Supplementary Material

Section 2.1

The parameterization scheme with key parameters is showed in Supplementary Table 1. For the vertical stretching function (Vstretching) we choose Shchepetkin (2010) UCLA-ROMS current function (Shchepetkin & Williams, 2009), and for the vertical transformation equation (Vtransform), we choose the improved formulation from Shchepetkin (2005) (Shchepetkin & Williams, 2005; Shchepetkin & Williams, 2009). The S-coordinate surface control parameter (THETA_S) is set to 2, the bottom control parameter (THETA_B) is set to 4, and the critical depth (TCLINE) is set to 100 meters. The nonlinear model lateral, harmonic, constant, mixing coefficient for momentum (VISC2) is set to 300 m^2 s^{-1}. The nonlinear model lateral, harmonic, constant, mixing coefficient for active and inert tracer variables (TNU2) is set to 10 m^2 s^{-1}.

Section 2.2

We eliminated eight small, grounded ice areas that are smaller than 4 grid cells from the MEaSUREs grounding line in the domain topography, and replaced with ice shelf cavity. These grounded regions are probably significant for the stability of the ice shelf but can cause instability issues in our ocean simulations. We also modified the water column of TIS and MUIS cavity. Following Galton-Fenzi et al. (2012) and Gwyther et al., (2014), we added isobathic lines and points as the water column thickness beneath the ice shelf with a width of 1 to 5 grid cells along the center of each cavity, following the direction of the grounding lines on both sides. For the area east of the main TIS cavity. we set the water column thickness T_{wc} to be 300 m. For the main TIS cavity, we apply much thicker water columns according to recent observational studies which set T_{wc} to be 1,000 m to the east of the grounded ice area and 1200 m to the west. We linear interpolated water thickness from these central lines to the surrounding grounding lines, where T_{wc} is 20 m - the minimum water column in the model. The biggest iceberg we add, is C-18B (see Figure 1); four small icebergs (no larger than 20 grid cells) are near the northern edge of the landfast ice around 115.5° E, 65.7° S, and 12 small icebergs (no larger than 21 grid cells) are within the Dalton Iceberg Tongue.

Section 2.3

We choose the year of 2014 as the representative year in this study based on the ranking of annual mean to the climatology (absolute anomaly) of 26 years as well as the standard deviation of four forcing components. The value of absolute anomaly and standard deviation are shown in Table 2. The order of the year is the result of our final rankings. And the ranking of each value of the four component for 26 years are shown in Table 3. As a result, we score the year with the sum of 8 rankings and choose the year with the smallest score, which is the year 2014. Note that, though the score of 2005 is close to 2014, we prefer to choose 2014, considering this year is more recent.

Model Results:

The annual mean potential temperature and velocity fields immediately below the surface and at the bottom layer are shown in Supplementary Figure 1. The surface waters are generally warmer than the bottom waters, though this is more pronounced off the Continental shelf (Supplementary Figure 1A). On the continental shelf, deeper waters can be warmer than near the surface, showing the influence of cross-shelf exchange. Beneath the ice shelves, the surface layer waters are cooler than at the bathymetry (Supplementary Figure 1B), showing the presence of the ice pump mechanism, with warmer waters at depth driving melt and cooler meltwater exiting the cavity through buoyant convection. Velocities on the continental shelf show the presence of a surface intensified, westwards-flowing coastal current (Supplementary Figure 1A) and the presence of the Antarctic Slope Current from surface to bottom (Supplementary Figure 1A-B). Beneath the TIS and MUIS, bottom ocean currents are mostly southwards flowing (into the cavity), while at the surface, stronger currents flow northeast (out of the cavity). This average circulation and temperature distribution are consistent with previous simulations (e.g. Khazendar et al., 2013; Gwyther et al., 2014), whereby warmer ocean intrudes into the TIS and MUIS cavity at depth, increases basal melting and the cold and fresh meltwater exits the cavities through buoyant convection.

References:

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Supplementary Table 1. Choice of some key parameter schemes.

Supplementary Table 2. The value of absolute anomaly and standard deviation to the surface heat flux, surface salt flux, wind stresses in the zonal and meridional directions of 26 years (1992-2017). The order of the years follows the descending order of the score (shown in Table 3.).

Supplementary Table 3. The ordered ranking (best to worst of total ranking) of absolute anomaly and standard deviation to the surface heat flux, surface salt flux, wind stresses in the zonal and meridional directions of 26 years (1992-2017).

Supplementary Figure 1. Annual mean potential temperature and velocity field near surface layer (A) and near bottom layer (B). The continental shelf break and the TIS and MUIS calving fronts are shown with white contours.