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Supporting Information for "Preconditioning of Antarctic maximum sea-ice extent by upper-ocean stratification on a seasonal timescale"

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Introduction

This document contains supporting information. Figure S1 shows the 1992-2015 mean sea ice concentration (SIC) in September, when the maximum extent is reached, by ECCO v4 and by satellite observations, respectively. The full name of the observation data is "NOAA/NSIDC Climate Data Record of Passive Microwave Monthly Southern Hemisphere Sea Ice Concentration", which can be downloaded from http://nsidc.org/data/G02202. Figures S2-S3 are similar to Figures 1-2, but for July to September. The points of Figures S2-S3 are to show that the associated conclusions for April to June, as derived from this paper, generally also hold for July to September (Figures 1-2 vs Figures S2-S3).

Text S1: Definition of vertical heat flux divergence

Denote F_v as the vertical heat flux (in unit of W/m^2). The vertical heat flux divergence is then dF_v/dz in unit of W/m^3, where z is the vertical coordinate. The integral of vertical heat flux divergence over the upper 100m ocean is $\int_{100m}^{0}(dF_v/dz)dz = F_v(0m) - F_v(100m)$, in unit of W/m^2.

Text S2: More explanation for the deepening of mixed layer depth

The mixed layer to the north of the SSIE is deepened more quickly than that to the south (Figure 1e, more dark blue with time). A much quicker deepening is partly due to a weaker stratification beneath the mixed layer to the north than that to the south (Figure 3d). It is also because of (1) a larger acceleration distance and hence velocity for convective plumes to the north than to the south (~150m vs ~50m, Figure 3d), and (2) the northward Ekman transport of denser water in the upper ocean (white to blue in Figure 3d) that provides more local negative buoyancy forcing.

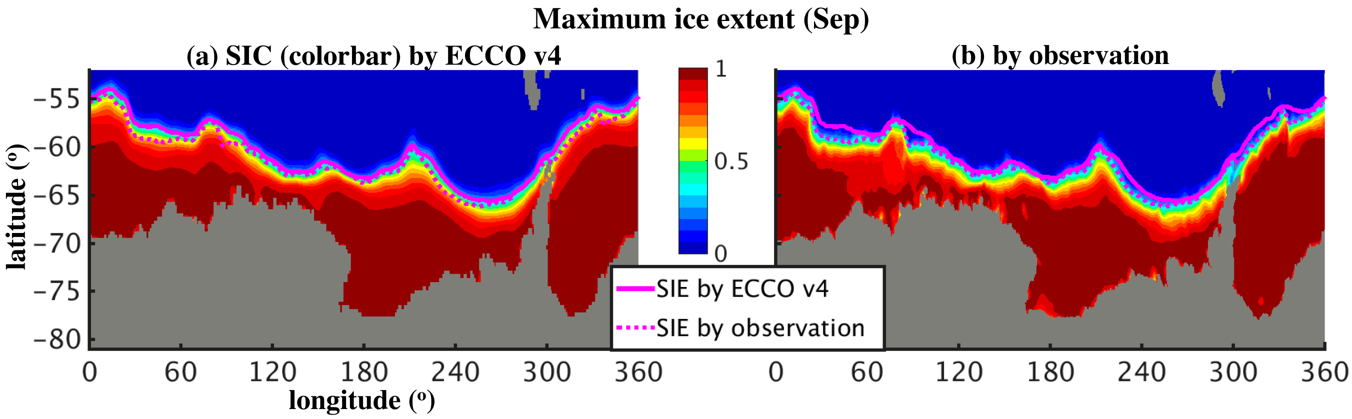

Figure S1. (a) 1992-2015 mean sea ice concentration (SIC) in September when the Antarctica sea ice reaches the maximum extent, by ECCO v4. (b) As (a) but by satellite observation (detailed in section 2). The magenta curves represent the associated sea ice edge (SIE) defined using the typical threshold of 15% of SIC. ECCO v4 (solid curve) generally captures the SIE of observed maximum ice extent (dashed curve).

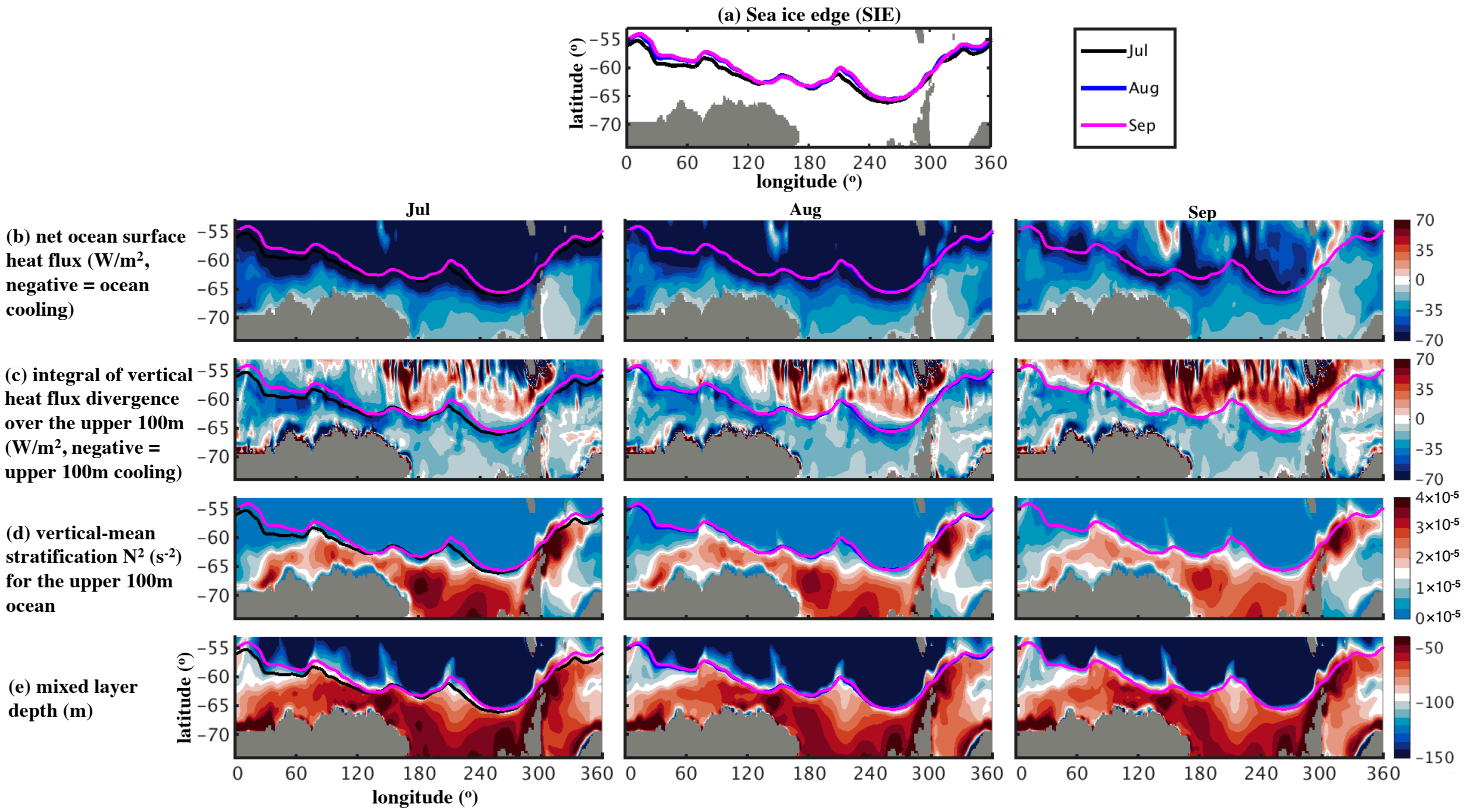

Figure S2. Same as Figure 1a-1e but for July to September. The results during July to September here are similar to those during April to June (Figure 1, section 3): most importantly, for July-September, there is also a narrow transition band (white, panels d-e) for stratification or mixed layer depth, which agrees well with the location of the edge of maximum sea-ice extent (magenta curve); for panel c, the cooling pattern (dark blue) is roughly between the SIE of each month and the SSIE (magenta curve). The red pattern in panel c is explained at the end of section 4. This warming pattern (red) largely cancels out the cooling pattern from a negative horizontal heat flux divergence due to Ekman transport (blue in Figure S3d).

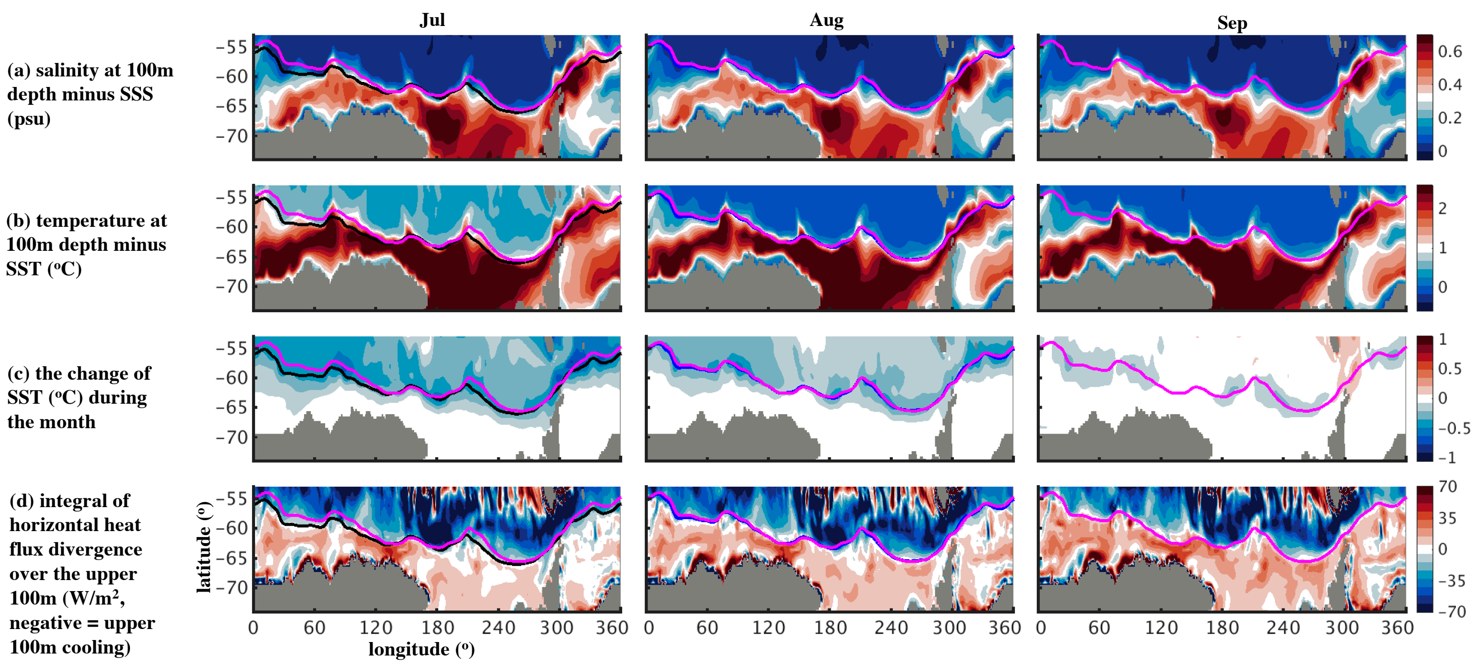

Figure S3. Same as Figure 2 but for July to September. The results during July to September here are similar to those during April to June (Figure 2, section 4): panels a-b indicate that the stratification pattern in Figure S2d is caused by salinity rather than by temperature; panel c shows that surface cooling occurs to the north of the SIE of each month, with the strongest cooling occurring to the south of SSIE; panel d shows that Ekman transport acts to cool the upper ocean to the north of SSIE (blue patterns, section 4). This, however, is largely canceled out by a positive vertical heat flux divergence (red in Figure S2c). This cancellation becomes significant during July to September (section 4).