Review responses to OS preprint egusphere-2025-3112

Reviewer #RC2:

This study uses glider observations, including physical and biogeochemical tracers, to investigate the distribution and intensity of ventilation events in the Agulhas Retrocession Current. The manuscript is well written and logically coherent. It is a fascinating study. However, it is too descriptive, so additional dynamics should be included to enrich and quantify the study further. Once the comments have been addressed, I suggest that the manuscript can be published. My detailed comments are below.

Thank you for your ideas. These are indeed excellent topics in the field and related to this interesting area of the Cape Basin and Agulhas Retroflection. However, the lack of the appropriate observations (mostly constraining the full velocity field) to be able to estimate and quantify additional dynamics means we are unable to undertake the analysis as you suggest. Detailed reasons for these are provided below. An encouraging aspect is that in the near future (within a year), newly planned experiments and observational efforts in the same region will hopefully be able to start to get at some of these metrics and analysis, which would make for some exciting future studies to come.

The paper is largely descriptive as you state, but we believe that is precisely its value. These types of observations are rare and offer key insights into ventilation dynamics. Providing these results in the literature and to the community serves as a foundation for future numerical experiments and for new observational approaches as technology advances (e.g. ADCPs floats, gliders and towed instruments).

Major comments 1.

The 2D quasi-geostrophic omega equation can be used to estimate the vertical velocities along the glider section and further demonstrate the vertical exchange of waters and tracers (Siegelman et al., 2020).

We were inspired by Siegelman et al. (2020) and considered the reviewer's suggestion of applying the 2D quasi-geostrophic omega equation to our dataset. This approach can indeed provide estimates of vertical velocities along a section and further demonstrate the vertical exchange of waters and tracers. However, its use requires sufficient spatial coverage to resolve both along- and cross-front gradients of density and velocity. In Siegelman et al. (2020), the tagged seals were less strongly advected by the flow, enabling a more robust estimation of the cross-frontal gradients of density. In contrast, our single glider is not necessarily representing a good estimate of cross-gradient flows due the the large advective component of the current on the glider itself. .

Estimating cross-track gradients from such a dataset would therefore require large assumptions and by doing so, introduce uncertainties that are probably too large to provide value to the estimate and would possibly provide strongly biased results to the community. Moreover, incorporating this analysis would considerably broaden the scope of the study and add complexity and uncertainty to an already comprehensive dataset and analysis. For these reasons, we chose not to quantify the vertical velocities in this study, as the results would still be largely qualitative given the inherent uncertainties using the QG Omega framework.

2. How to quantify the difference between diapycnal and isopycnal transport (mixing) in the study.

We thank the reviewer for the suggestion. Quantifying the difference between diapycnal and isopycnal transport requires multi-dimensional velocity and density fields to be able to estimate along- and across-isopycnal fluxes. Diapycnal transport, across density surfaces, depends on vertical tracer gradients and estimates of turbulent diffusivity, which are typically obtained from microstructure measurements or finescale parameterizations. Isopycnal transport, along density surfaces, requires horizontal tracer gradients and along-isopycnal velocities, which can be derived from ADCPs, floats, drifters, or high-resolution models. Combining both requires three-dimensional velocity and density fields to project fluxes along and across isopycnals. Our single glider mission does not provide the multi-dimensional coverage necessary to perform these calculations quantitatively. Yet, the high-resolution tracer profiles along the glider path provide qualitative insight into ventilation pathways, providing a starting point for future observational and modeling studies. Future glider deployments with ADCPs and microstructure packages will allow us to get to these different transport mechanisms.

3. The frontogenesis function (Siegelman, 2020) can also be estimated along the glider section to investigate its relationship with ventilation and related dynamic processes.

We thank the reviewer for this suggestion. The frontogenesis function requires high-resolution horizontal velocity fields across the study area to calculate horizontal derivatives of the flow. Our dataset lacks the lateral velocity coverage needed to compute these gradients, such as would be available if there were consistent, high resolution ADCP profiles available. While approximate approaches could be attempted (e.g., using altimetry-derived surface strain rates or assuming frontal symmetry), these methods would not capture the submesoscale variability resolved by the glider. Instead, our analysis identifies regions where persistent stirring and strong tracer gradients suggest active frontogenesis and associated ventilation. We consider these descriptive observations as a critical step toward future studies using emerging satellite missions, such as SWOT, to calculate the frontogenesis function directly and resolve submesoscale frontal dynamics.

Minor comments

1. Line 165, (x,y,t) to (x, y, t).

applied.

2. Line 175-180, the Sa , CT are absolute salinity and conservative temperature, respectively. This should be explained first.

Thank you! Changed to '*(absolute salinity Sa = 35.5 g kg−1; conservative temperature CT = 16 ∘C)*'

3. Line 186, "AAIW - Sa < 34.6 g kg−1 " revised to "AAIW, Sa < 34.6 g kg−1 "?

Applied.