Figure S1. Climatological (a) SIT and (b) sea ice age from 1989 to 2022. The magenta curves represent the central Arctic.
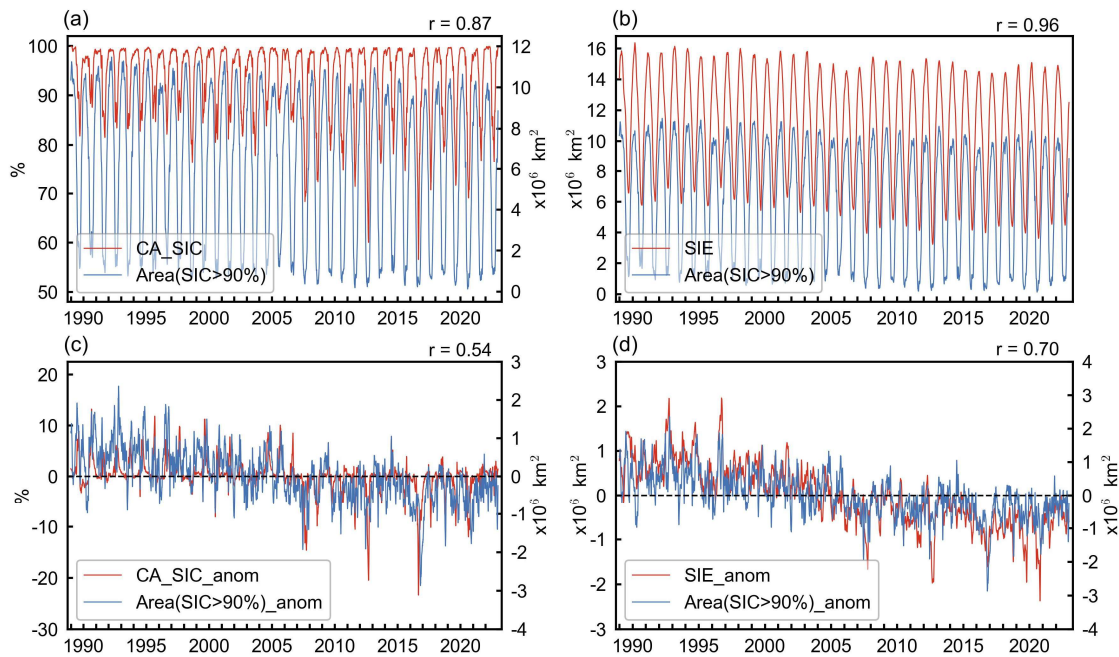
Figure S2. Time series of SIC in the central Arctic, area with SIC > 90%, and Arctic sea ice extent: **(a, b)** original values and **(c, d)** anomalies. The correlation coefficients between the two time series in each panel are shown in the upper right corner.

Line 20
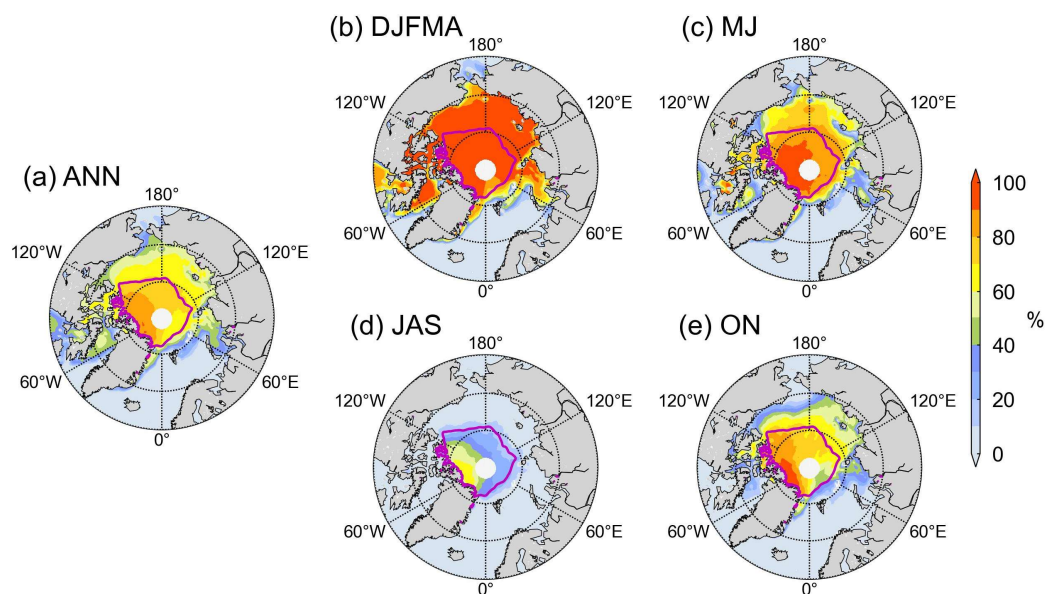
Figure S3. Probability of SIC exceeding 90% for **(a)** annual mean, **(b)** winter, **(c)** spring, **(d)** summer, and **(e)** autumn. The seasons are defined by SIC seasonal variation according to Fig.1 d.

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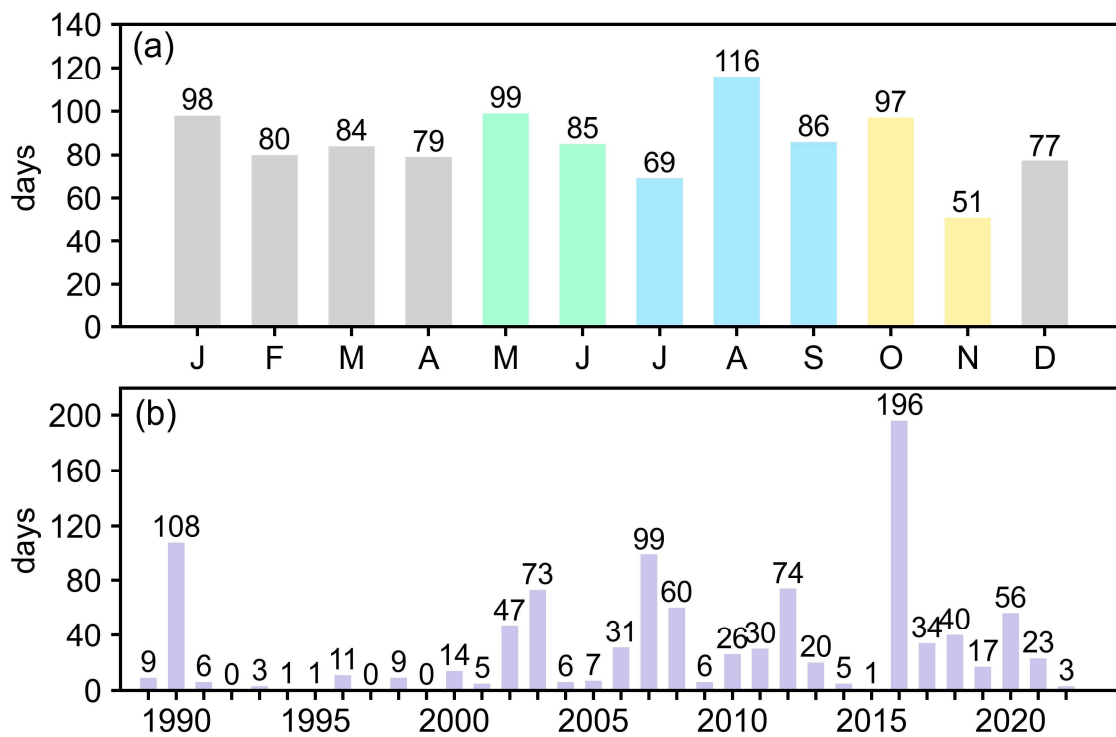
29 **Figure S4. (a)** seasonal and **(b)** interannual distributions of ELSEs in the central Arctic. In **(a)**, the colors of the bars

30 correspond to that in Fig. 1e.

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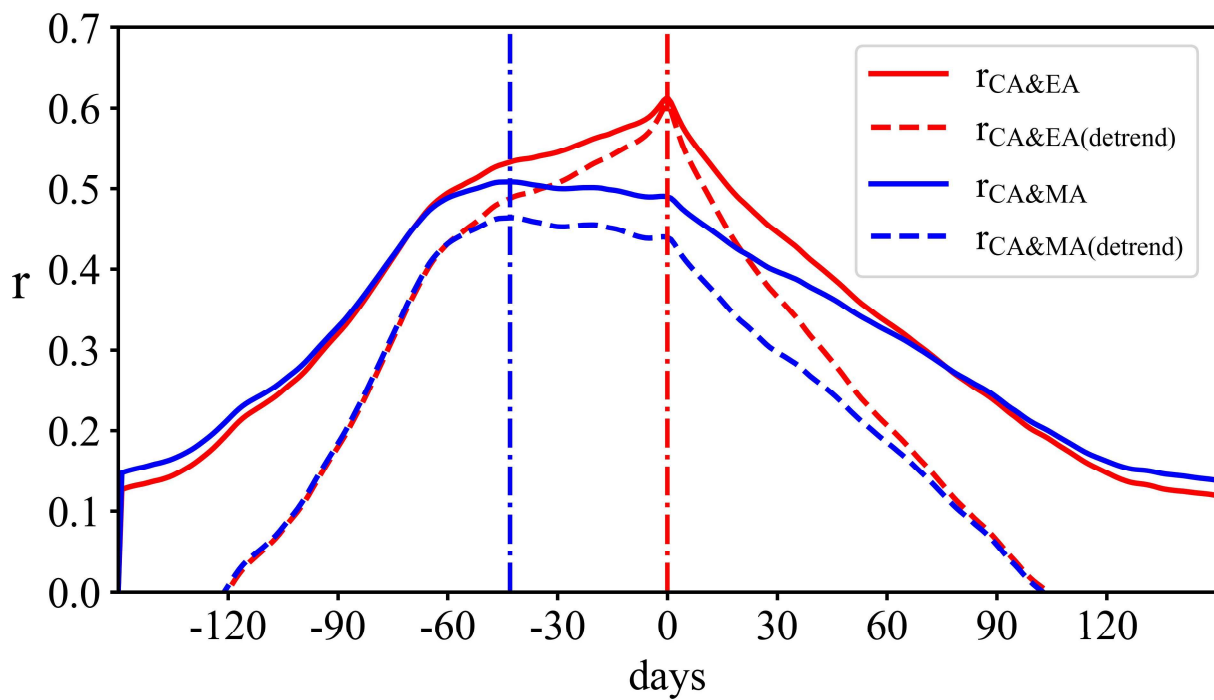
34 **Figure S5.** Lead-lag correlation coefficients between the SIC anomaly in the central Arctic and the SIC anomaly in the

35 entire Arctic (red line) or the marginal Arctic (blue line). The positive (negative) value of the abscissa indicates the days

36 that the SIC anomaly in the central Arctic leads (lags) the SIC anomaly in the entire Arctic or marginal Arctic. The dot

37 dash lines indicate the days corresponding to the maximum correlation coefficients (0 and -43 days). Solid (dashed) lines

38 represent the untrended (detrended) results.

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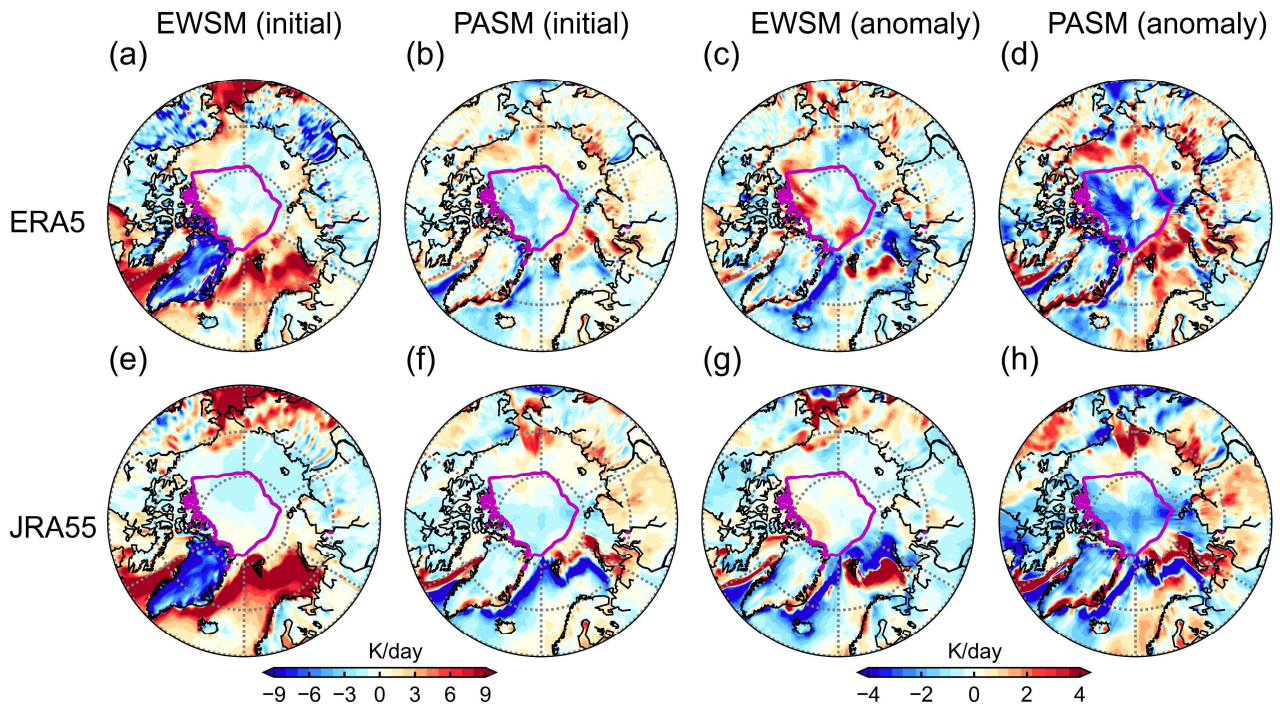
Figure S6. Composite differences between the positive and negative phases of the **(a, c, e, g)** EWSM and **(b, d, f, h)** the PASM for diabatic heating rates, showing **(a, b, e, f)** the raw values and **(c, d, g, h)** the anomaly values. The upper row displays results based on ERA5 data, while the lower row shows results based on JRA-55 data. The magenta lines denote the central Arctic. Note that different color bars are used for the raw fields and the anomaly fields.
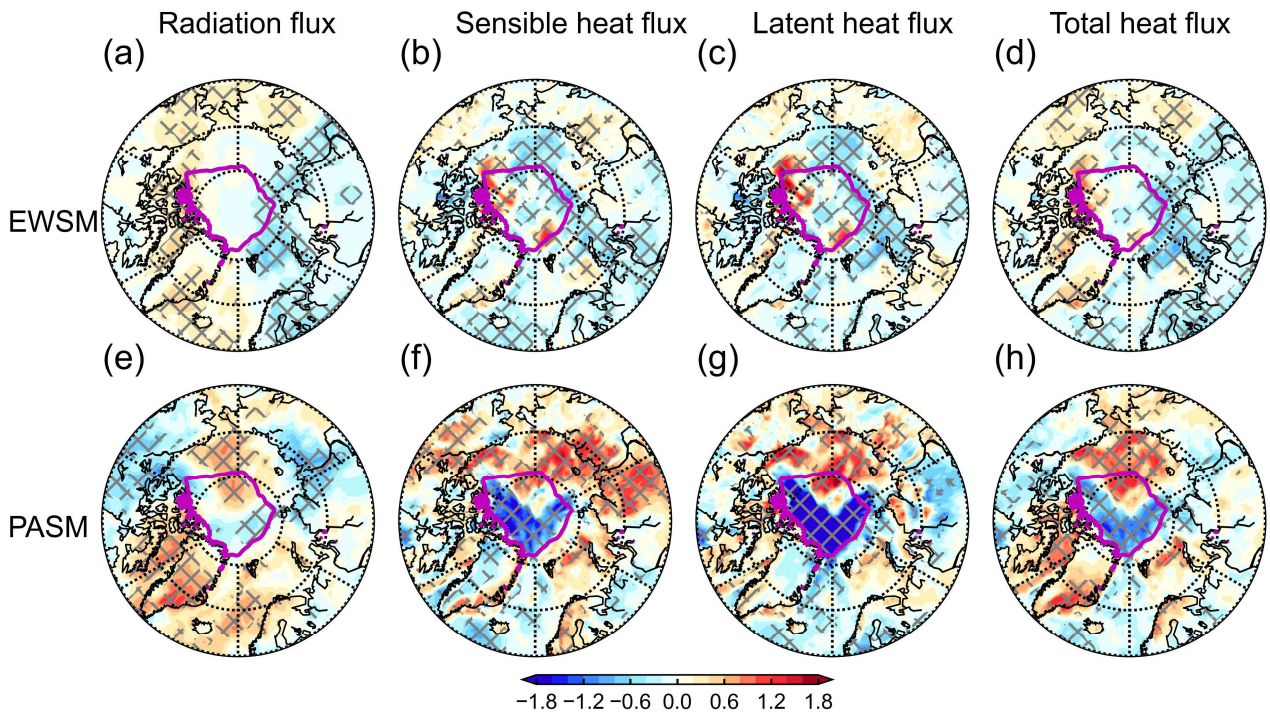
Figure S7. Composite differences between the positive and negative phases of the standardized anomalies for **(a–d)** the EWSM and **(e–h)** the PASM for **(a, e)** atmospheric surface boundary radiation flux, **(b, f)** sensible heat flux, **(c, g)** latent heat flux, and **(d, h)** total flux. Positive values indicate downward flux. The magenta lines denote the central Arctic. Grey crossings indicate areas with significant difference at the 0.05 significance level based on Student's t-test. Note that due to the different SDs of the total radiation flux and its three components, panels **(d)** or **(h)** do not equate to the sum of **(a)** + **(b)** + **(c)** or **(e)** + **(f)** + **(g)**, respectively.

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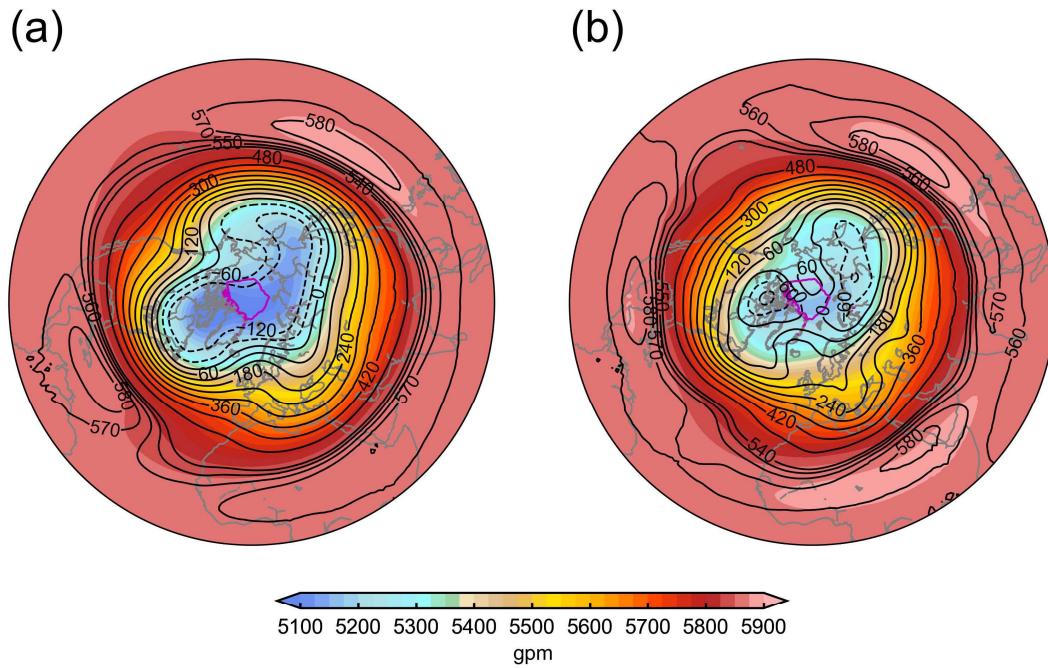
Figure S8. Composite fields of the 500 hPa geopotential height for **(a)** the EWSM and **(b)** the PASM, showing the original fields (shadings) and the anomaly fields (contours). To enhance clarity, the contour values have been subtracted the climatological mean of geopotential height north of 60°N (5300 m). Solid lines represent positive values and dashed lines represent negative values.

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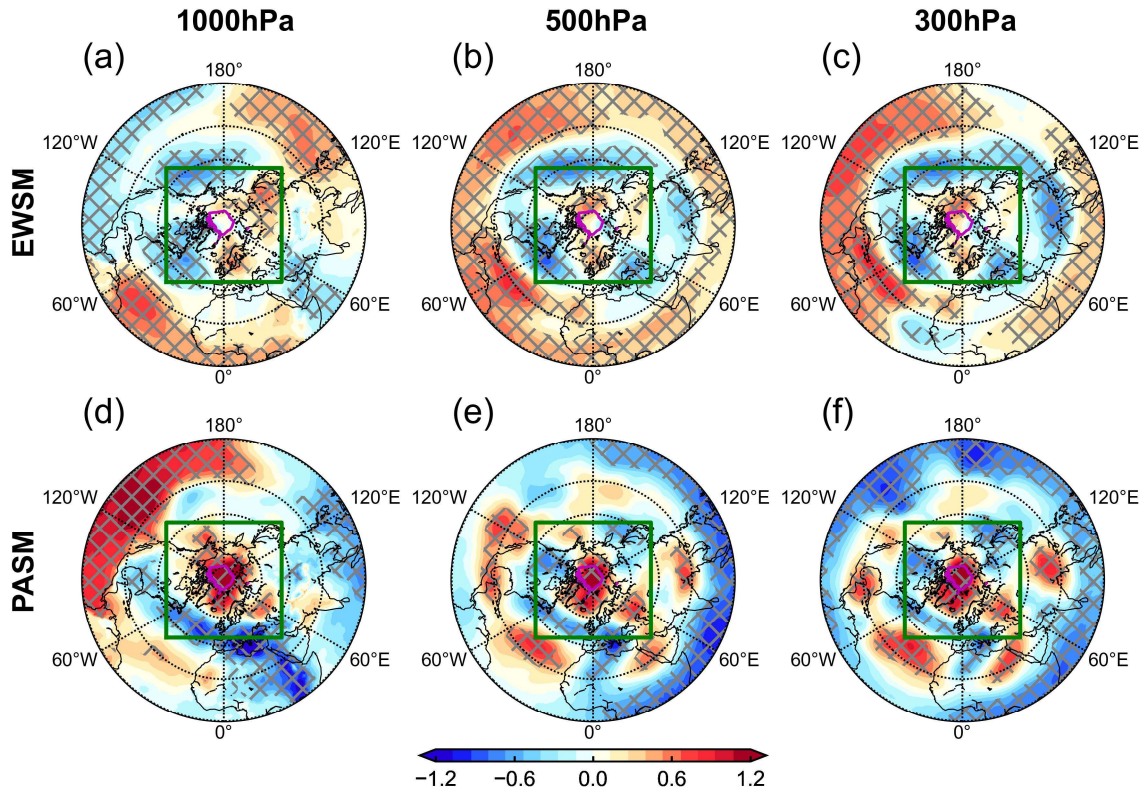
Figure S9. Same as Fig. 6 but with a larger spatial extent (0°–90°N) and the addition of 300 hPa results. The green box indicates the spatial range of Fig. 6. Grey crossings denote areas with significant difference at the 0.05 significance level based on Student's *t*-test. Magenta lines represent the central Arctic.
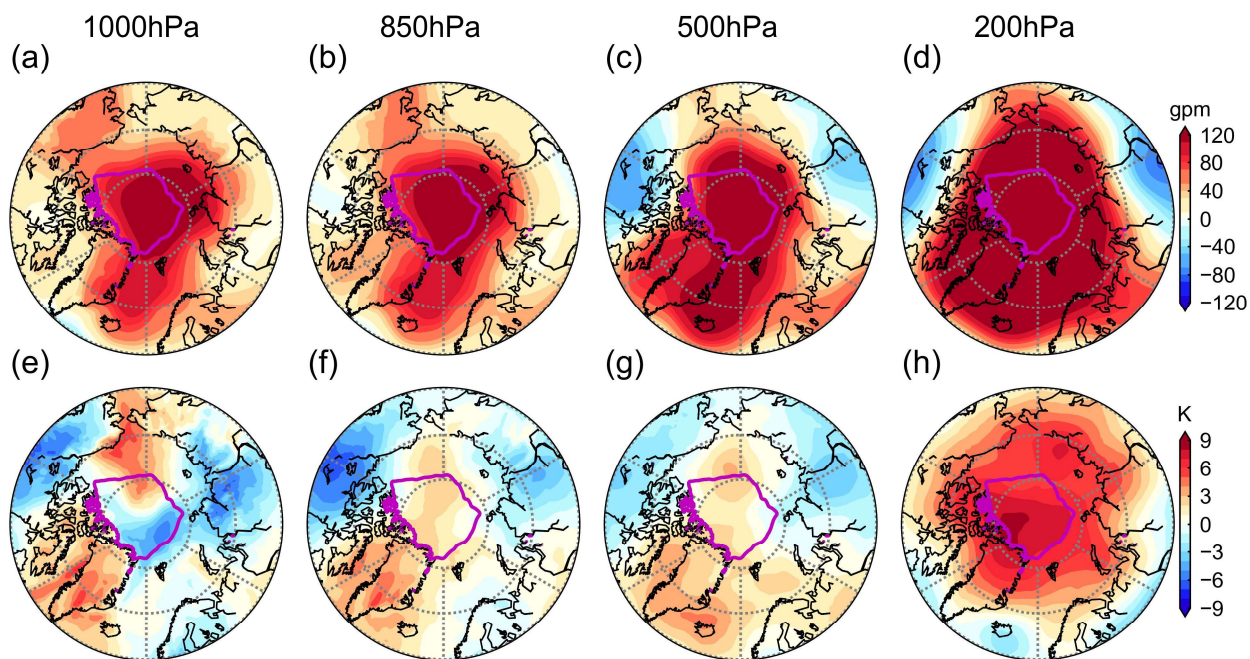
Figure S10. Composite fields of **(a–d)** geopotential height and **(e–h)** temperature anomaly at **(a, e)** 1000 hPa, **(b, f)** 850 hPa, **(c, g)** 500 hPa, and **(d, h)** 200 hPa for the PASM. The magenta lines denote the central Arctic.

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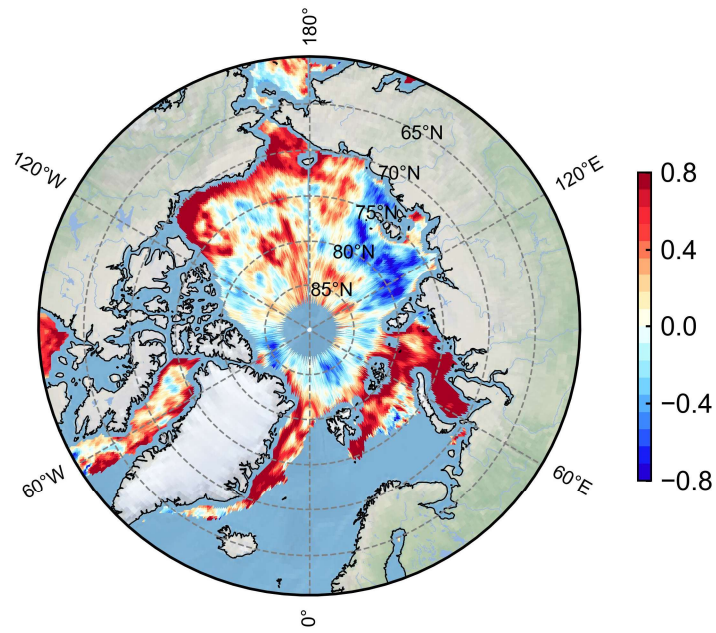
83 **Figure S11.** Composite differences between the positive and negative phases of the standardized anomalies of sea ice

84 deformation for the PASM.

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