Record Low Antarctic Sea Ice in Austral Winter 2023: Mechanisms and Predictability

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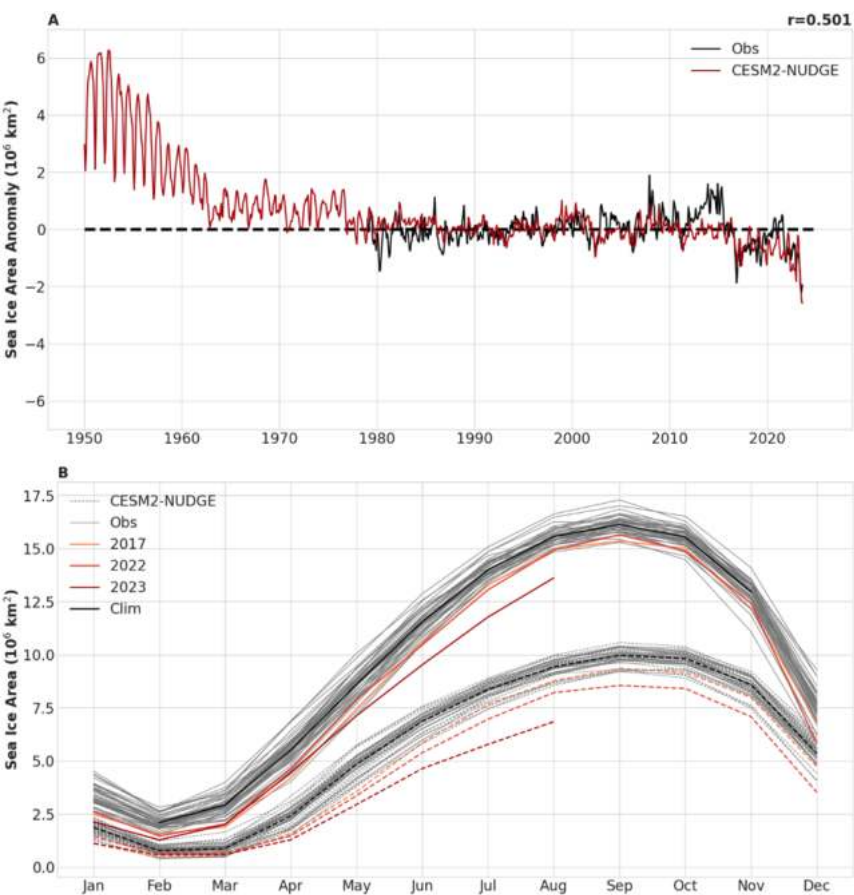**Contents of this file**

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- S2: Time series of region SIA anomalies from observations

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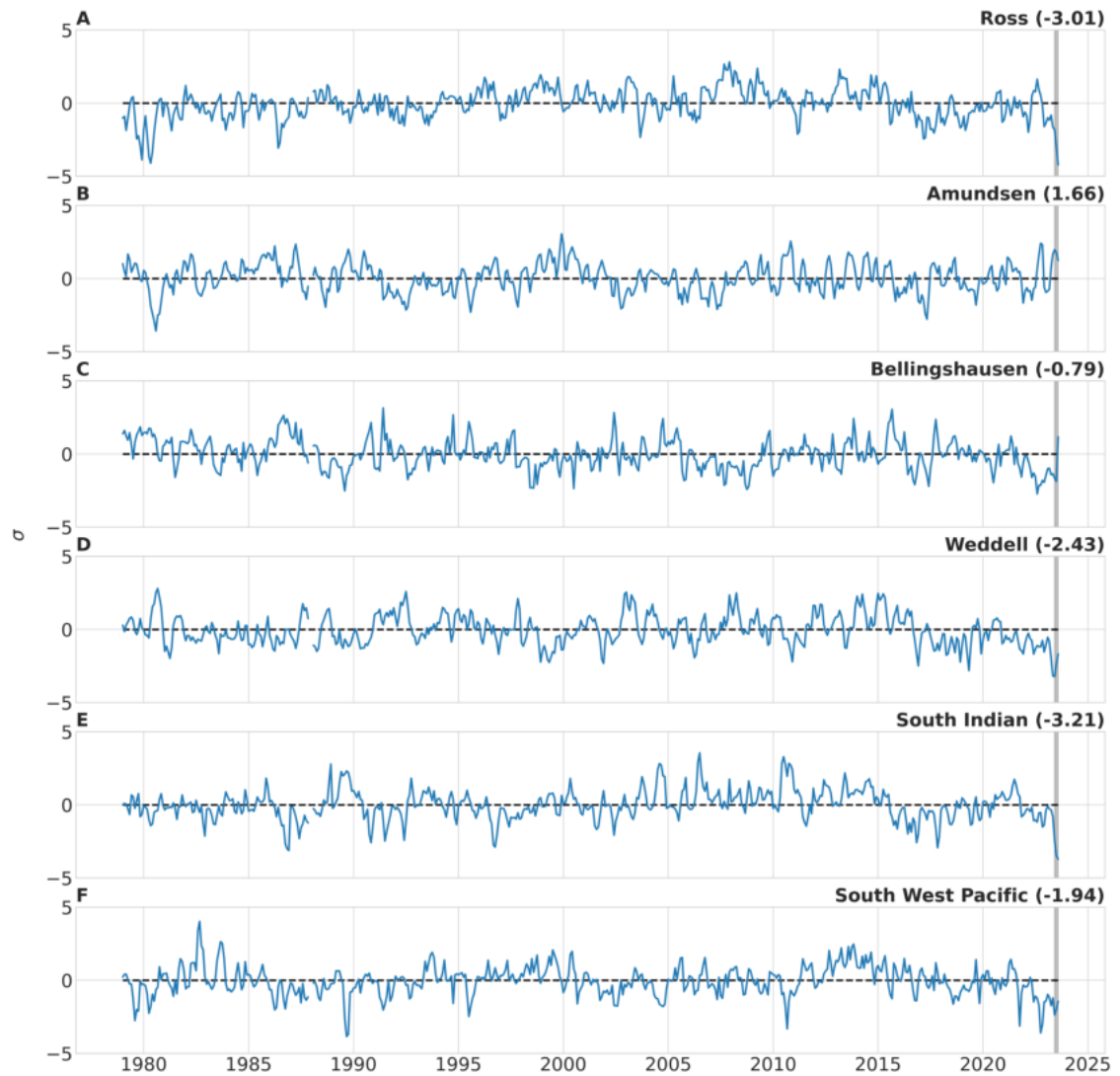
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- S12: MSLP and wind anomalies for each ensemble member in CESM2-REFORECAST-2023

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Table S1: Summary of model simulations. For the list of years used for nudging in CESM2-REFORECAST-2023 and CESM2-FORECAST-2024 refer to Figure S10-S14.
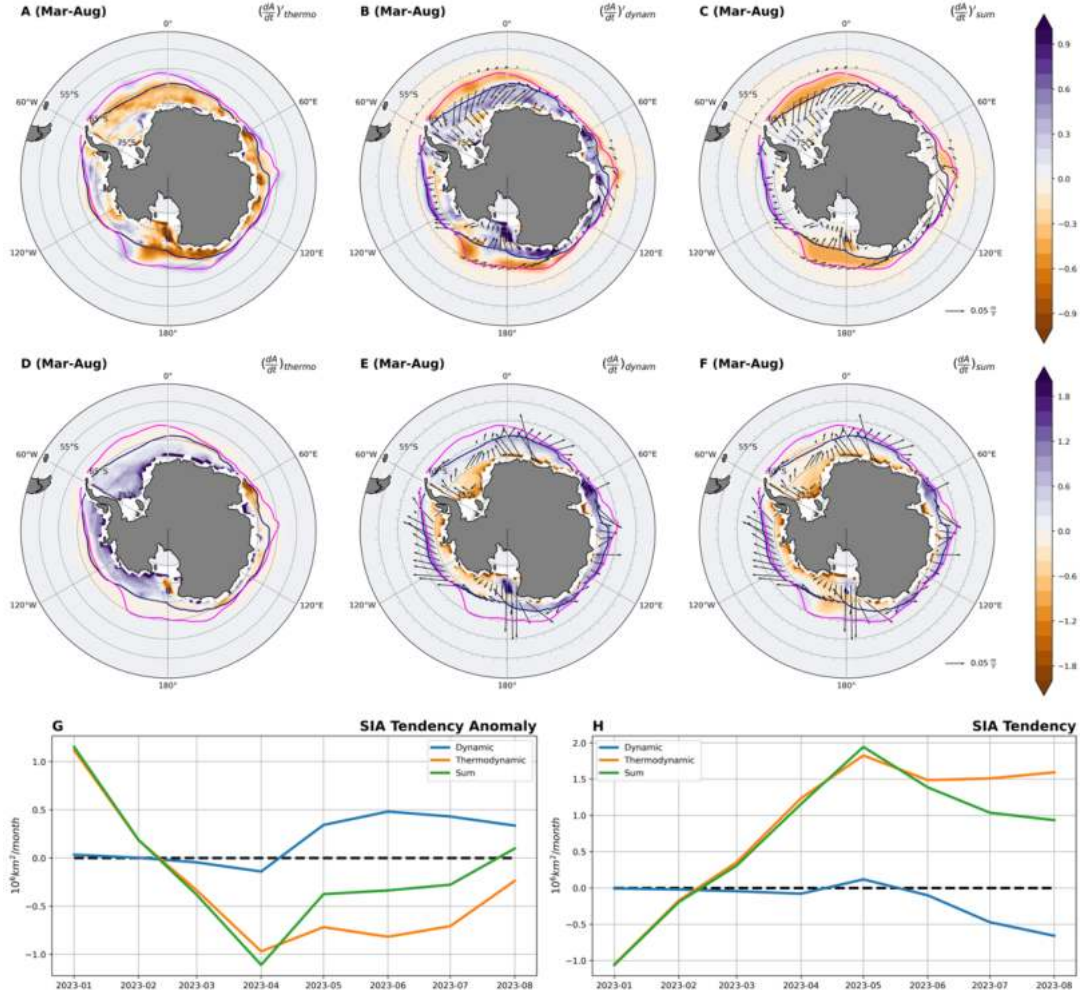
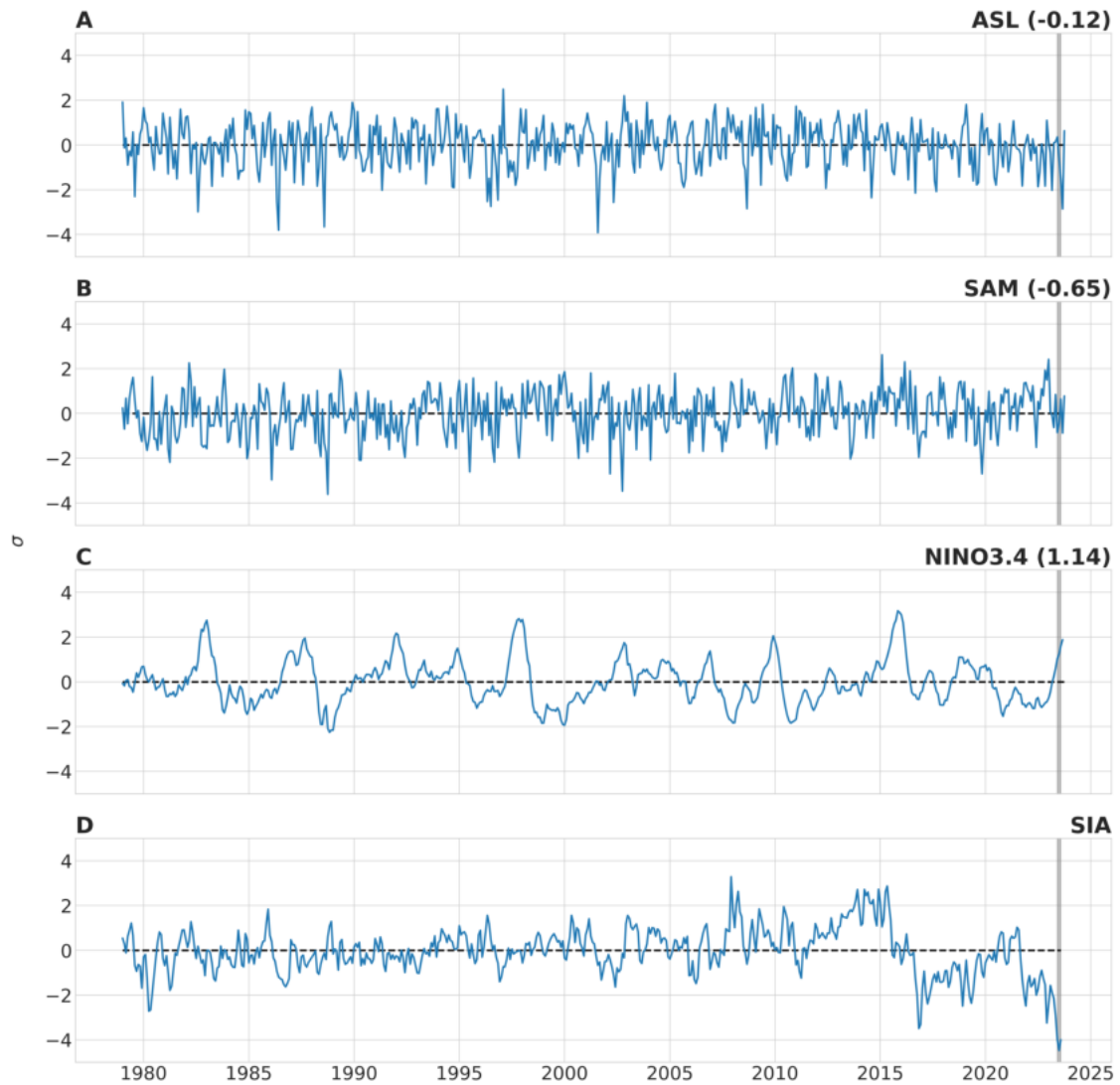| Model ID	Initial conditions	No. Members	Year of Nudged Winds
CESM2-NUDGE	BHIST-CMIP6-f09_g17 (01-1950)	1	1950 - 2023
CESM2-NO-ENSO-NUDGE	CESM2-NUDGE (01-2023)	1	2023
CESM2-REFORECAST-2023	CESM2-NUDGE (01-2023)	21	one year from 1980 to 2022
CESM2-FORECAST-2024	CESM2-NUDGE (01-2024)	22	one year from 1980 to 2023

Figure S1. Times series of monthly Antarctic SIA anomaly (million km^2) between January 1950 and August 2023 for CESM2-NUDGE (red) observations (black) (A). Annual cycle of monthly Antarctic SIA (million km^2) in CESM2-NUDGE (dashed lines) and observations (solid lines) (B). r values is upper right shows the Pearson correlation coefficient between Antarctic SIA anomalies in CESM2-NUDGE and observations between January 1979 and August 2023.
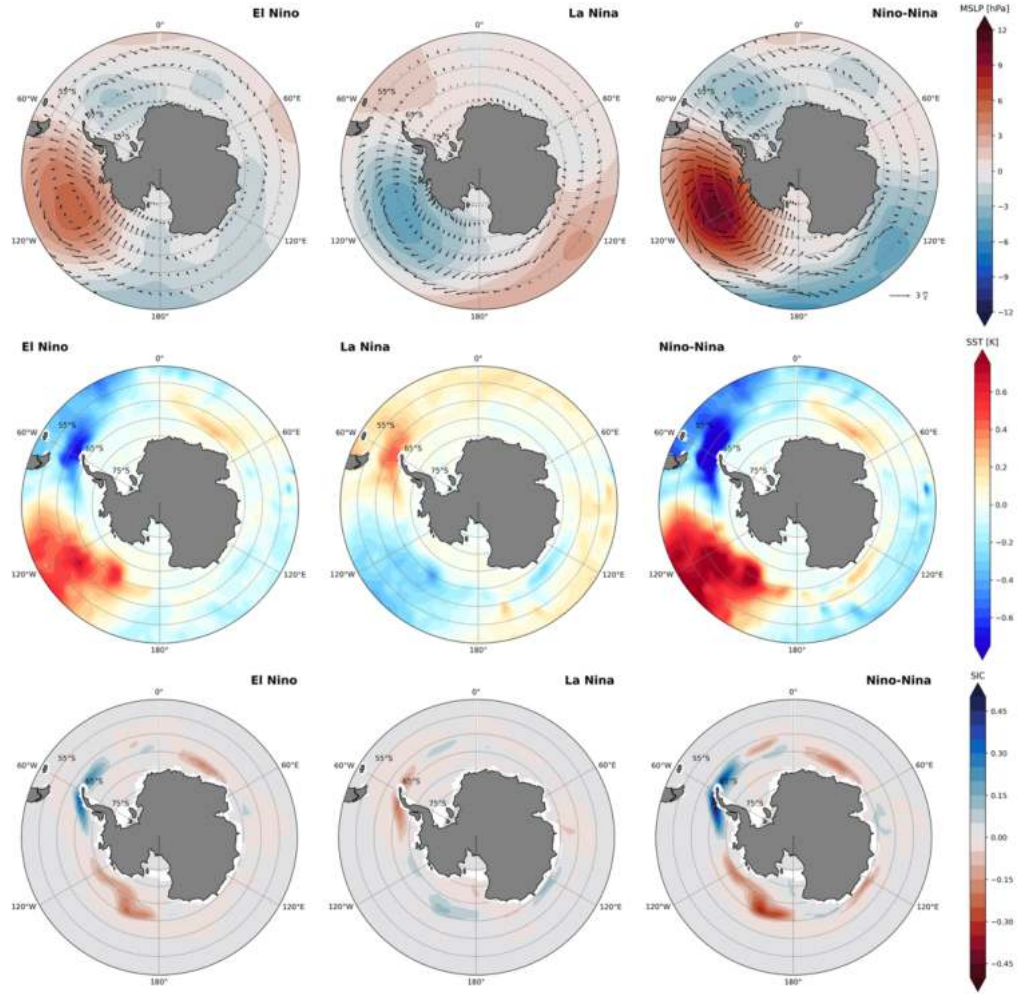
Figure S2. Times series of monthly standardized Antarctic SIA anomaly (σ) for each region between January 1979 and August 2023 for observations. Values in upper right parenthesis show the standardized anomaly for each index in JJA 2023.

Figure S3. Spatial pattern in ice-area tendency anomalies (A-C) and ice-area tendency (D-E) due to thermodynamic contributions (left column), dynamic contributions (middle column), and total contributions (right column) for March - August 2023 from CESM2-NUDGE. Arrows indicate March - August 2023 sea ice motion anomalies. Black contour indicates JJA 2023 sea ice edge (15% concentration). Time series of spatially averaged ice-area tendency anomalies (G) and raw values (H) between January and August 2023. Legend shows the total SIA contribution for each term reconstructed by integrating the tendency timeseries between January 1, 2023 and August 1, 2023.
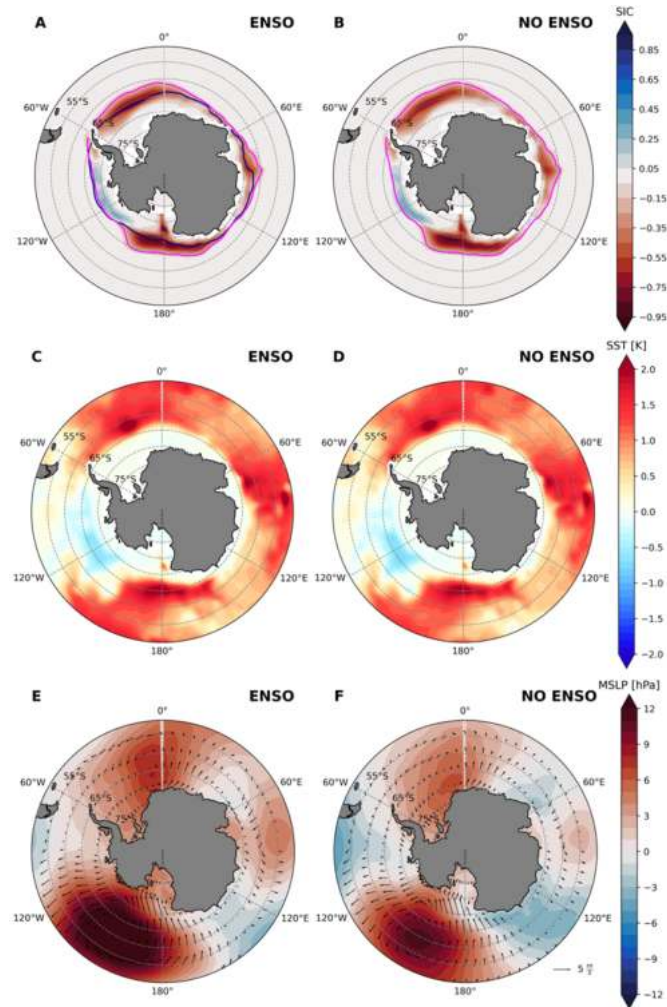
Figure S4. Time series of monthly standardized anomaly in Amundsen Sea Low central pressure (A), Southern Annual Mode (B), Niño3.4 index (C), and Antarctic SIA (D). The JJA 2023 mean for each index is shown in the upper right of each panel.
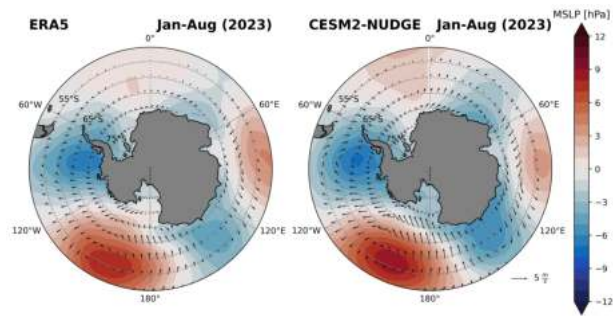
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Figure S5. Composites of MSLP and near-surface winds (top row), SSTs (middle row) and SIC (bottom row) anomalies from CESM2-NUDGE for all JJA between 1979 and 2022 when the observed standardized Niño3.4 index is greater than or equal to 1-standard deviation (left column; El Niño) or less than or equal to negative 1-standard deviation (middle column; La Niña). The difference between El Niño and La Niña composites (left and middle columns) is shown in the right-most column.
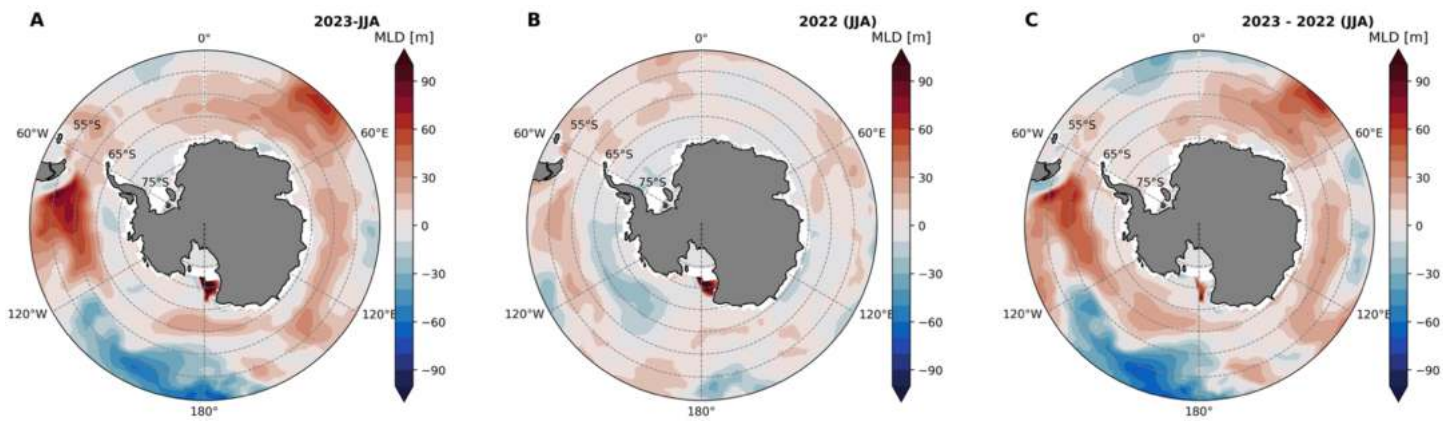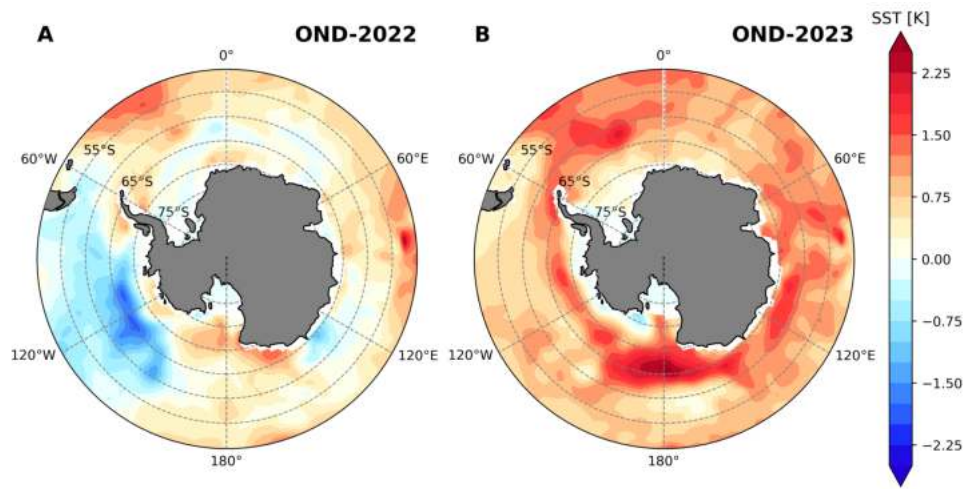
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Figure S6. SIC, SST, and MSLP and near-surface wind anomalies in JJA 2023 for CESM2-NUDGE (left column) and CESM2-NO-ENSO-NUDGE (right column).

Figure S7. MSLP and near-surface wind anomalies in January - August 2023 for ERA5 and CESM2-NUDGE.

Figure S8. Mixed-layer depth anomalies (m) in 2023 JJA (A), 2022 JJA (B), and their difference (C).
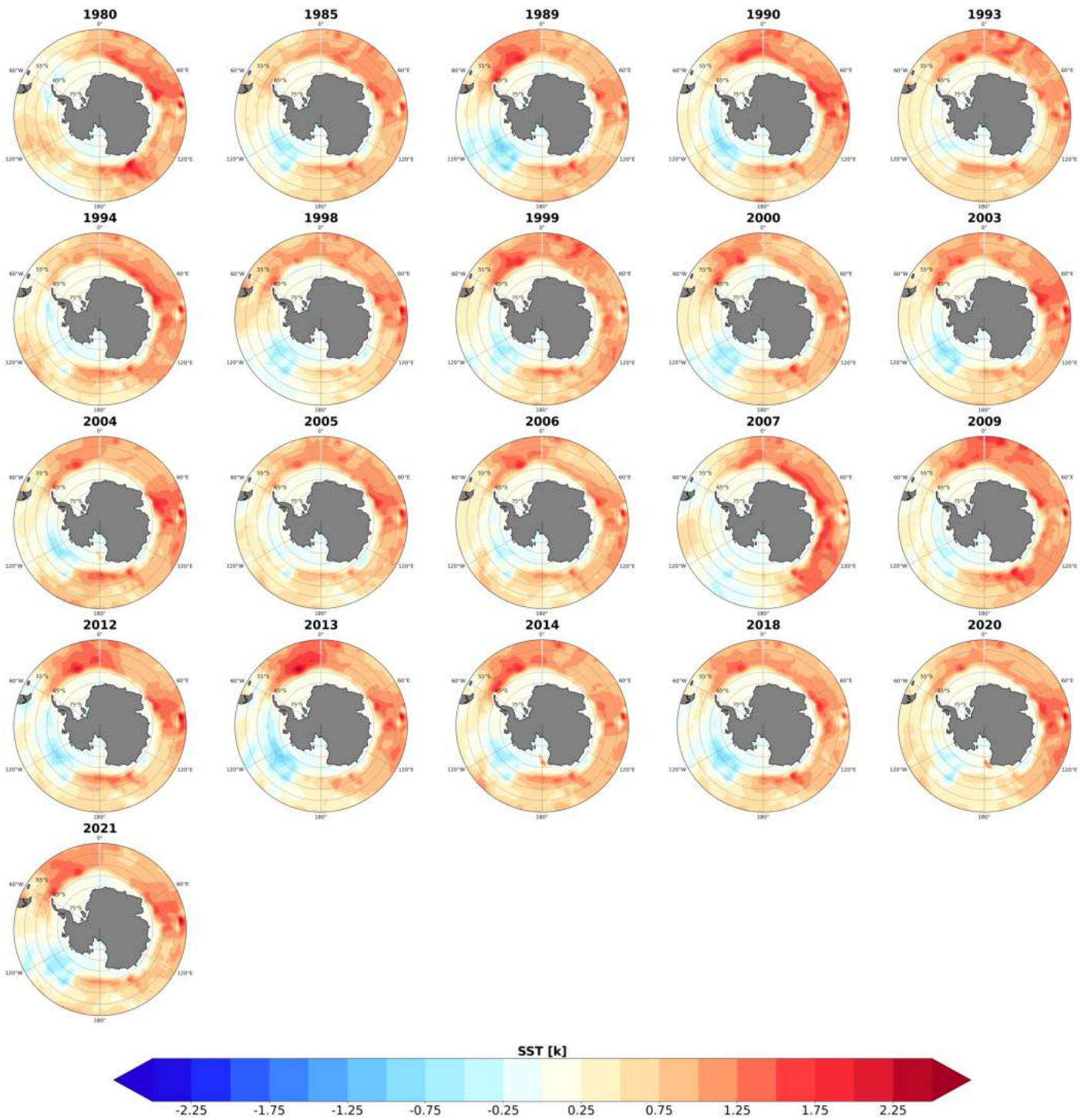
Figure S9. SST anomalies in October, November and December (OND) in 2022 (A) and 2023 (B) in CESM2-NUDGE.

CESM2-REFORECAST-2023 (SIC)

Figure S10.   SIC anomalies in JJA 2023 for each ensemble member from CESM2-REFORECAST-2023. Year at the top indicates the year that winds are nudged to in 2023.
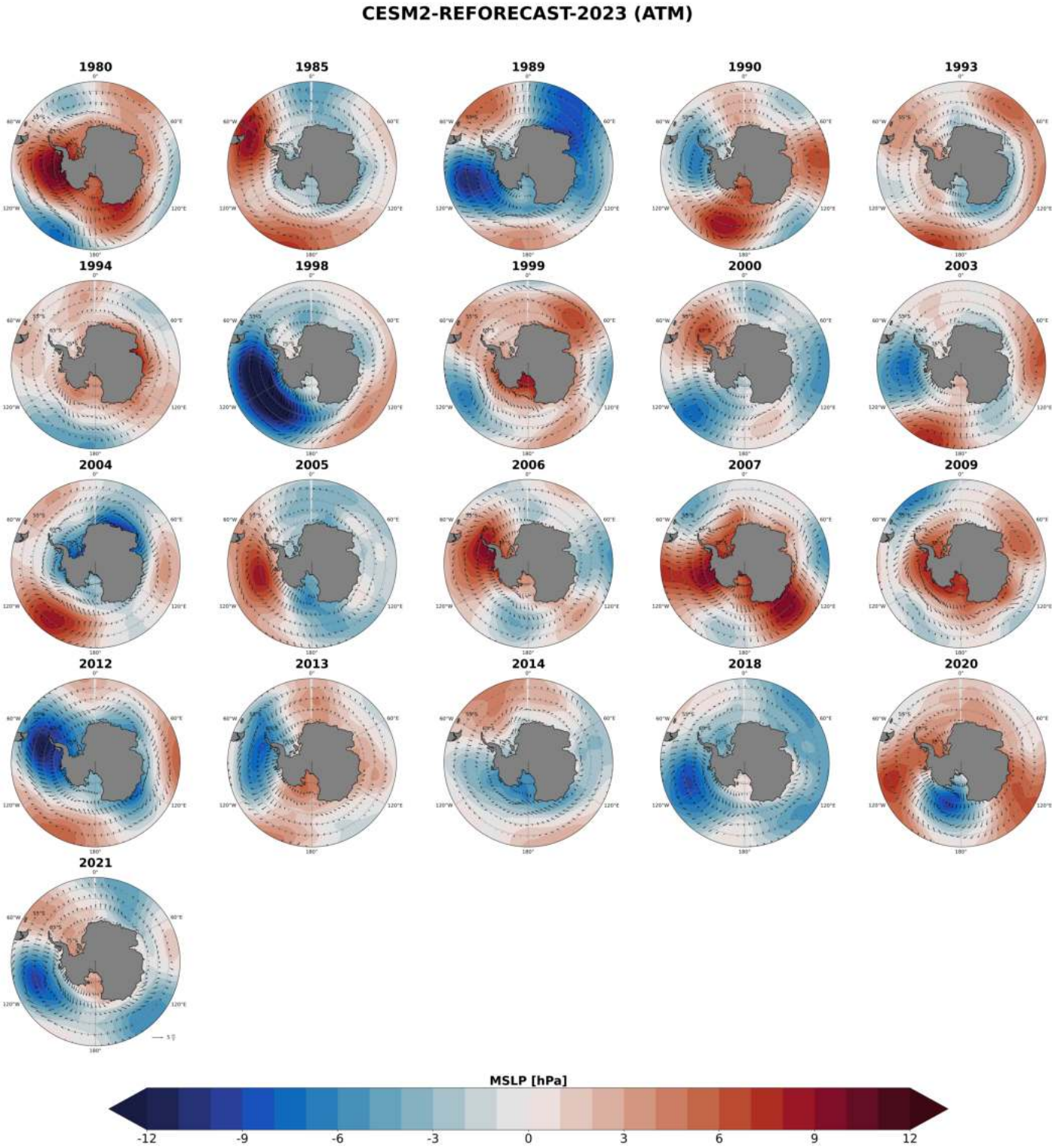
CESM2-REFORECAST-2023 (SST)

Figure S11. SST anomalies in JJA 2023 for each ensemble member from CESM2-REFORECAST-2023. Year at the top of each panel indicates the year that winds are nudged to in 2023.

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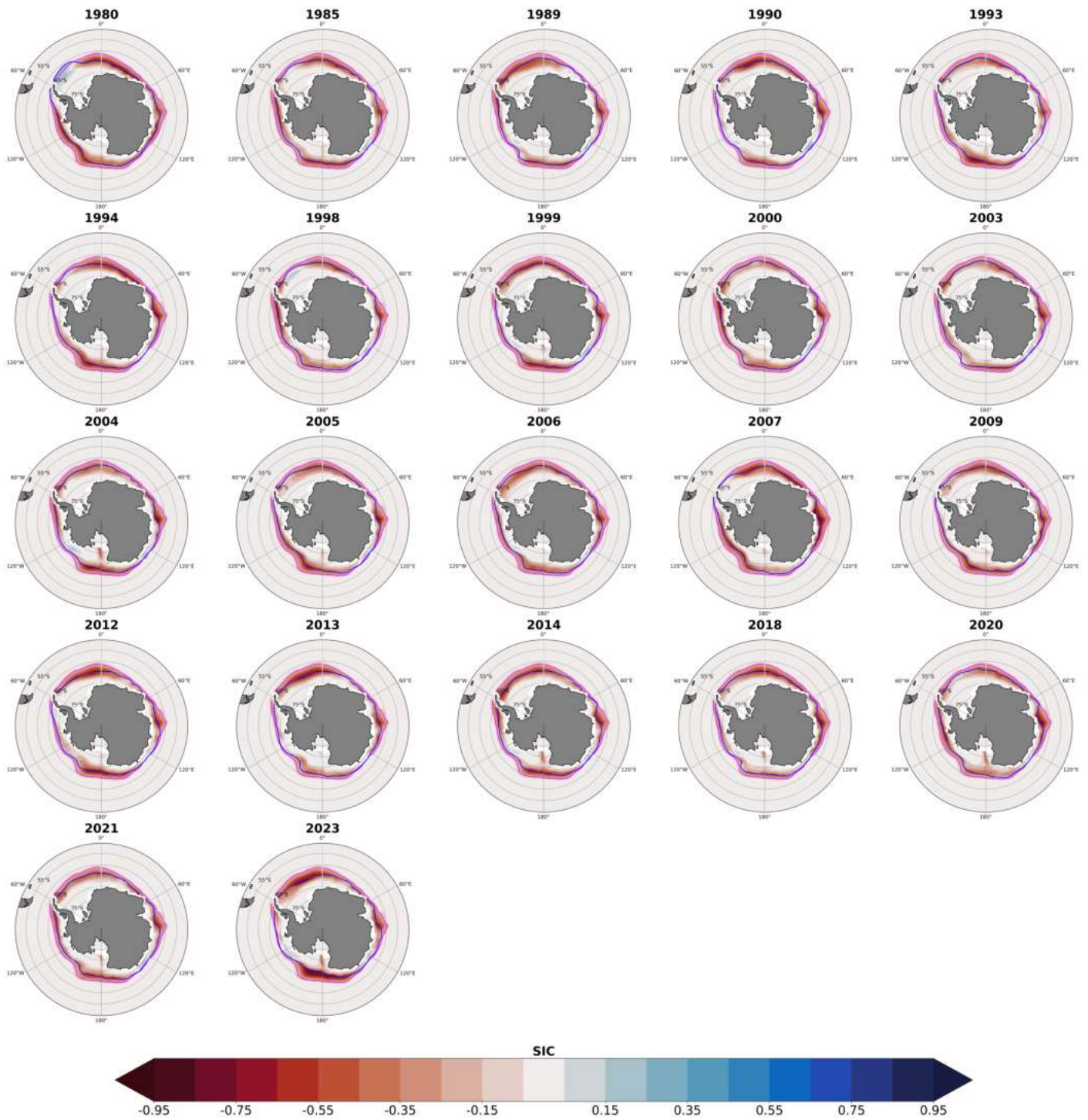
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CESM2-REFORECAST-2023 (ATM)

Figure S12. MSLP and near-surface wind anomalies in JJA 2023 for each ensemble member from CESM2-REFORECAST-2023. Year at the top of each panel indicates the year that winds are nudged to in 2023. These are nearly identical to the MSLP and near-surface wind anomalies in JJA 2024 from CESM2-FORECAST-2024 (omitted for brevity).
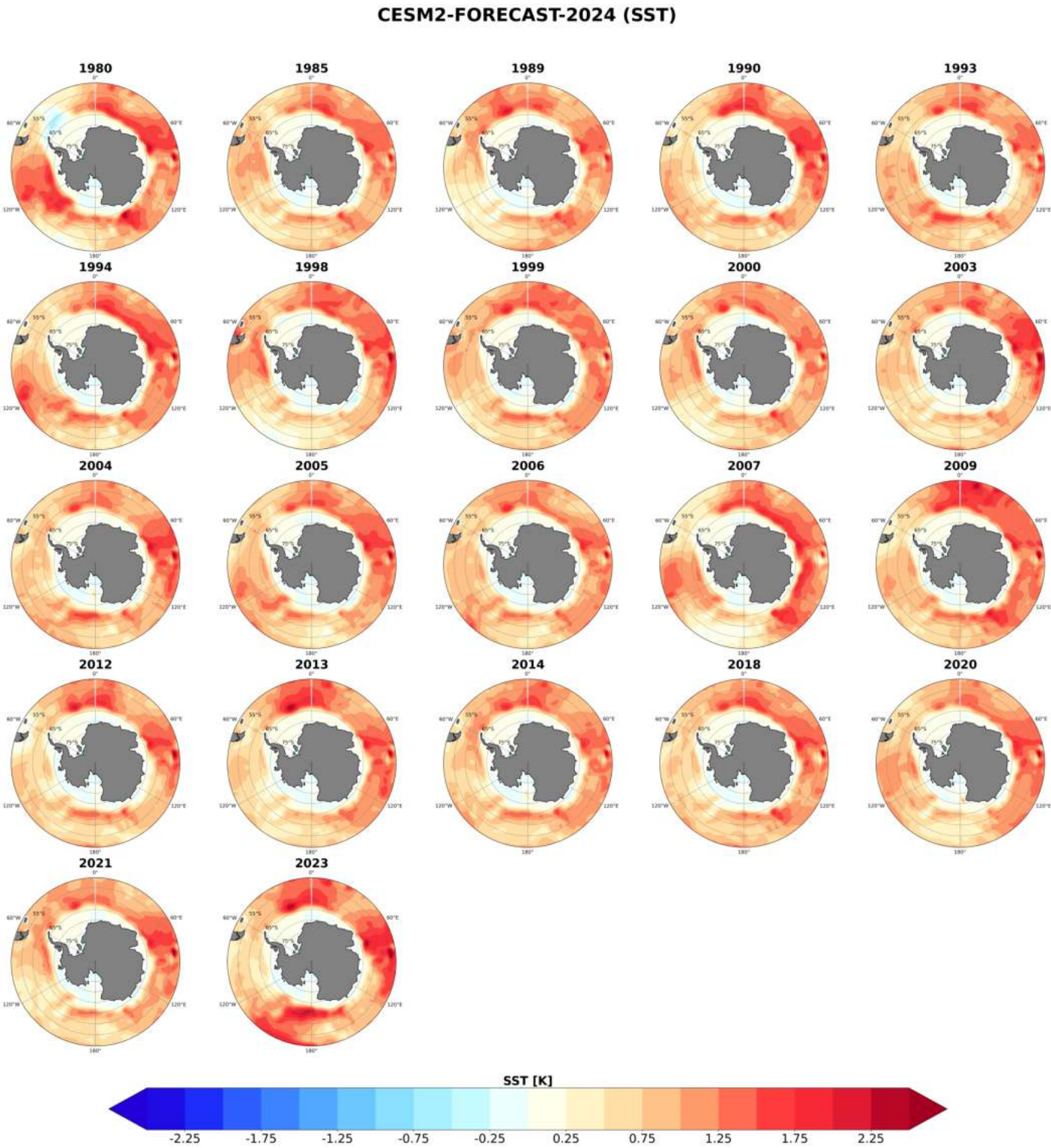
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CESM2-FORECAST-2024 (SIC)

Figure S13. SIC anomalies in JJA 2024 for each ensemble member from CESM2-FORECAST-2024. Year at the top indicates the year that winds are nudged to in 2024.

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CESM2-FORECAST-2024 (SST)

Figure S14. SST anomalies in JJA 2024 for each ensemble member from CESM2-FORECAST-2024. Year at the top of each panel indicates the year that winds are nudged to in 2024.

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