Supplement

for the reply to Reviewer 1's comments

Multidecadal Variability and Predictability of Antarctic Sea Ice in GFDL SPEAR_LO Model

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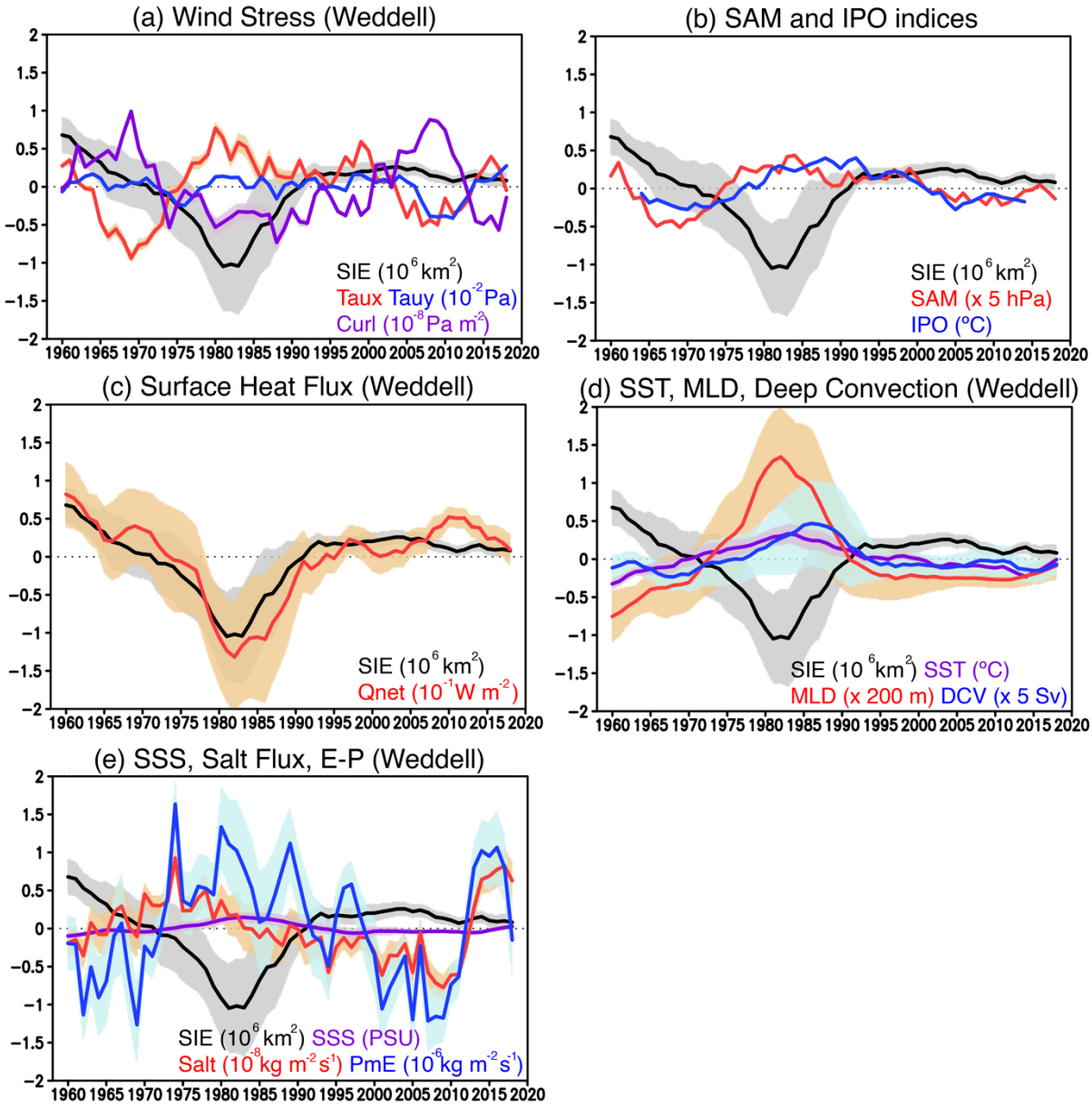


Figure 3 (a) Time series of 5-yr running mean SIE (black in 10^6 km^2), zonal (Taux; red in 10^{-2} Pa) and meridional (Tauy; blue in 10^{-2} Pa) wind stress, and wind stress curl (Curl; purple in 10^{-8} Pa m^{-2}) anomalies averaged in the Weddell Sea (60ºW-0º, south of 55ºS) during 1958-2020. Shades indicate one and minus one standard deviations of the anomalies from 30 ensemble members of the SPEAR_LO_DCIS. Positive wind stress curl anomalies correspond to downwelling anomalies in the ocean. **(b)** Same as in **(a)**, but for the 5-yr running mean SAM index (red in 5 hPa) and 13-yr running mean IPO index (blue in ºC). **(c)** Same as in **(a)**, but for the SIE (black in 10^6 km^2) and the net surface heat flux (Qnet; red in 10^{-1} W m^{-2}) anomalies. Positive surface heat flux anomalies correspond to more heat going into the ocean. **(d)** Same as in **(a)**, but for the SIE (black in 10^6 km^2), sea surface temperature (SST; purple in ºC), mixed-layer depth (MLD; red in 200 m), and deep convection (DCV; blue in 5 Sv) anomalies. **(e)**

Same as in **(a)**, but for the SIE (black in 10^6 km^2), sea surface salinity (SSS; purple in PSU), salt flux (Salt; red in 10^{-8} kg m^{-2} s^{-1}), and precipitation minus evaporation (PmE; blue in 10^{-6} kg m^{-2} s^{-1}) anomalies. Positive salt flux anomalies correspond to anomalous salt going into the ocean at the surface associated with sea ice formation, whereas the positive PmE anomalies mean more freshwater going into the ocean.

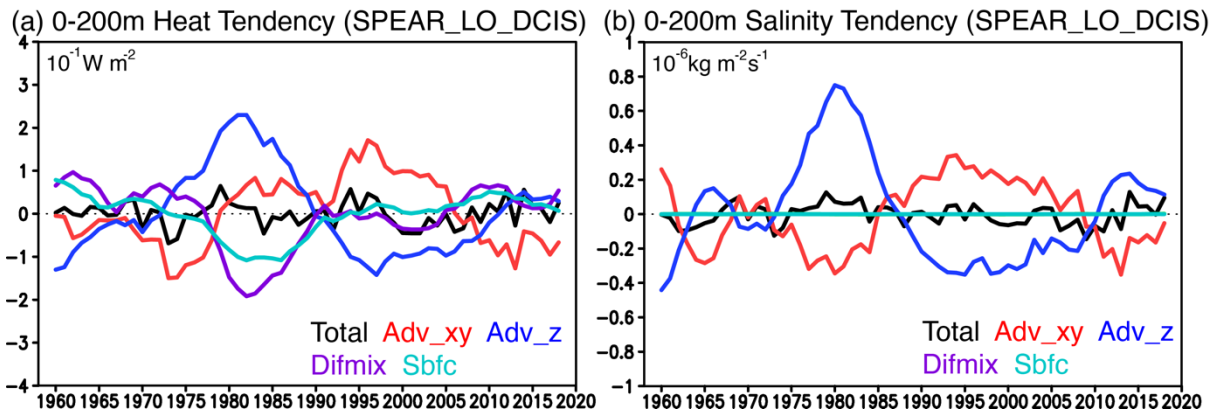


Figure 6 (a) Time series of 5-yr running mean ocean heat tendency (in 10^{-1} W m^{-2}) anomalies in the upper 200 m of the Weddell Sea from the SPEAR_LO_DCIS. Total ocean heat tendency (Total; black), horizontal advection (Adv_xy; red), vertical advection (Adv_z; blue), mesoscale diffusion and dianeutral mixing (Difmix; purple), and surface boundary forcing (Sbfc; light blue) anomalies are shown, respectively. **(b)** Same as in **(a)**, but for the salinity tendency (in 10^{-6} kg m^{-2} s^{-1}) anomalies.

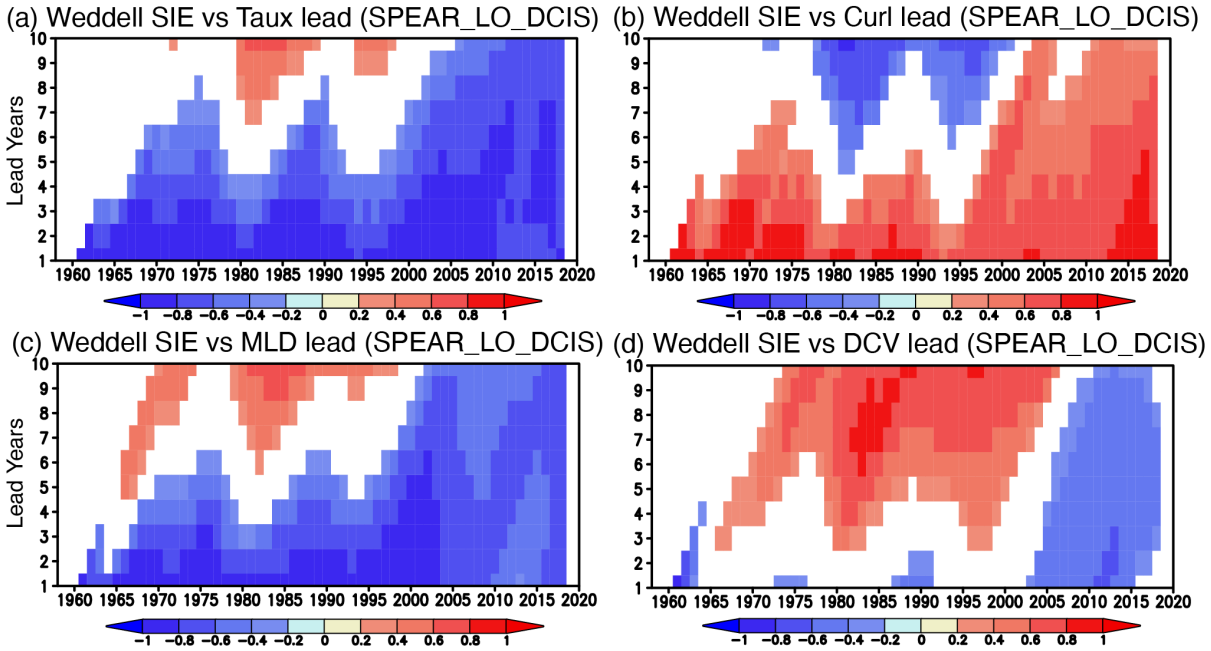


Figure 7 (a) Temporal evolution of inter-member correlation between the 5-yr running mean SIE anomalies and the 5-yr running mean zonal wind stress (Taux) averaged in the Weddell Sea from 30 ensemble members of the SPEAR_LO_DCIS as a function of lead years. Positive lead years (Y-axis) mean that the Taux anomalies lead the SIE anomalies by the number of years. Correlation coefficients that are statistically significant at 90 % using Student's *t*-test are shown in color. **(b)** Same as in **(a)**, but for the inter-member correlation between the SIE anomalies and the wind stress curl (Curl) anomalies. **(c)** Same as in **(a)**, but for the inter-member correlation between the SIE anomalies and the mixed-layer depth (MLD) anomalies. **(d)** Same as in **(a)**, but for the inter-member correlation between the SIE anomalies and the deep convection (DCV) anomalies.

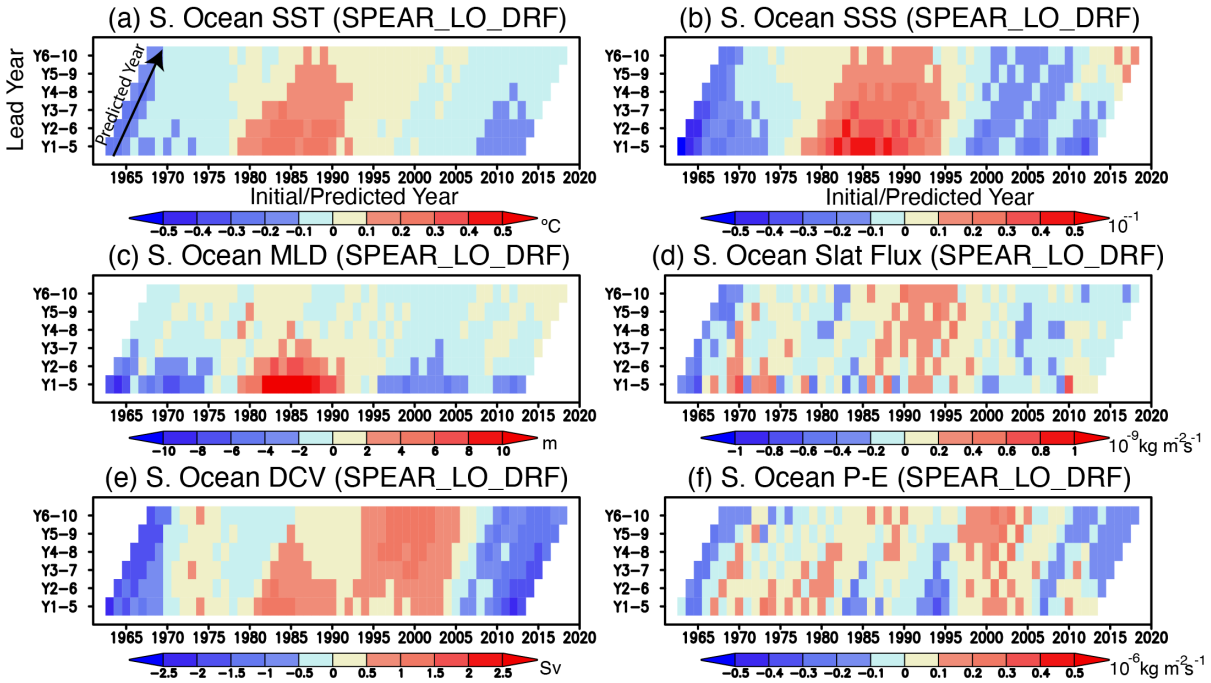


Figure 11 (a) Temporal evolution of ensemble mean Southern Ocean (south of 55ºS) SST anomalies predicted at lead times from 1-5 years to 6-10 years in the SPEAR_LO_DRF as a function of initial/predicted years (x-axis) and lead years (y-axis). A black arrow indicates the correlations with the same initial year for different lead times, while the corresponding x-axis indicates the predicted years. **(b-f)** Same as in **(a)**, but for the SSS (in 10^{-1} PSU), mixed-layer depth (MLD; in m), salt flux (in 10^{-9} kg m^{-2} s^{-1}), deep convection (DCV; in Sv), and precipitation minus evaporation (P-E; in 10^{-6} kg m^{-2} s^{-1}) anomalies averaged in the Southern Ocean, respectively.

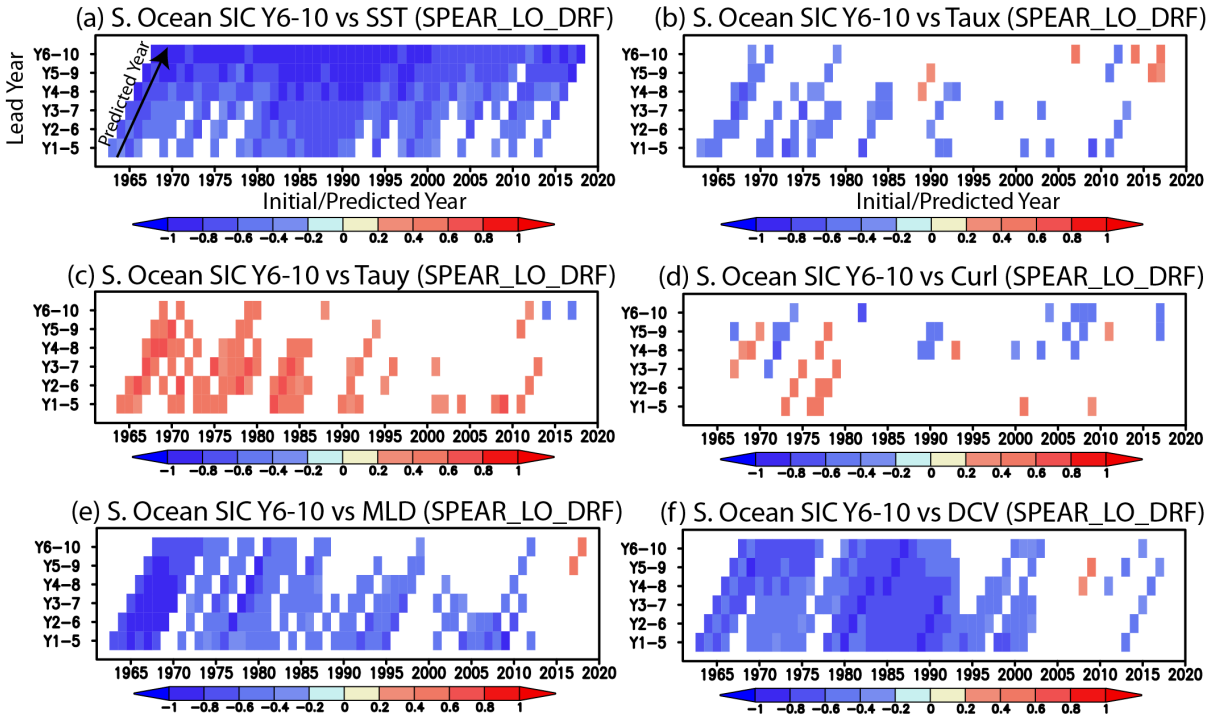
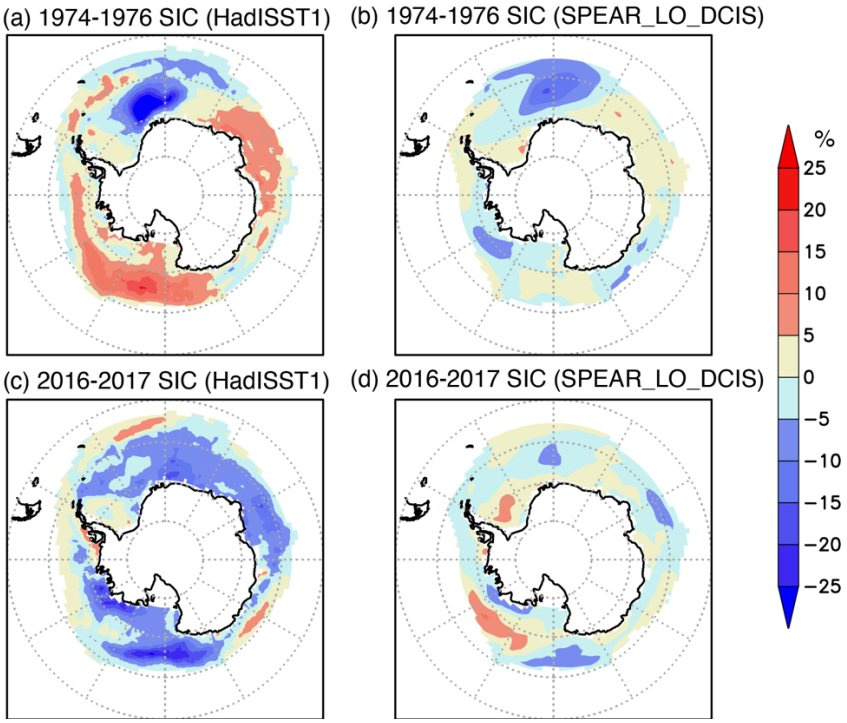


Figure 12 (a) Temporal evolution of inter-member correlation between the pan-Antarctic SIC anomalies predicted at a lead time of 6-10 years and the Southern Ocean SST anomalies predicted at lead times from 1-5 years to 6-10 years for the 20 ensemble members of the SPEAR_LO_DRF as a function of initial/predicted years (x-axis) and lead years (y-axis). A black arrow indicates the correlations with the same initial year for different lead times, while the corresponding x-axis indicates the predicted years. Correlation coefficients that are statistically significant at 90 % using Student's *t*-test are colored. **(b-f)** Same as in **(a)**, but for the inter-member correlation with the zonal wind stress, meridional wind stress, wind stress curl, mixed-layer depth, and deep convection anomalies averaged in the Southern Ocean.



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86 **Figure S4 (a)** Sea ice concentration (SIC, in %) anomaly averaged over 1974-1976 from the
87 HadISST1. **(b)** Same as in **(a)**, but for the SIC from the SPEAR_LO_DCIS. **(c, d)** Same as in
88 **(a, b)**, but for the SIC anomalies averaged over 2016-2017.

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