南極沿岸の棚氷の融解を促進するメカニズムの解明

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Introduction

The Antarctic Circumpolar Current (ACC) has been recognized to play a key role in the ocean heat transport towards the subpolar region. Recent studies have suggested that the ocean heat transport under intensified westerlies potentially leads to the shelf ice melting. However, the mechanisms that contribute to the poleward heat transport have been veiled (e.g. Yamazaki et al. 2021, *Sci. Adv.*). We investigate the changes of the meridional overturning circulation in the ACC region as a potential driver of the heat transport from the subtropical region to the subarctic region. Numerical experiments are conducted to simulate the heat transport across the zonal jet under intensified westerlies.

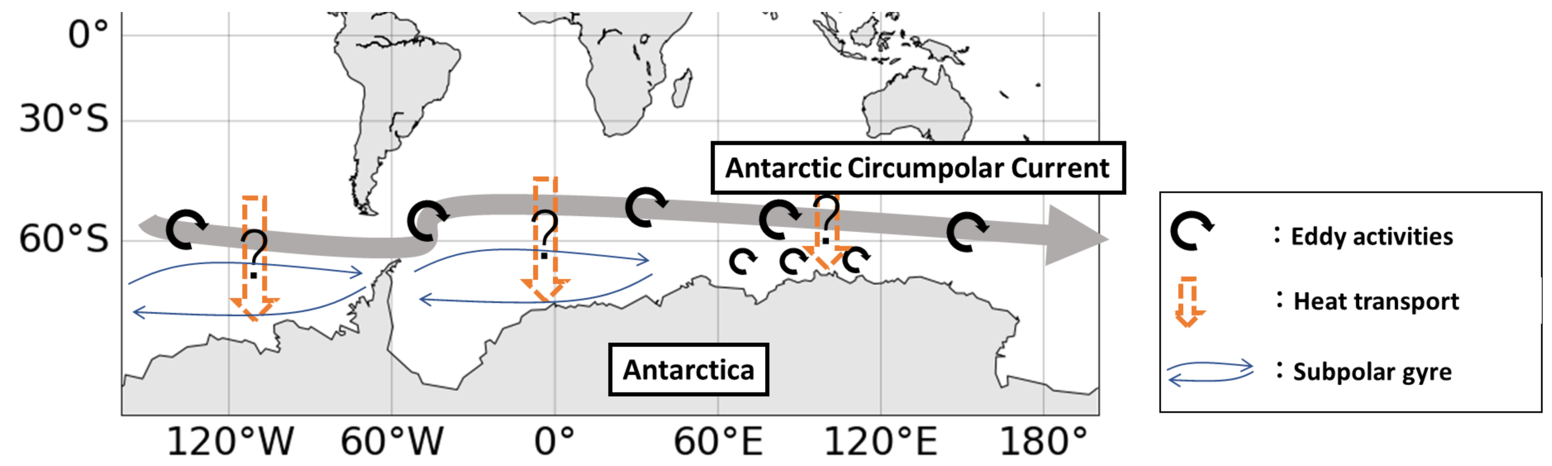

Figure.1: Schematic figure of the Southern Ocean. Routes of the heat transport from the subtropical to the subpolar region have been veiled.

Model configuration

We conducted simulations using the Massachusetts Institute of Technology general circulation model (MITgcm; Marshall et al. 1997, *J. Geophys. Res. Oceans*), which solves the hydrostatic Boussinesq equations on a beta plane periodic channel. The bottom topography is assumed to have a Gaussian shape centered at $x_0 = 1000$ km:

$$h(x, y) = H - h_0 \exp\left(-\frac{(x - x_0)^2}{\sigma_x^2}\right), (1)$$

where $h_0 = 1500$ m is the peak of topography and $\sigma_x = 200$ km denotes the zonal width of topography. This topographic forcing induces the energetic eddy activities through baroclinic instability. The stratifications are determined by the sponge layer at the northern boundary.

The idealized westerly was applied at the surface

$$\tau = \tau_0 \sin\left(\frac{\pi y}{L_y}\right), (2)$$

where τ_0 is the maximum strength of the wind forcing. We investigate the response to changes in τ_0 in this study. The model is forced by the wind of $\tau_0 = 0.2$ N m^{-2}for the first 30 years. The wind forcing is set to be $\tau_0 = 0.4$ N m^{-2} after 30th year in the enhanced wind experiment.

Responses to wind forcing

Figure 2 shows the time series of the volume transport. In spite of enhanced wind forcing after 30th year, the increase in the baroclinic transport is little, suggesting eddy activities relaxes the changes in the isopycnal slope. This feature is sometimes dubbed as "eddy saturation".

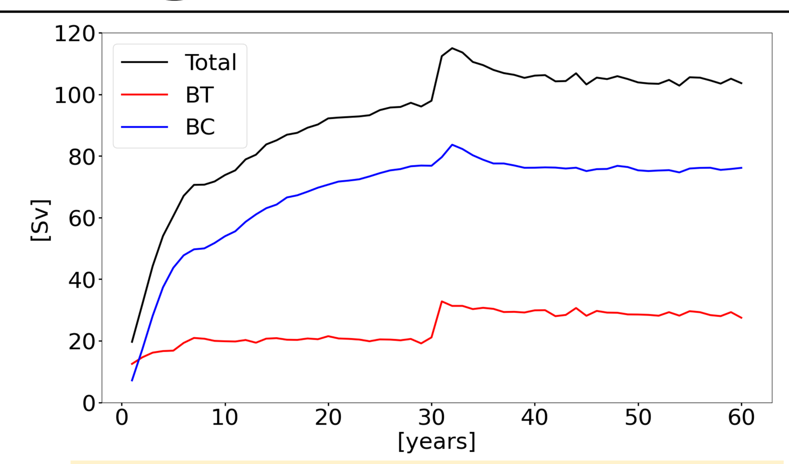

Figure 2: Timeseries of total transport (black), barotropic transport (red), and baroclinic transport (blue).

Figure 3 shows the temperature anomalies between the enhanced wind experiment and the control experiment.. The temperature anomalies are large at the southern boundary, while the surface temperature at the northern boundary decreases due to the enhanced Ekman flow. This pattern indicates that the upper cell of the meridional overturning and associated subsurface heat transport are enhanced by the wind forcing. Passive tracer distribution (not shown) also supports this idea.

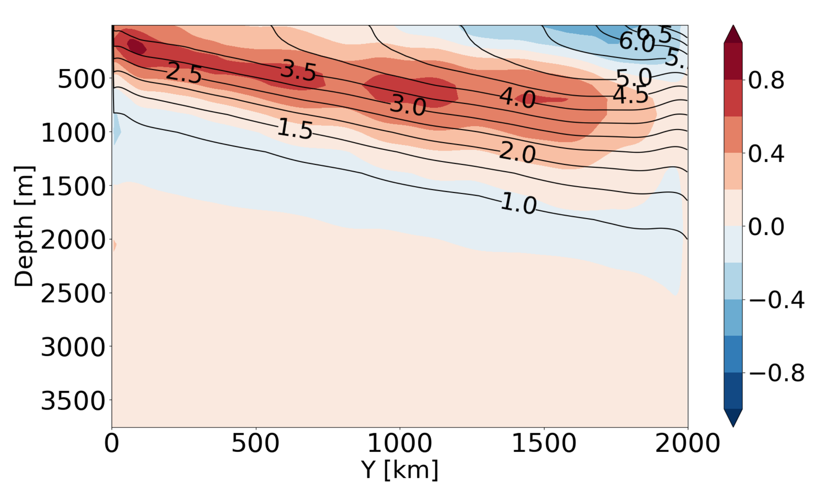

Figure 3:Color shade indicates the temperature anomalies between the enhanced wind experiment and the control experiment. Black contours indicate the temperature under the enhanced wind.

Responses to global warming

Previous study (Shi et al. 2021, *Nat Clim Chang*) suggested that the surface warming at the midlatitude changes the Antarctic Circumpolar Current as well as the wind forcing. We thus investigated the response to the thermal forcing of the northern boundary. The temperature in the upper 500 m is increased by 1.5 C° at the northern boundary to emulate the global warming in the midlatitude regions.

Figure 4 shows that the baroclinic transport is enhanced under the global warming, while the bottom flow is unchanged. This result suggest that the eddy activities that offsets the changes in the baroclinic transport does not respond to the global warming. Furthermore, Figure 5 suggests that the warming at the southern boundary is smaller than those in the enhanced wind experiment. Changes in the wind-driven transport are possibly more efficient for the poleward heat transport compared to the global warming.

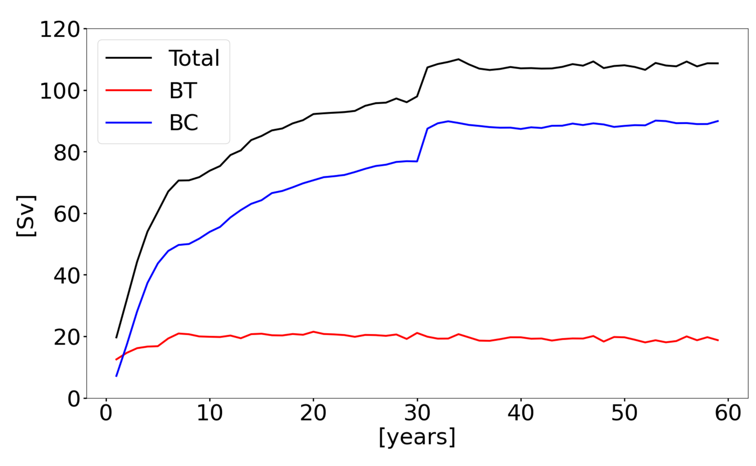

Figure 4: Same as Figure 2 but for the warming experiment.

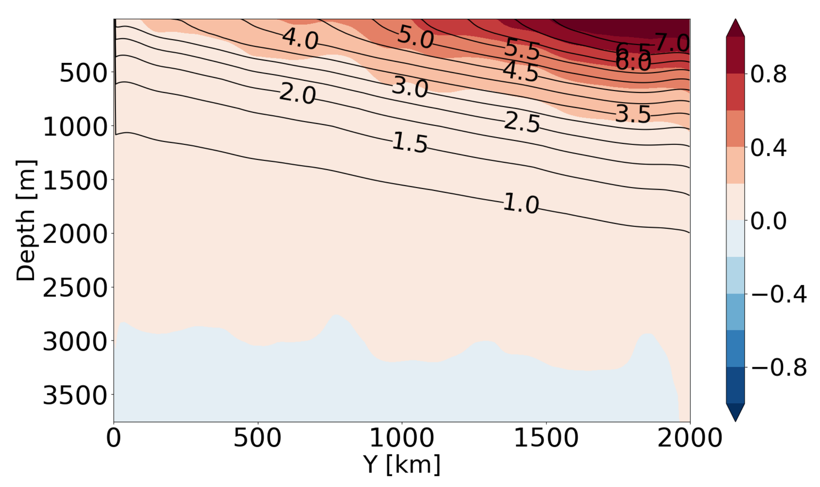

Figure 5: Same as Figure 3 but for the warming experiment.

Summary

・ Changes in the meridional overturning circulation enhances the southward heat transport.

・ Global warming may not be a main driver of the ocean warming in the Antarctic shelf regions.

Future work

・ Spatial structures of the meridional overturning circulation.

・ More accurate modeling of the subpolar region.

・ Interaction between the Antarctic Circumpolar Current and the subpolar gyre.