Responses to Reviewers

Stirring across the Antarctic Circumpolar Current's Southern Boundary at the Greenwich Meridian, Weddell Sea

We thank the reviewer for their helpful comments and suggestions that have strengthened our paper. In our responses below, the reviewers' comments are in black, our responses are in blue and the revised text is in purple.

Reviewer 2

5 repeated glider surveys across the Southern Boundary (SBDY) of Antarctic Circumpolar Current are used to investigate SBDY's cross-frontal behaviours under eddy and non-eddy regimes. Eddy presence enhances cross-frontal density gradient supressing the cross-frontal mixing whereas eddy absence, comparing to eddy presence, is accompanied by a weaker cross-frontal density gradient. These results are interpreted under the context of a multidecadal evolution of SBDY speed/location derived from satellite data. Authors concluded that the enhanced eddy activities and accelerated SBDY are occurring at the same time in opposition in affecting the meridional exchanges of tracers cross SBDY at Greenwich Meridian. I found this work is interesting and potentially important for the community in understanding the Weddell Gyre heat content evolution under the context of climate changes.

I have one concern about this manuscript. This work highlights that the different cross-fontal properties are associated with eddy presences exemplified by comparing transect A and transect C. These contrasting results between eddy and non-eddy regimes need to be strengthened by a quantified uncertainty that could be raised from different glider sampling intensity along the transect because it seems to me that the transect C does not take profiles as frequently as transect A by looking at the station distribution from two transects. See also the relevant comments below. I am happy to see this manuscript published once my concerns herein are addressed properly.

General comments:

1. Most results present in this manuscript based on the comparison between transect A and transect C, where the authors argue that eddy presence/absence is the reason for the observe difference. The glider station (marked as triangle on top of cross-section plot, most evident in Figure 8) distribution between A and C is different. Can author quantify the potential uncertainty caused by different glider station distributions on the present cross-frontal difference?

   Yes, the reviewer is correct that the data are sampled in a higher horizontal resolution in Transect A (290 vertical profiles, 145 dives), whereas Transect C has a lower horizontal resolution (92 vertical profiles, 46 dives). However, within this study the difference in glider station distribution is negligible as all data are horizontally gridded onto a uniform grid. Thus, for all calculations and final results the horizontal and vertical resolution of all transects considered is uniform. We further tested a subsampling of Transect A (bootstrapping

method) with the number of profiles of Transect C and found that key characteristics in Transect A remained unchanged. Specifically for Fig. 8 we have changed the diamonds at the top of each transects to show that the grid for Transect A and C is uniform. We have added the above mentioned information to the caption of Fig. 8 (see below) as well as in the text of the manuscript to clarify for the readers.

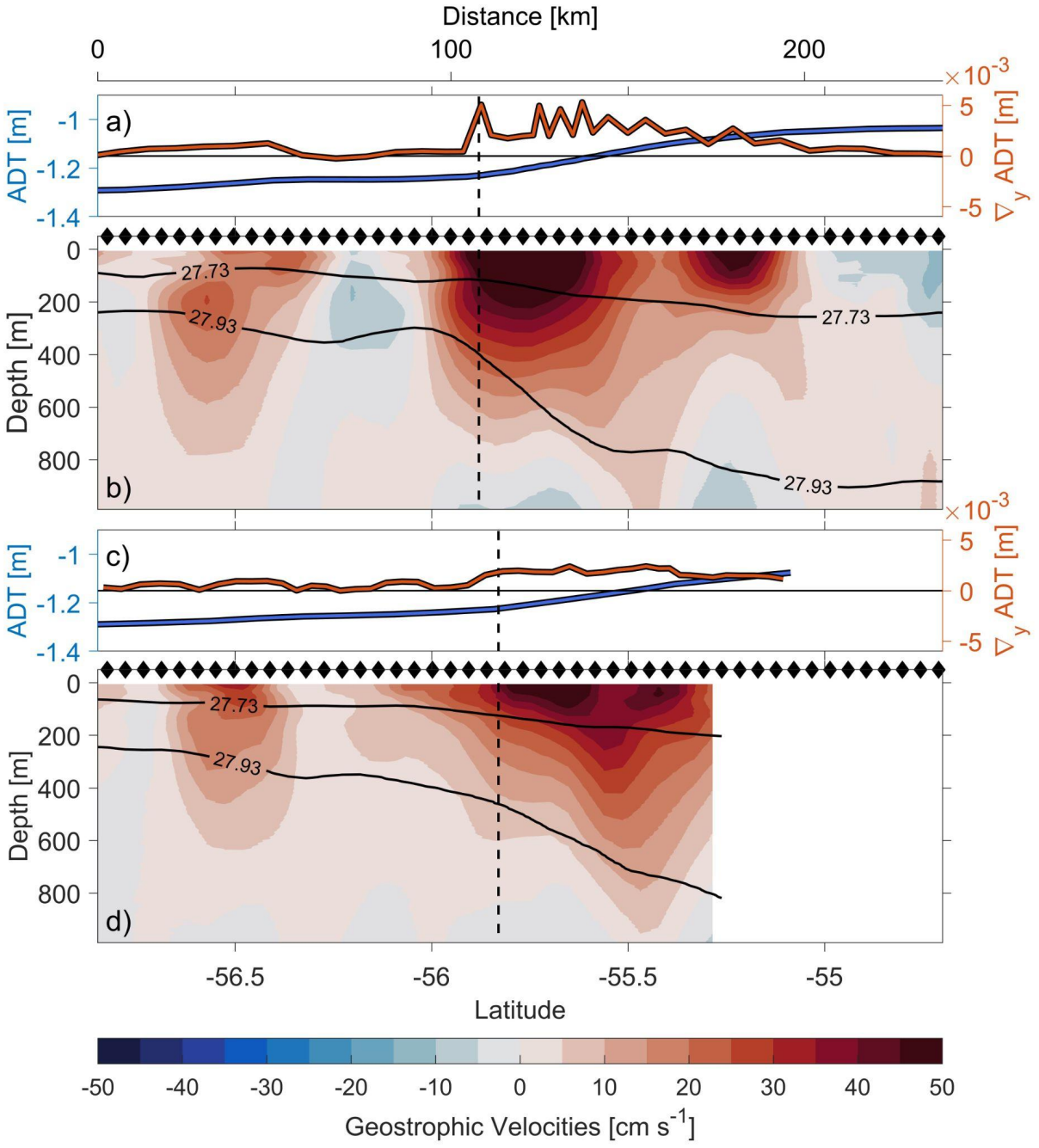

Figure 8. Real-time altimetric ADT and gradients of ADT (∇y ADT) for (a) transect A and (c) transect C. (b,d) Geostrophic velocities perpendicular to the respective glider transects A and C and referenced to the DAC with a horizontal smoothing (moving mean filter) of approx. 15 km (Rossby radius within the region of interest). Positive geostrophic velocities are defined as eastwards (red). Black contours are as in Fig. 2. The black diamonds at the top of each panel show the uniform horizontal gridding with 5 km spacing of

transect A and C. The dashed black lines indicate the location of the Southern Boundary based on the southernmost strong ADT gradient.

2. This may or may not be resolved by typesetting, but I found that quite a few figures are far from where they were discussed. For example, section 3 in page 8 discussed Figure 4 to Figure 8, while Figure 8 is displayed at Page 14. I suggest authors to condense down figure volume, such as, putting multiple subpanels into one integrated figure, leaving the results for transect B, D, E in Supp Mats as they were barely mentioned, T-S plots with highlighted regimes taking up one subpanel spaces can be replaced by combining mainly discussed regimes in one T-S plot and mask other data points with grey colour, etc.

   We suggest merging Fig. 6 and 7 to reduce Fig. volume. The figures can surely be brought closer to where they are discussed in the manuscript. This is a matter of the typesetting of the final article. We will raise your concerns if the figures are still poorly placed when we receive the proof of the article. With respect to Figs. 1 and 2 we think that transects B, D, E should still be included to introduce the entire data set and to justify why we focus on Transects A and C later.

Specific comments:

L6: 'quite rapid'→'high-frequency' or 'transient'?
Quite rapid has been changed to transient.

L35: delete 'globally', the word 'globally' is misplaced as the SBDY is not a global feature, is it? 'Climatologically' is sufficient here.
This has been changed as suggested by the reviewer.

L42: '…further represent the southernmost boundary to mixing'. I found this sentence a bit ambiguous… I believe that the mixing process in general is happening everywhere, and I don't think authors have set the context of using the term mixing to refer the cross-frontal mixing happened at the SBDY.
This sentence has been edited according to the reviewers concern. The sentence now reads as:
The frontal jets of the ACC are often seen as barriers to meridional horizontal mixing (e.g. Naveira Garabato et al. (2011)). The frontal jet associated with the Southern Boundary, as the southernmost of the ACC frontal jets, marks the boundary between the northern limit of sea ice formation and the ACC.

L60:'The majority of studies almost entirely…', need refs here or is author referring to aforementioned studies? If so, please indicate.
Yes, all aforementioned studies are referred to here. This has been edited in the manuscript as suggested by the reviewer.

L160: 'converge'. The T-S plots do not show this 'convergence' particularly clear. Adding arrows to indicate this in the T-S plots.
Edited according to the reviewer's suggestion.

L164-167: I do not fully understand this. The similarity of the properties between eddy and south of SBDY suggest eddy originated from south of SBDY, okay, then what is the meaning of mentioning the slight temperature/salinity difference below/above the thermocline? Plus, why do authors mention the salinity difference in reference to thermocline?
We have adjusted the sentence to clarify:
The clockwise eddy identified in transect A (Fig. 6 a,d,e) presents properties similar to the cold regime but with slightly higher temperatures (about 0.4 to 0.6◦C higher) below the thermocline and slightly reduced salinities above the depth of the thermocline. Note that the eddy is surface intensified and therefore changes in the surface properties are expected, although the eddy is more clearly identified in the sub-thermocline temperatures and salinities. The similar water mass properties of the eddy and the cold regime suggest that the eddy originated south of the Southern Boundary.

L179-182: Mention the criteria and the table somewhere earlier in the section. This section has covered many figures that use such color-coding criteria. Best to mention it in the first place to avoid confusion for readers.
We agree with the reviewer and have moved the table with the criteria earlier in the section to improve clarity.

L185: the eddy passage could be one of the reasons for the difference in horizontal density gradient between transect A and C. Figure 8 shows a smooth ADT for C and rough ADT for A which makes me realize that the profiling intensity of A and C is also different. Transect A has more profiles in general than Transect C across the front. Does this fact play any role? Authors should quantify the uncertainty on horizontal density gradient caused by different sampling intensity by subsampling a high-res model results/reanalysis or any other sensible measures.
Please see response to major point 1.

L204: It is not clearly stated how the temperature fluctuation, θ', is computed.
The temperature root mean square Θ_{rms} is calculated as the standard deviation of the temperature anomalies from the mean 'large scale' temperature field and the high resolution temperature field ($\Theta_m - \Theta$). This has been added to the method description.

L285: The discussion on the long-term behavior of the SBDY and its core speed is sufficiently supported by literatures. However, the sea ice extent seems to be a bit out of place here. I suggest authors to either specify the reason for examining sea ice extent and discuss it extensively in the context of past literatures or simply not to show the sea ice extent at all since it does not correlate well with the available data here and authors just briefly mentioned it… Sea ice advancing and retreats on yearly basis is also controlled by large-scale wind variability, thermal forcing and also internal sea ice dynamic, so it perhaps requires some extra effort to decipher sea ice extent in the context of enhanced frontal jet.

According to the suggestion of the reviewer we have removed the sea ice extent from Fig. 11 as there is currently not enough literature to support our findings and the lack of correlation between frontal jet speed and sea ice extent does not provide

enough evidence to further discuss the sea ice extent within this manuscript. We have further removed L44-45 and L285 from the manuscript.

L294: If authors are referring to the positive SLA blobs into the 2010s, then perhaps the phrase ‘anti-cyclonic eddies’ is more appropriate than warm core eddies? Studies have shown that not all anti-cyclonic eddies have a coherent warm core structure throughout the vertical extent.
The expression warm core eddy has been replaced with anti-cyclonic eddy.

L309: ‘…. consistent with Williams et al. (2007) who demonstrated …’
Edited according to the reviewers suggestion.

L301: ‘… in all transects …’, authors mainly discussed transects A, relevant results for B, D, E should be included at least in Supp Mats to make this claim.
Relevant results for B, D and E have been added to the supplementary material.