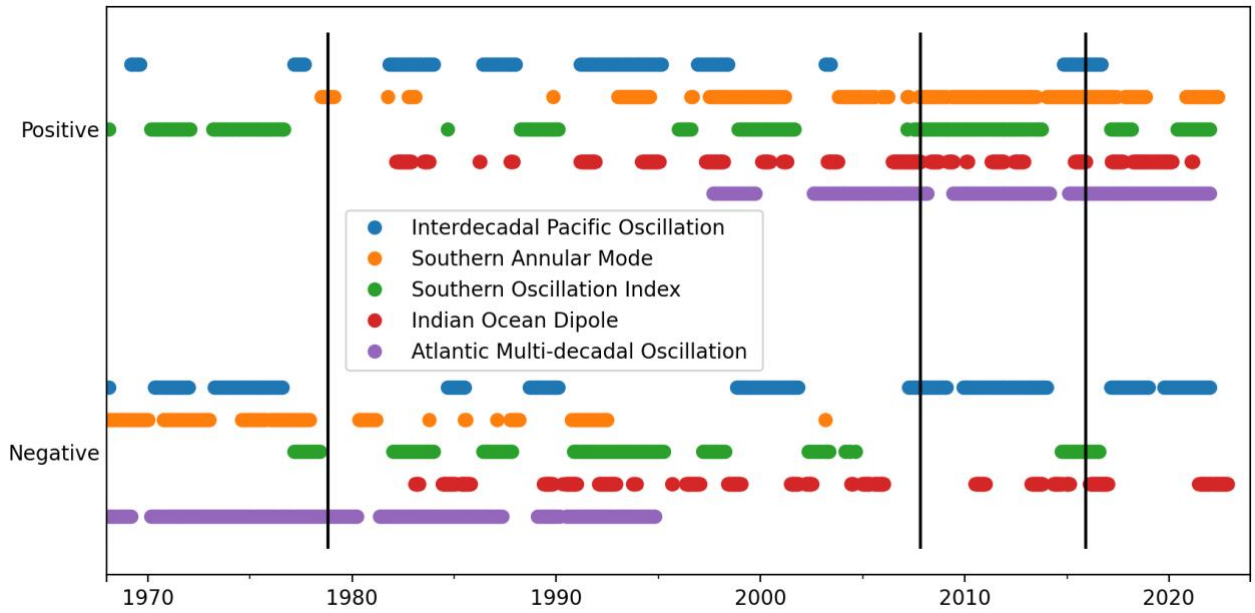
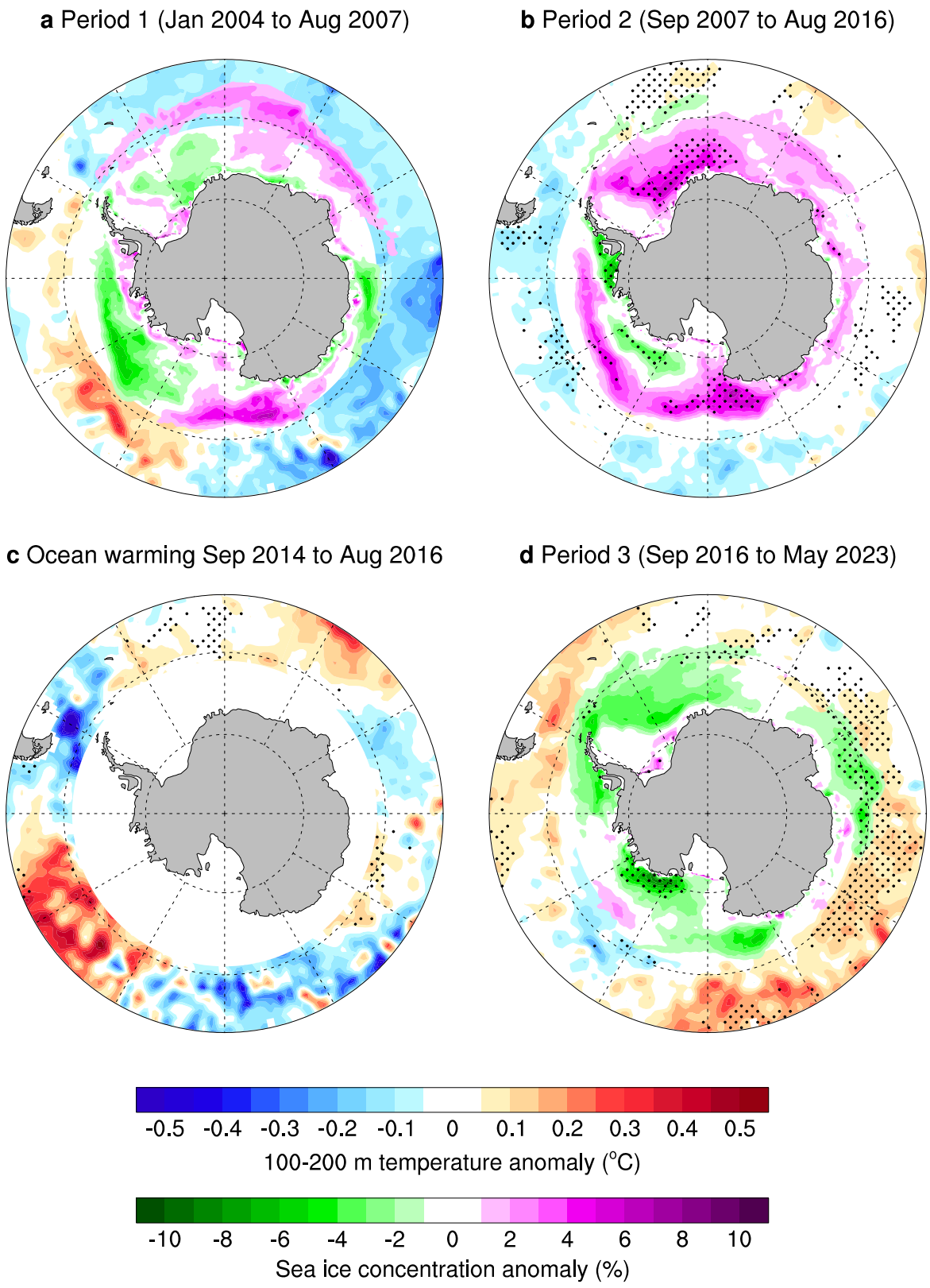
Supplementary Figure List

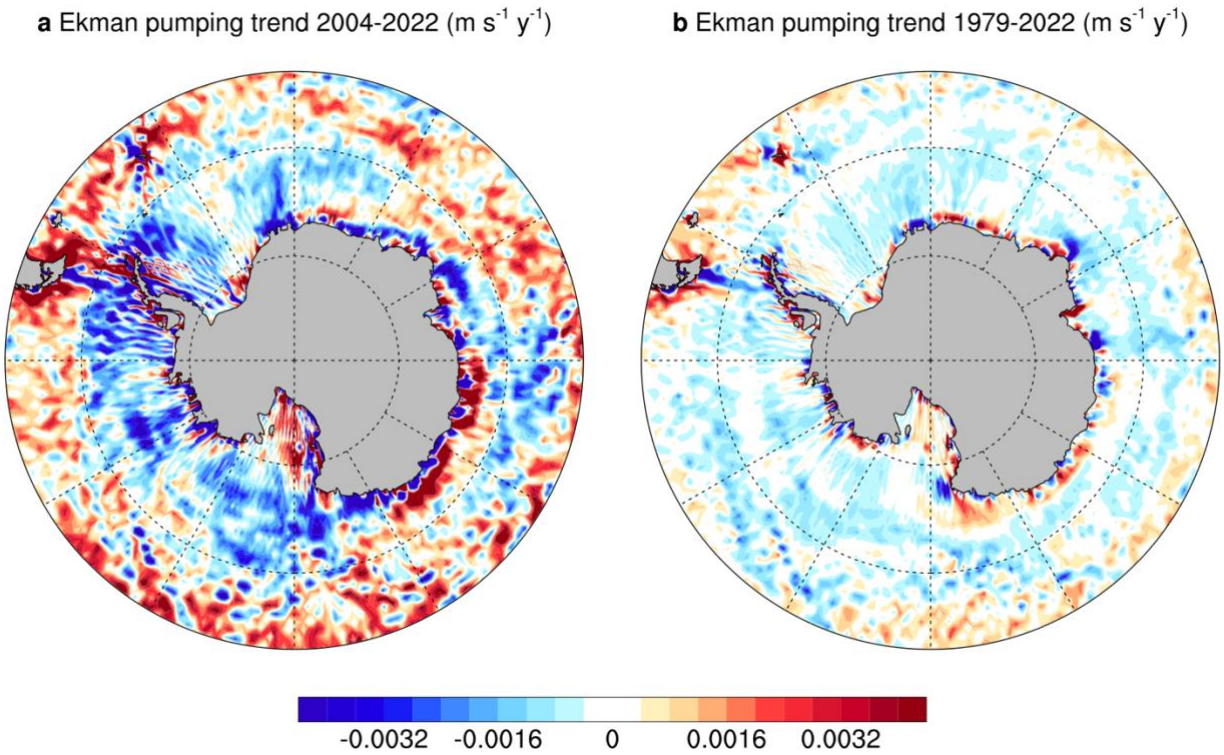


Supplementary Fig. 1: Positive and negative phases of large-scale climate indices do not align with the three sea ice periods identified with change point analysis. Monthly positive and negative phases of the Interdecadal Pacific Oscillation (blue), Southern Annular Mode (orange), Southern Oscillation Index (green), Indian Ocean Dipole (red), and Atlantic Multidecadal Oscillation (purple). All monthly indices are smoothed with a rolling mean using a two-year centred window and values within half a standard deviation of zero are masked. The vertical lines represent the start of the sea ice record (November 1978) and the two identified sea ice extent change points (August 2007 and August 2016).

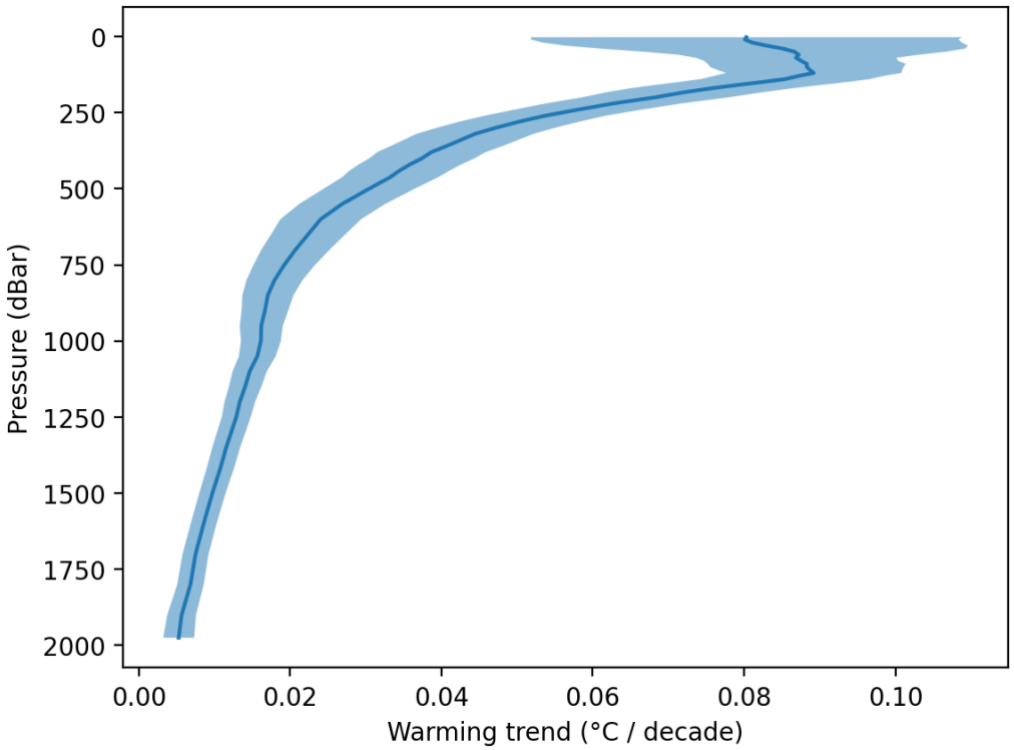


Supplementary Fig. 2: Spatial patterns of sea ice and ocean temperature anomalies reveal contrasting regional anomalies in the early period, high sea ice coverage in the second period, and circumpolar low sea ice coverage and a warm subsurface ocean in the current period. Sea ice concentration anomalies and 100-200 m temperature anomalies averaged over **a** the latter part of the first period with Argo coverage (January 2004 to August 2007), **b** the high-sea ice second period (September 2007 to August 2016), **c** ocean temperature in the two years preceding the third

period (September 2014 to August 2016), and **d** the low-sea ice third period (September 2016 to May 2023). Sea ice concentration anomalies are calculated relative to the 1979-2022 climatology and shown in green-magenta, and temperature anomalies are calculated relative to the 2004-2022 climatology and shown in blue-red. Stippling in **b**, **c**, and **d** indicates anomalies that are statistically different from the first period (November 1978 to August 2007 for sea ice concentration, January 2004 to August 2007 for temperature). A Bonferroni correction is applied (Methods), and significance is indicated where $p < 9e^{-6}$, representing a very stringent measure of significance.



Supplementary Fig. 3: Strengthened westerly winds over the Southern Ocean have increased Ekman upwelling over the past four decades. Ekman pumping trends over **a** 2004-2022, **b** 1979-2022, where positive (red) values indicate downward Ekman pumping and negative (blue) values indicate Ekman upwelling. Ekman pumping is calculated using annually-averaged surface wind stresses from the fifth generation European Centre for Medium-Range Weather Forecasts atmospheric reanalysis.



Supplementary Fig. 4: The subsurface Southern Ocean shows a strong warming trend over the Argo period (2004-present). At all depths in the gridded Argo dataset, there is a statistically significant warming trend ($p < 2.5e^{-6}$).