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Supporting Information for

Ocean-sea ice processes and their role on multi-month predictability of Antarctic sea ice

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Introduction

This supporting information contains the description of the methodological choice of selecting hydrographical profiles to denote the permanent pycnocline in the sea ice-covered Weddell Sea region (Text S1). Figure S1 shows ice-ocean correlations in the Weddell Sea region for all 12 initial months and Figure S2 shows the climatological hydrological profiles for temperature, salinity, and their vertical gradients for the Weddell Sea region.

Text S1. Defining the permanent pycnocline and seasonal pycnocline

In our analysis, we want to identify the boundary between three watermasses: Circumpolar Deep Water (CDW), which has little seasonal variation; Winter Water (WW, the cold layer formed during sea ice formation); and the mixed layer (i.e., the surface layer at any month that is in close thermal equilibrium with sea ice). In polar waters, the traditional methods for identifying mixed layer depth may not be always as relevant as it is in much of the open-ocean regions, because polar waters are typically weakly-stratified and are dominated by haline rather than thermal buoyancy fluxes. In this analysis, we have used a few simple proxies for our discrimination of these oceanic boundaries, mainly for computational simplicity.

The permanent pycnocline (PP) that bounds the CDW from the seasonally evolving layer above remains at approximately constant depth throughout the year. For the Weddell Sea region, the PP is encountered at about 100m, where all hydrographic profiles (Figure S2, a-d) converge from their highly fluctuating seasonal values to the nonvarying properties of CDW. To identify this point from the hydrographic profiles, we find that the vertical temperature gradient (dT/dz) maximum and the secondary maximum of vertical salinity gradients are located at the depth range of PP. It is computationally easier to pick out dT/dz maximum values than finding the secondary maximum values of dS/dz and both of these values are occurring at more or less the same depth. This is because, due to the presence of WW, temperature inversions are produced, generating minima for vertical thermal gradient (negative values, instead of positive ones in dS/dz) due to warm summer surface ocean layer over the cold WW in summer. Whereas with dS/dz with the sea ice meltwater, strong vertical salinity gradients are produced, and compared to these strong gradients near the surface, the secondary vertical salinity gradients are hard to tease out. Hence, we find using dT/dz maximum values (Figure S2, all panels black circles) as an effective and easy way of identifying the depth of PP.

For the seasonal pycnocline, which acts mostly as the base of the mixed layer, we find using the maximum vertical density gradient (Figure S2, all panels red crosses) as the effective method. Although not shown in Figure S2, the profiles of vertical density gradient closely follow those of vertical salinity gradient, once again to say that the density changes are haline dominated. Freshwater and surface ocean warming during the ice-melt season (December-February) produce a thin and highly stratified surface layer that becomes the summer mixed layer and the maximum density gradient in the upper ocean (0-100m) helps to follow the seasonal evolution of this stratification that forms the base of the mixed layer.

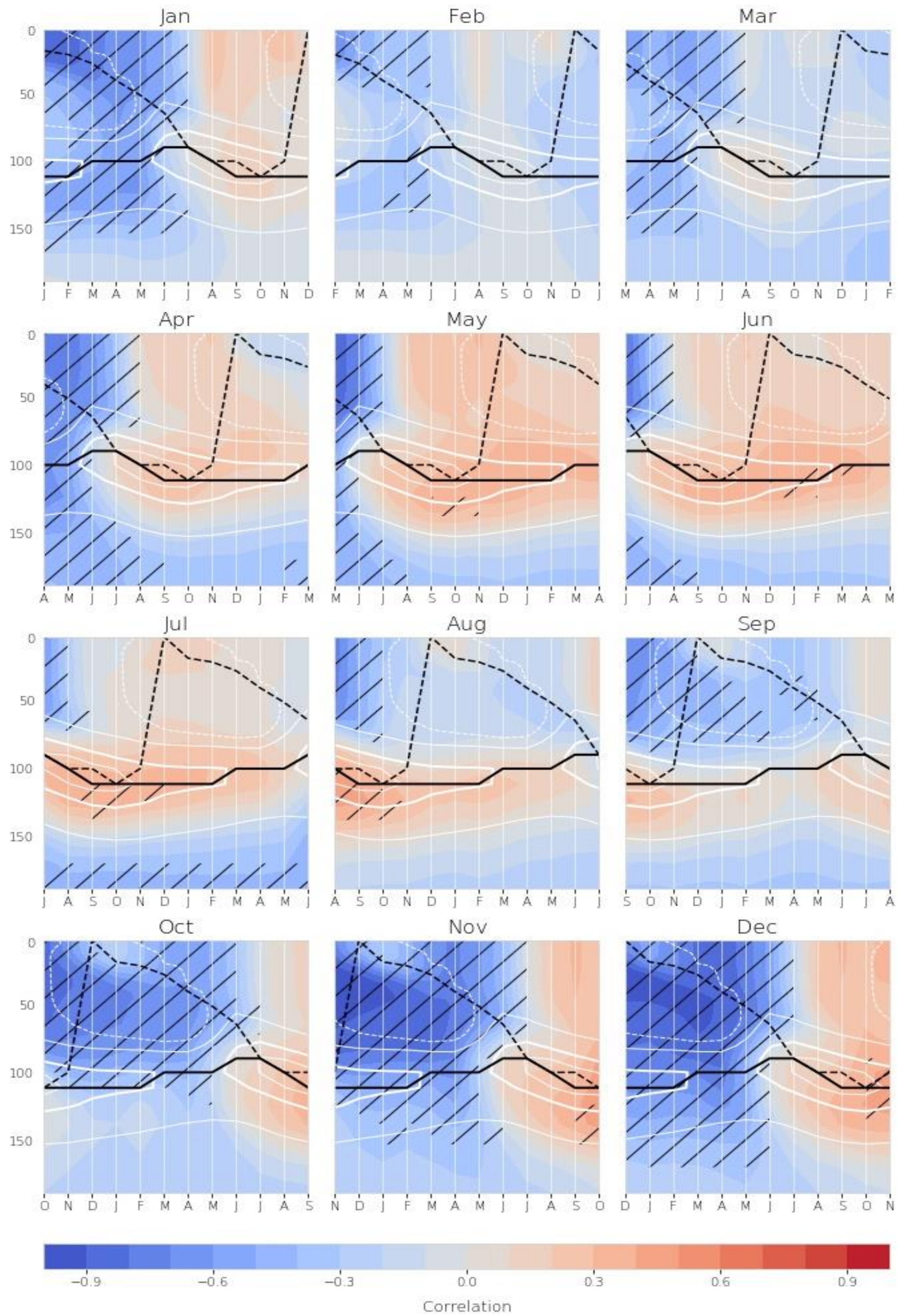

Figure S1. Correlation between sea ice area (SIA) and ocean temperature in future months (ice-ocean correlations) for all 12 initial months. The black line is the vertical temperature gradient (dT/dz) maximum, the dashed black line is the vertical density gradient (dρ/dz) maximum, white contours are dT/dz contours, and white dashed contours bound the dT/dz values that are negative during summer stratification. Statistically significant values (>95%) are hatched in all panels.

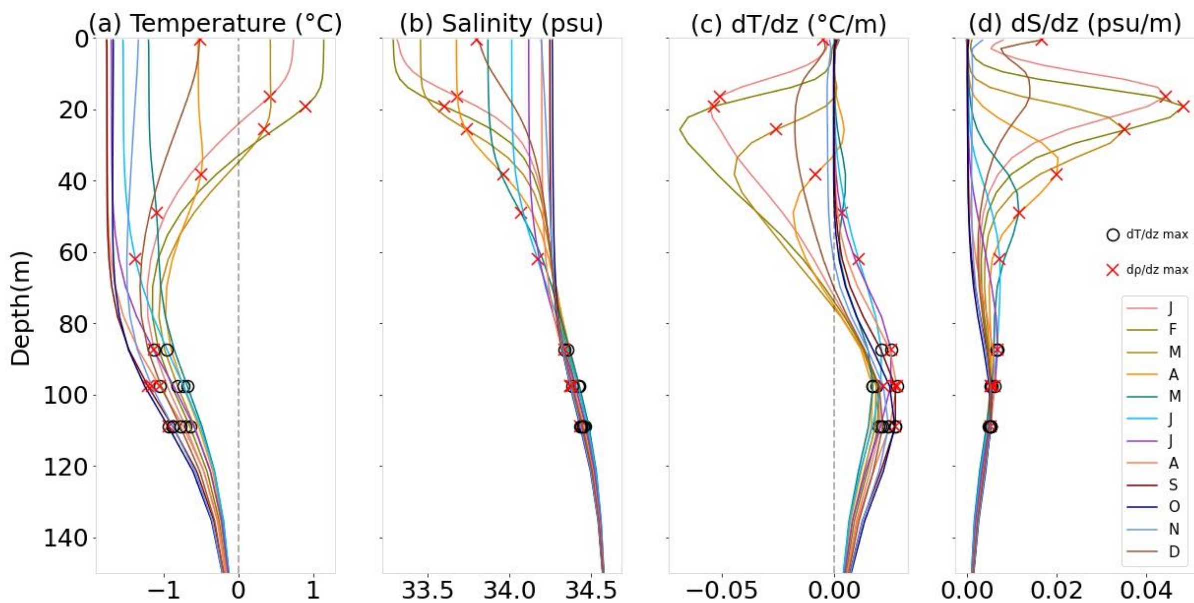

Figure S2. Hydrological profiles of spatially averaged monthly climatological (a) temperature, (b) salinity, (c) vertical temperature gradient, (d) vertical salinity gradient with markers of vertical temperature gradient maximum (black circles) and vertical density gradient maximum (red circles).