

## Reviewer 2

### General Comments

The manuscript by Castillo et al. explores the seasonal hydrography and mixing processes of the Almirantazgo Fjord (AF) in Southern Patagonia. This study stands out for its multiplatform approach, particularly the integration of traditional mooring data with autonomous sensors deployed on Southern elephant seals, which provides a significant spatial expansion of hydrographic data in a logistically difficult region.

Thematically, the paper is well-aligned with current trends in fjord oceanography, which have moved beyond purely buoyancy-driven models to recognize the role of synoptic wind events in regulating exchange flow and vertical structure. While the dataset and the research questions are relevant to the scope of Ocean Science, the manuscript requires substantial revision to address critical inconsistencies in physical scaling and the generalization of its conclusions. Several key numerical statements are internally inconsistent (units, magnitudes, and parameter choices), which currently limits reproducibility. These issues must be corrected and the full set of inputs reported for each diagnostic.

### Major Comments

- A primary concern is the selection of the parameters used to calculate the Wedderburn number ( $W_b$ ). The authors use a length scale  $L = 165$  km, representing the distance from the Magellan Strait to the fjord head. Given the complex and curved geometry of the Almirantazgo Fjord and its connection to the Whiteside Channel, using the total path length as the effective scale for wind action is physically debatable.

### Ans:

Thanks for your comment, now we changed that and we make all these estimations only for the Almirantazgo fjord (AF) and  $L = 75$  km, none curvature it is contained in this fjord and is highly aligned to the main axis of variability of winds. All the estimation from the along-fjord made using the elephant seals data were re-calculated and verified, also concentrated only for January and June month instead of seasonal averages and we selected data from 2 km at the center of the basin's axis. We explained this in detail in a new section in Methods.

Moreover, the manuscript defines  $h_1$  as the thickness of the upper layer in the two-layer framework underlying  $W_b$ , yet the calculation adopts  $h_1 = 30$  m described as “the basin depth in Maria Cove”, this is conceptually inconsistent. Because  $W_b \propto h^{-2}$ , this choice can strongly bias the magnitude of  $W_b$  and thus the inferred importance of wind-driven tilting. The authors should (i) clearly state how  $h_1$  is diagnosed from the hydrography (e.g., mixed-layer depth, interface depth, or depth of maximum stratification) and (ii) provide a sensitivity analysis showing how  $W_b$  varies across plausible ranges of both  $h_1$  and  $L$  (e.g., using straighter sub-basin lengths and upper-layer thickness estimates). Without this, the claim of wind dominance remains sensitive to a small set of potentially over-scaled parameters.

### Ans:

Thanks, we include in section 4.3 a new Table 3 with the statistics of the parameters used in these estimations. The upper and lower layer were defined by N2 maximum obtained from the along-fjord data, and comparing with the cross-fjord data we used distinct upper depth for January and June to incorporate the seasonal differences and, we use typical values of winds for both months.

In order to incorporate a sensitivity analysis to our selection depths, we based the test following Wan et al (2017) where the study compares the depth of the layer with the influenced depth obtained from set  $Wb = 1$ , thus analysis indicates that  $h_1 = 20$  m for January was highly consistent with  $h_w = 22$  m, whereas in June  $h_1 = 5$  m but  $h_w = 27$  m. Both results suggest that winds could perturb the pycnocline in both months in the AF.

- The estimation of flushing times (TF1, TF2) in Section 4.1 is physically inconsistent and lacks a clear methodological basis. The authors must explicitly include the fundamental equations used and define every term. Currently, the explanation is confusing: a layer depth of  $h_1 = 30$  m is used for volume ( $V_1$ ), while a drastically different  $h_1 = 5$  m is used for the transversal area ( $A_1$ ), all while assuming a phase velocity ( $c_1 = 1.1$  m  $s^{-1}$ ) as the scale for mass transport.

Ans:

Thanks, we change the along-fjord data and that gives us better ways to estimate the upper layer that now changed in January  $h_1 = 20$  m and June  $h_1 = 5$  m. And we use mean modeled velocities (see Appendix 3) to estimate the upper velocity and the outflow of the brackish layer.

It is not clear why a wave phase speed ( $c_1$ ) is assumed as the advective velocity for this approximation. In a typical Knudsen balance, the conservation of volume and salt is defined by  $Q_1 = Q_2 + Q_R$  and  $Q_1 S_1 = Q_2 S_2$ , where  $Q_1$  is the upper layer outflow,  $Q_2$  the deep layer inflow, and  $Q_R$  represents the net freshwater discharge (rivers, glacial melt, and precipitation).

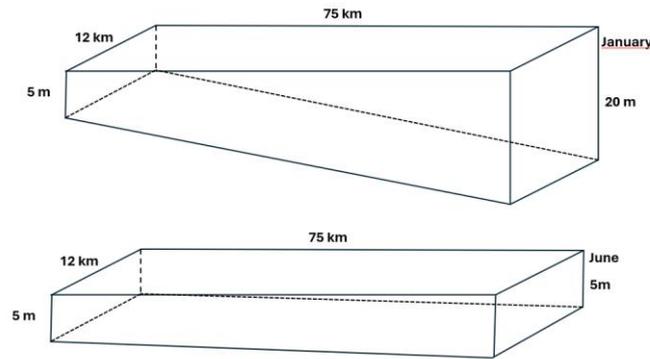
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If one applies this balance to the authors' results, where  $Q_1 = A_1 c_1 \approx 22,000$  m<sup>3</sup> s<sup>-1</sup>, the implied freshwater input ( $Q_R = Q_1(S_2 - S_1)/S_2$ ) would range between 2,000 and 5,000 m<sup>3</sup> s<sup>-1</sup> (assuming typical  $S_1, S_2$  gradients for the area), which appears implausibly large relative to the AF catchment and typical regional freshwater inputs; the authors should reconcile this with discharge estimates and revise the transport scaling using advective velocities instead of phase speeds and provide the specific references supporting their choice of parameters.

Ans:

Thanks, that example helps us to improve our estimations. As the study focuses on the wind's influence, we decide to focus only on the exchange of the upper brackish layer. Thus, we estimate the Volume of the upper layer making a difference between the geometry of the upper layer during January, and during June, also as above we are focusing on the Almirantazgo fjord.

Then considering that the along-fjord data showed a salt-wedge structure we estimated as a first approximation the volumes by the following geometries:



That consideration was based on the averages estimations made in Table 3, for each month and taken into consideration. Now, the results are more consistent and based on more reliable estimations, but as first approximations that requires future studies based on circulation measurements to adjust these results.

- The manuscript concludes that atmospheric forcing is essential for ” ventilating the deep basin.” However, the observational evidence provided (stations A1 and A2) is restricted to approximately 30 m depth near the shallow head of the fjord. Since the Almirantazgo Fjord reaches depths greater than 200 m, characterizing oxygen pulses at 30 m as evidence of basin-wide deep-water renewal is an overstatement. The authors must distinguish between the ventilation of the shallow sub-basin at the head and the renewal processes of the truly deep layers of the main basin, as the current generalization lacks vertical observational support.

Ans:

Thanks, we change all to be clear that we are not referring to the deep basin at all, and we put clearly that our results refer to a depth of 30 m at the head of the fjord. Renewal study requires time-series of the deep basin and we think to focusing on that in a next project.

#### Minor Comments

There are several instances where the values reported in the text are inconsistent with the underlying physics and likely represent clerical errors:

- Wedderburn  $\Delta \rho$ : On line 653, the authors cite  $\Delta \rho = 3 \times 10^{-3} \text{ kg m}^{-3}$  for the Wb calculation. This value is physically unrealistic for a stratified fjord and contradicts the mooring data showing  $\Delta \rho > 10 \text{ kg m}^{-3}$ . Back-calculation suggests the intended value was likely  $\sim 3.1 \text{ kg m}^{-3}$ , and the text should be corrected accordingly.

Ans:

Thanks, we change that in the new version.

- Seasonal Trends: The reported negative trend for Conservative Temperature of  $-1.212^\circ\text{C d}^{-1}$  (line 425) is impossible given the  $5^\circ\text{C}$  range over five months. It appears the authors may have reported a monthly rate as a daily one. Salinity and oxygen trends show similar discrepancies.

Ans:

Thanks, you are right we make a mistake now to inform the trend now we verify and the correct daily values are included.

- The use of instrumented Southern elephant seals is a major highlight and a key contribution of this study. While Figure A2 in the Appendix provides a comparison with other data sources, this figure is not discussed in the main text, nor does it allow for a direct validation of the CTD-SRDL accuracy specifically within the Almirantazgo Fjord using conventional sensors. It would be highly beneficial for the scientific community if the authors included a brief description of the quality control filters applied and quantified the deviation of the seal-borne data relative to the in-situ conventional measurements. Such a discussion is necessary to assess the reliability of these sensors in resolving the vertical stratification patterns of the fjord.

Ans:

### Quality control and data processing

Seal-borne data were filtered by date. Only the dives closest to stations E2 and E3 were retained for comparison because they had closest dives within a time window of no more than two weeks. Profiles were inspected to remove outliers. Both CTD-SRDL and conventional CTD data were linearly interpolated to a uniform 1 m vertical grid, considering the depth range between the minimum and maximum pressure recorded by the seal-borne sensor and the CTD. The minimum pressure recorded by the CTD-SRDL was 4 dbar; therefore, no extrapolation was applied to shallower depths.

### Inside the fjord

- Summer: CTD casts (maximum depth: 144 m) were collected on 25–26 January 2024 and compared with the nearest seal dives from 27 January 2024.
- Winter: CTD casts (maximum depth: 140 m) were collected on 26 June 2024 and compared with the nearest seal dives from 6 and 9 July 2024.

For both seasons, the water column was divided into two layers: the surface layer (~4–50 m) and the deep layer (50 m to maximum profile depth).

### Outside the fjord (oceanic waters)

- For offshore comparisons, seal-borne data from February 2025 (664 profiles) were compared with the February climatology from the World Ocean Atlas (WOA), covering the period 1991–2020. The large number of seal profiles adds statistical robustness to the analysis. The same layer definition was applied: surface layer (~4–50 m) and deep layer (50–667 m).

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Location	Season	Variable	RMSD (Surface Layer)	r (Surface Layer)	RMSD (Deep Layer)	r (Deep Layer)
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<b>Inside Fjord</b>	Summer	Temperature	0.24	<b>0.99</b>	0.09	<b>0.96</b>
	Summer	Salinity	1.88	-0.09	0.2	<b>-0.95</b>
	Winter	Temperature	0.81	<b>0.80</b>	0.2	<b>0.64(*)</b>
	Winter	Salinity	1.17	<b>0.95</b>	1.13	<b>-0.68</b>
<b>Outside Fjord</b>	Summer	Temperature	0.48	<b>0.99</b>	0.32	<b>0.99</b>
	Summer	Salinity	0.22	<b>0.91</b>	0.03	<b>0.98</b>

Table 1: Comparison between CTD-SRDL (seal-borne) and conventional CTD measurements (inside fjord),

and climatological profiles (outside fjord) from the World Ocean Atlas (WOA). Statistics include the Root Mean Square Deviation (RMSD) and correlation coefficient ( $r$ ). Statistically significant correlations ( $p < 0.05$ ) are shown in bold.

(\*) At station E3 in winter, the improvement threshold deepened to 75 m. Below this depth, the correlation reaches 0.96, compared to 0.64 above 50 m.

#### **Inside the fjord (estuarine waters)**

In the surface layer (4–50 m), the sensors showed the best agreement with CTD data during summer for temperature (RMSD = 0.24;  $r = 0.99$ ). However, a contrasting behavior was observed between variables: while temperature increased its error and decreased its correlation in winter, salinity reduced its error and significantly increased its correlation. During summer, temperature exhibited the highest correlation in this layer, whereas salinity showed the highest errors of the study (RMSD = 1.88) and low, non-significant correlations ( $r = -0.09$ ). This suggests that seal-borne sensors have greater difficulty resolving the haline structure in the upper 50 m during stratified periods.

In the deep layer (>50 m), the fit improved notably in all cases, as evidenced by the decrease in error (RMSD < 0.3), except for salinity in winter (RMSD = 1.13). Temperature maintained consistently high correlations and the lowest errors inside the fjord (RMSD < 0.2) in both seasons (with the exception of one profile where the improvement threshold deepened to 75 m). Salinity, on the other hand, exhibited a weaker relationship ( $r = -0.95$  during summer and  $r = -0.68$  in winter). Only in one particular profile (winter, station E3) did the improvement threshold shift from 50 m to 75 m, possibly due to deeper vertical mixing.

#### **Outside the fjord**

Outside the fjord, the lowest errors and highest correlations were concentrated in the much deeper deep layer, with RMSD < 0.3 and  $r > 0.8$  for both temperature and salinity, indicating a good overall representation. Although the values in the surface layer were slightly lower, they

remained consistently good for both variables, suggesting a reliable representation in this geographic sector.

- In Sect. 4.1, the reported transport is internally inconsistent: the text states  $A_1 = 3 \times 10^4 \text{ m}^2$  and  $c_1 = 1.1 \text{ ms}^{-1}$ , but then reports  $Q_1 = A_1 c_1 = 2.2 \times 10^4 \text{ m}^3 \text{ s}^{-1}$ . Arithmetically,  $3 \times 10^4 \times 1.1 = 3.3 \times 10^4 \text{ m}^3 \text{ s}^{-1}$ , so the numbers (and/or the stated  $A_1$ ) should be corrected.

Ans:

Thanks, we changes the estimations and focusing on the Almirantazgo fjord.

- Line 450-455: Correct " ang-fjord" to " along-fjord" .

Ans:

Corrected

- Ensure Figure 4 labels are consistent between the map and the vertical sections.

Ans:

We change the figure, the data, and colormap

#### Summary Recommendation

The study presents a unique dataset, but a major revision is required to correct numerical inconsistencies and ensure that the scaling, mass balance, and ventilation arguments are physically sound.