In search for Antarctic Bottom Water pathways

Polina Sholeninova | Australian National University | CLEX | ACEAS

Antarctic Bottom Water (AABW), composing a lower limb of Meridional Overturning Circulation and, therefore, playing a crucial role in Earth's climate, is of lack of direct observations due to its deep position and limited observations around Antarctica. This project aims to find out the AABW pathways using ACCESS-OM2 model with 0.1° horizontal resolution.

Introduction

AABW is exported to Atlantic, Pacific and Indian oceans through the lower cell of MOC (Talley, 2013); fills up to 40% of the ocean volume and covers 58% of the ocean floor (Johnson, 2008), consequently affecting stratification, circulation and mixing globally (e.g. see discussion in Zhang et al. (2020)).

The sparce spatial coverage of direct observations of AABW and its source waters sometimes done decades apart leaves many blank spots in our understanding of AABW circulation and variability. Recently recovered Deep Argo floats operated in the Australian-Antarctic basin (AAB) and collected measurements as deep as 6000 dbar. The deep and continuous measurements brought to light spatial and seasonal variability of AABW source waters in AAB–Ross Sea and Adélie Land Bottom Waters (RSBW and ALBW, respectively), as well as provided with some insights on their pathways (see Foppert et al. (2020)).

Methods

Model: ACCESS-OM2-01, cycle 3 of interannual forcing experiment run from 1958 to 2018.

1. Use passive tracer concentration

ACCESS-OM2 consists tracer variables associated with four main formation regions of AABW precursors. Focusing on AAB, this project considers Adélie Land and Ross Sea passive tracers. A single tracer is released in the model the way its concentration value equal 1 at the surface of its formation region and 0 elsewhere. As the model spins up, the tracers passively flow downstream off the source regions.

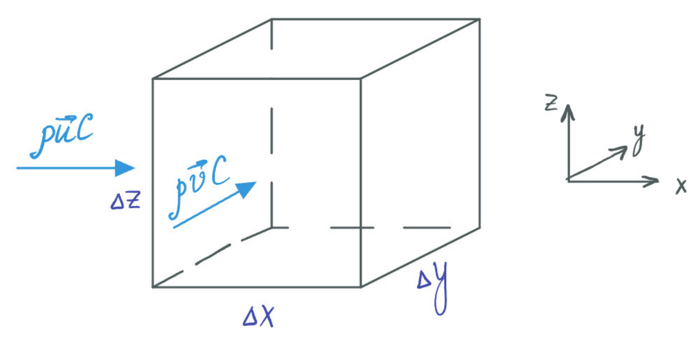
2. Use temperature & salinity threshold values

Different temperature and salinity values for bottom water were picked and used to explore what areas are occupied with water having certain T and/or S signature. Based on daily T and S data, I computed number of days in a year during which water with certain T and/or S values occupied the bottom layer. The example is shown in Fig. 1.

3. Use passive tracer advective fluxes

A passive tracer advective flux in ACCESS-OM2 is a mass flux through a grid cell face multiplied by the tracer concentration C:

$$F_x = \rho u C \Delta y \Delta z$$
$$F_y = \rho v C \Delta x \Delta z$$



The tracer transport was then computed as $\overline{U} = \sqrt{a^2 + b^2}$, where $a = \frac{1}{\rho}\int_{-z}^{0} F_x dz$ and $b = \frac{1}{\rho}\int_{-z}^{0} F_y dz$

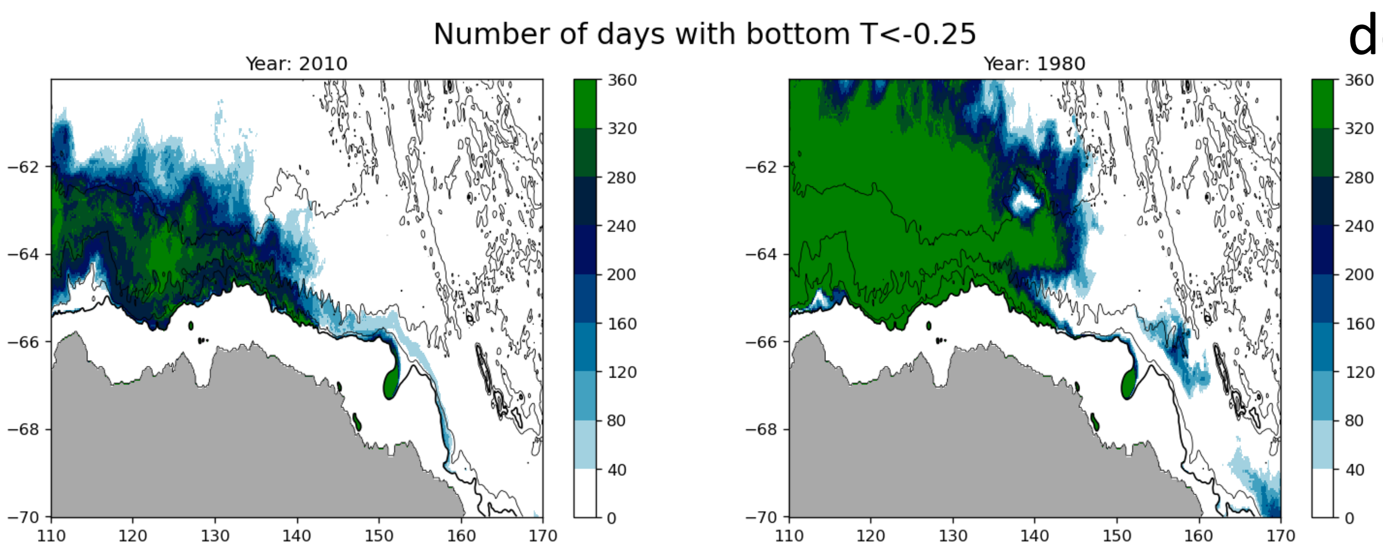


Figure 1. Number of days with bottom temperature lower -0.25°C in 2010 (left panel) and 1980 (right panel).

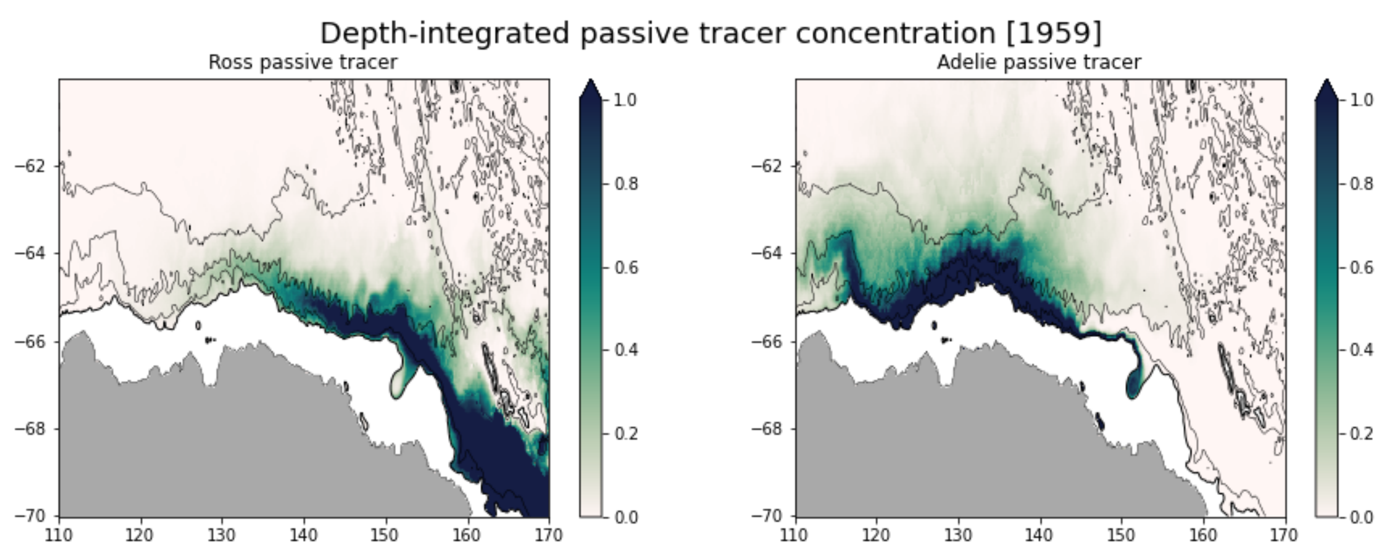


Figure 2. Depth-integrated concentrations of Ross (left panel) and Adélie (right panel) passive tracers averaged over year 1959 (second year from the beginning of the model run). Computed from daily data.

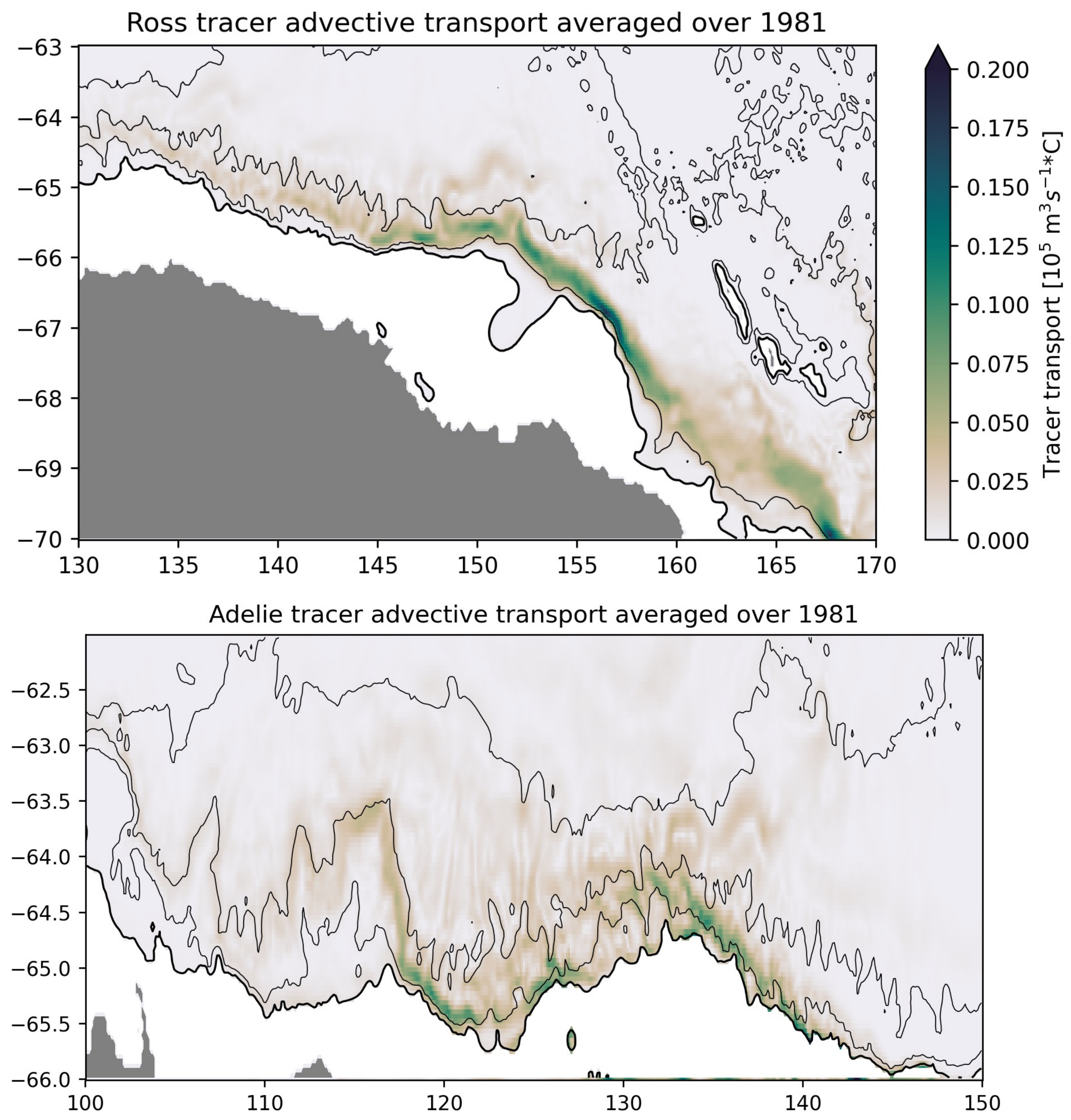


Figure 3. Ross (top) and Adélie (bottom) passive tracer transport averaged over year 1981 (second year from the beginning of the model run). Computed from daily data.

Results & Discussion

Maps of mean properties (not shown) show similar distribution of T, S, ρ as those reported by Foppert et al. (2020). The map of bottom water age (not shown) highlights a flow of young water between 2000 and 3000 m isobaths with even younger water joining the flow off the Adélie Land coast.

T, S signature of AABW varies significantly in the model (see Fig. 1) which makes it complicated to identify pathways by T, S threshold values (unique threshold values should be used for every year?). In addition, there is a lot of mixing happening downstream from the source regions.

Use of tracer advective fluxes (Fig. 3) are preferrable over tracer concentration (Fig. 2) since they ignore diffusion and provide information on the flow strength.

Future steps include finding the way to accurately distinguish ALBW and RSBW in the model and computing tracer transports along isobaths.

References

Foppert, A., Rintoul, S. R., Purkey, S. G., Zilberman, N., Kobayashi, T., Sallèe, J.-B., et al. (2021). Deep Argo reveals bottom water properties and pathways in the Australian-Antarctic Basin. *Journal of Geophysical Research: Oceans*, 126.

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