Reviewer 1

Review of *'The answer if blowing in the wind: seasonal hydrography and mixing of the inner sea of Tierra del Fuego, Southern Patagonia'* by Castillo et al.

The manuscript by Castillo et al. uses in situ, seal-collected, and moored oceanographic data along with wind data to explain physical processes in Almirantazgo Fjord, Southern Patagonia. While the observations are interesting and the manuscript generally well-written, I had many questions about the methods of data collection and interpretation. These questions will have to be addressed before I can recommend the manuscript for publication. Below I will detail my major and minor concerns.

Major concerns

My first major concern is the lack of discussion of different layers in fjords. Specifically, the authors didn't introduce the different layers in the fjord and how these layers could potentially impact the results that they presented. Most literature suggests 3 to 4 layers in fjords (e.g. Farmer and Freeland, 1983 The physical oceanography of Fjords - ScienceDirect; Wan et al., 2017 Subtidal circulation in a deep-silled fjord: Douglas Channel, British Columbia - Wan - 2017 - Journal of Geophysical Research: Oceans - Wiley Online Library) so a simplified 2 layer would impact the results.

Ans:

We appreciate the reviewer's insight regarding the multi-layered structure of fjords. While our study uses a two-layer model as a first-order approximation for estimating flushing times, we acknowledge that intermediate waters play a crucial role in fjord dynamics. In the revised manuscript, we included a specific paragraph about the influence of the intermediate waters in the region. You must notice that the study region between Inutil bay and Maria cove lacks a sill, and the hydrography do not showed influence of a distinct water masses than the Modified Subantarctic Water mSAAW to verify is there a 3 or more layer in the system we require a circulation moored system with ADCPs similar to the study of Wan et al (2017) or Castillo et al (2012) but this study was focused in hydrography data and we are looking for funding to complement this first approximation with a circulation project in the near future. Thus, we don't have evidence of a 3 or 4 layers circulation scheme for this region. In fact, in the region near the second narrow (northward Inutil bay), Brun et al (2020) showed a mostly barotropic residual circulation, and near Carlos III island, Valle-Levinson et al (2006) shows similar patterns dominated tidally driven in Seno Ballena a glacial fjord in Magellan strait.

We included on Discussion, your suggestion about how a simplest 2 layer model will be affected if instead we considers a 3-layer models.

My second major concern centers around the map figures that were used. In particular, it is difficult to see the regions that the paper discusses and many names and areas aren't on the maps. In addition, it would greatly help the reader to add known currents and also to make the station locations bigger and easier to see. Since this is such a complicated region, it is possible that 2 maps (1 regional, one local) are required.

Ans:

We agree that the complexity of the region warrants better cartographic representation. We will revise Figure 1 to include a larger regional map and a detailed local map. We will also add key geographical features mentioned in the text (e.g., Carlos III Island, Darwin Glacier) and plot the major regional currents, such as the Cape Horn Current (CHC) and the Patagonian Current, to improve the reader's spatial understanding of the system.

My third major concern is related to instruments used and the apparent lack of CTD data processing. First, AML instruments don't have software that processes the data so were the data post-processed? If so, how was this done? Post-processing is important for aligning the sensors, removing spikes, etc. and the data are usually not considered publishable until the data have been full processed (e.g. see GitHub - Sea-BirdScientific/seabirdscientific: The Sea-Bird Scientific Community Toolkit). This concern is specifically apparent in Figure 5, where there is a significant near-bottom salinity inversion. It is possible that the CTD hit the bottom to cause this because fjords are generally salt-stratified (see Farmer and Freeland, 1983). Similarly, how were the seal data processed? Figure 4 shows many strange features including salinity inversions that could be caused by processing errors or could be linked to the data averaging.

Ans:

Regarding data processing, all CTD data (both AML and seal-deployed SRLDs) underwent rigorous quality control. We used TEOS-10 standards for converting measurements to Absolute Salinity (S_A) and Conservative Temperature (CT). First, we reprocessed all data sets CTD-SRLD and CTD-AML, also changed the colormap scale that maybe not contribute to describe the hydrography of the study region. The short answer to whether CTD hit the bottom is **NO.** The ship has an echosounder and we check the bottom during the CTD deploy because as usual the downcast is typically nearly a free fall at 1 m per second the AML was configurated to record at 4 Hz interval, despite the AML-CTD has the capacity of 25 Hz interval we decided that in order to save power during colder conditions even during the austral summer of Tierra del Fuego. Additionally, because our team doesn't have another CTD we take care of the instrument, calibration, deploy and recover.

For the seals CTD we avoid averaging in several months, instead we use data for the months (January and June) that coincide with traditional CTDs at the head of the fjord. In addition, we selected seals profiles nearest to the center axis of the fjord and selected the seals profiles around 2 km at each point and then we averaged at standard depths, we avoided distance interpolation and graph contours of Salinity and Temperature for January and June of 2024. We describe this in detail on Methods. We also included a description of the post-processing of the traditional CTD measurements.

Minor concerns

- Line 35 – Graphical abstract – again the intermediate water is absent here, which is misleading. I think that in this case the water column depth is 30 m (the depth of the bottom sensor and I think that should be make clear in the caption. Also, the box at the surface beside the ship doesn't make sense to me and should be explained in the caption.

Ans:

The graphical abstract doesn't include intermediate water because we don't have evidence that structures are present in the study region. The study of Brun et al (2020) in the Magellan strait also recognizes the mSAAW as dominant in the inner sea of the Magellan strait with salinities ~ 31 g kg^{-1}. The box represents cross-fjord structure of the water column. Now, we have corrected the captions to avoid misunderstanding.

- Lines 47-48 – How do you know that the primary mechanism for the physical dynamics is the along-fjord pressure gradient? The primary mechanism is likely fjord-dependent. Citations are needed to back this up.

  Ans:
  The statement was re-arranged and now includes several (and classical) quotations.

- Lines 60 to 63 – This is a weak paragraph and the point of it wasn't clear to me.

  Ans:
  We delete that paragraph but included the impact of the freshening in the renewal of bottom waters of Greenland (Boone et al 2018).

- Lines 69 to 70 – I suggest adding some examples of recent work in BC fjords since it is quite relevant to the work shown here (e.g. Bianucci et al., 2024 OS - Fjord circulation permits a persistent subsurface water mass in a long, deep mid-latitude inlet; Jackson et al., 2023 Winter Arctic Outflow Winds Cause Upper Ocean Cooling and Reoxygenation in a Temperate Canadian Fjord - Jackson - 2023 - Geophysical Research Letters - Wiley Online Library; Jackson et al., 2025 Why Deep-Water Dissolved Oxygen Is Higher in G̱ngaay Xyangs (Juan Perez Sound), Haida Gwaii, Than Other British Columbia Fjords - Jackson - 2025 - Journal of Geophysical Research: Oceans - Wiley Online Library; Hannah et al., 2024 Oxygen dynamics in a deep-silled fjord: Tight coupling to the open shelf - Hannah - 2024 - Limnology and Oceanography - Wiley Online Library)

  Ans:
  Thanks, now we have selected some of the suggested references to be included in the new version. The paragraph included was mainly focused on wind interaction with the water column of the fjords which is the scopes of the study, into Discussion section we included the studies with deep oxygen and ventilation of deep waters but that is out of the scopes of this study.

- Line 84 – I suggest adding another sentence here about how katabatic winds specifically impacts this region.

  Ans:
  Thanks, we included in the paragraph quoted above a study that katabatic winds and its impacts on the down-fjord circulation and a study of Bravo et al. (2019) about the influence of the katabatic flow in Southern Patagonia.

- Lines 97 – 99 – I suggest adding a reference here

  Ans:
  Thanks, a reference was added.

- Line 103 – A reference is needed here after SPI

  Ans:
  We included a reference of Cisternas et al (2026) that is already published on PIO.

- Lines 103-104 – Here is an example (South Pacific Current) of a current that should be added to an introductory figure

  Ans:
  Now in the new Fig. 1, we corrected the currents circulation to reference to Humboldt Current System (HCS), and Cape Horn Currents system (CHC).

- Line 106 – Here and elsewhere – I don't think you can cite papers that are in review

  Ans:
  Thanks, we included the Cisternas et al (2026) and Garces-Vargas et al (2026) references because those papers were in the second round of revisions and now are already published.

- Line 125 – Another example of map improvements – the full Magellan Strait isn't seen in Figure 1 so the Pacific connection is difficult to see

  Ans:
  Now is included on Fig. 1.

- Figure 1 – In addition to points above - Since the 3 different fjord zones are discussed, I suggested adding them to this introductory figure. Also I suggest adding the names of the meteorological stations to Figure 1

  Ans:
  thanks now the names were included on new Fig. 1.

- Line 140 – Patagonian Current not on Figure 1

  Ans: Thanks for your comment despite this term is included on one quoted literature, now we avoid to refers to this feature which seems to be part of the Cape Horn Current system, we deleted the sentence.

- Line 141 – Antarctic Circumpolar Current not on Figure 1

  Ans:
  Thanks, now the location was included on new Fig. 1.

- Line 143 – Punta Arenas and Carlos III Island not on Figure 1

  Ans:
  Thanks now the location was included on new Fig. 1.

- Lines 147 – 148 – The sentence starting with ‘The DC’ doesn’t make sense to me

  Ans:
  Thanks, the DC is Darwin Cordillera, now the location name was included on general Fig. 1.

- Line 148 – What gradient are the authors referring to?

  Ans:
  Thanks for the comment, we are referring here in a Temperature gradient, we included

- Line 150 – Darwin Glacier not on Figure 1

  Ans:
  Thanks, we changed the name for Darwin Cordillera and we included on new Fig. 1.

- Line 186 – What does CTDOF stand for?

  Ans:
  Thanks, we changed for AML-CTD which is a Conductivity, Depth, Temperature, Oxygen and Fluorescence CTDOF.

- Lines 211 – 212 – What reference salinity was used to calculate FWC? How was this reference salinity decided?

  Ans:
  You must consider that now we re-calculated the along-fjord hydrography data deployed on the elephant’s seals, we explain above the changes. We have decided on the Reference based on the averaged Salinity of the deeper layer and now included the statistics of that on a new Table 3.

- Lines 214-215 – I suggest adding a citation here to show that this is the definition of MSAAW

  Ans:
  Thanks, but I don’t pretty sure where do you require the reference, because that definitions are already in Silva et al (2009) which is included at the end of the paragraph.

- Line 224 – How were data from the WiSens NKE CTD processed? Also, some CTD sensors have interference with stainless steel frames that cause sensor drift (see https://docs.rbr-global.com/__attachments/16941886/0012918revA%20Proximity%20effects%20on%20conductivity%20measurements%20for%20the%202000dbar%20CT%20cell.pdf?inst-v=16a1419f-71a8-4d9a-9fa2-79f4a187420f#:~:text=As%20a%20point%20of%20reference,distances%20from%20th e%20conductivity%20cell.) Is there documentation showing that stainless steel frames are not an issue for the WiSens CTDs?

Ans:
Thanks, there is no documentation about the problem that you mention for NKE Wisens but we had the opportunity to discuss this in a meeting and mail exchange with NKE technicians. They indicated that there aren't reports about interference between stainless steel frames and the conductivity cell of the WiSens they mention that there are differences between the RBR and WiSens cells. According to that, the RBR cell is based on electromagnetic beam whereas NKE cell is based on an electromagnetic signal generated between two electrodes integrated and capsuled made this cell robust and compatible with stainless steel protective frames, in fact they are developing protective frames for another system called WiMo which uses the same conductivity cell as WiSens. NKE instrumentation has been developing low-cost coastal sensors that is growing up in the use for different oceanic applications, recently they are providing the CTD for the ARGO floats.

- Line 234 – Are the authors referring here to station A2 on the map? If so, please state

  Ans:
  Yes, thanks we included A2 and the references to Fig2 and Table 1.

- Line 235 – What do the authors mean by near-surface? Please state the actual Depth

  Ans:
  We included the depth.

- Lines 237 – 239 – I don't recall that the authors examined the Hobo data. I suggest removing this sentence from here if the data weren't used in this paper.

  Ans:
  We deleted the paragraph.

- Section 3.1 – I'm not convinced that these regional scale winds are accurate in coastal waters, particularly fjords (see The influence of mesoscale land–sea breeze circulation on local wind climatology in the Svalbard fjords of Kongsfjorden and Hornsund - Kitowska - 2021 - International Journal of Climatology - Wiley Online Library) Have the authors explored the difference between the ERA5 and meteorological winds?

  Ans:
  Thanks, we made a comparison between the meteorological stations of the region. We already included that on Appendix 1 (A1). Here, we made a seasonal comparison of the main patterns of the wind of the region. The stations of Punta Arenas, Porvenir, and Puerto Williams are meteorological stations based on airports of the region and were the results of several years of data (54 years). The main patterns were highly consistent in direction, but the ERA 5 intensity was c.a. 20% lower than observations. We maintain the paragraph at the beginning of section 4.3. Now the new A1 includes the scatter plot

of u,v components of the ERA 5 pixel to shows the main axis of variability of the winds in the region and again it was consistent with the AF orientation and westward which mean to the interior of the AF. In addition, strong winds events (above of 90 percentile) all were highly well related with similar peaks on Temperature, DO and Salinity changes, highly coherent in time and frequency domain suggesting a dynamical response of the variables to the wind variability beyond of a random response.

- Line 277 – I don't see S1 – could the authors explain?

  Ans:
  We corrected to Appendix 1.

- Line 280 – Where is the location of the ERA5 station used. Please add to Figure 1

  Ans:
  Now is included on Fig. 1

- Line 286 – I don't see Table 2

  Ans:
  We added the Table 2

- Line 287 – Gregorio station isn't on Figure 1

  Ans:
  Now the location name is included

- Line 290 – This is the first time that form factor is mentioned. I suggest adding it to the methods and include citations

  Ans:
  Now form factor is included on Methods.

- Figure 3 – It looks like the labels in the figure and captions are different for S2 and N2 constituents. Also I suggest specifying in the caption that the amplitude shown is from the model that was discussed in section 2.3

  Ans:
  We checked the labels and we included on caption that are amplitudes based on the tidal model.

- Lines 309 to 313 – I don't see where low absolute salinity water was observed in deeper waters

Ans:
This results is based on the whole data set of the elephants' seals showed on Appendix 1d. Now we have corrected to ensure that we are referencing the App. 1

- Figure 4 – In general I didn't see value in this figure as it is shown. The numerous salinity inversions made be question the accuracy of the data. And I'm not entirely sure how this picture fits with the larger story. If the authors use the data, I suggest calculating monthly or bi-monthly averages – I suspect that the inversions are a consequence of averaging a longer period of time. The length of time of the averages not the dates when the data were collected were not specified.

  Ans:
  We already indicates above that we made a new way to select the along-fjord data and we implemented in the new manuscript version.

- Lines 341-342 – I don't think that the DO data are shown in Figure 4?

  Ans:
  We corrected that.

- Figure 5 – As mentioned above, the large salinity inversion shown in b) and d) are strange. I don't know why the near-bottom salinity inversion isn't present in the bottom profile?

  Ans:
  We changed the along-fjord processing and now no inversion are observed.

- Line 352 – I suggest adding references to support the statement that thermal inversions are typical fjord structures

  Ans:
  We deleted that sentence

- Lines 352 – DO is not shown in Figure 5

  Ans:
  We deleted that results.

- Lines 353-354 – I'm not familiar with conservative density. Please explain

  Ans:
  Thanks was a mistake we are thinking in Conservative Temperature, we changed.

- Lines 354-355 – Again the authors state that the waters are salt-stratified yet Figure 5d shows a near-bottom salinity inversion

  Ans:
  All this results change in the new version of the manuscript.

- Figure 6 – Is this from data collected by the seals? How were summer and winter defined?

  Ans:
  Thanks, as a part of the changes implemented, now the results only mention the data of January and June 2024, to a better comparison with the traditional CTD measurements.

- Lines 370 to 372 – How does this compare to other similar studies (e.g. Hauri et al., 2013 Wind-driven mixing causes a reduction in the strength of the continental shelf carbon pump in the Chukchi Sea - Hauri - 2013 - Geophysical Research Letters - Wiley Online Library; Evans et al., 2019 Frontiers | Marine CO2 Patterns in the Northern Salish Sea)?

  Ans:
  Thanks for your comment, but the CO2 concentrations and carbon budget is out of the scope of the study.

- Line 387 – Winds blowing to the fjord head are not obvious in Figure 2

  Ans:
  Thanks, we added a component scatter plot in Appendix 1 and we think that the into the fjord persistent wind is more notorious.

- Figure 7 – What is the wind direction shown in a)? How was the seasonal trend for each time series estimated? How were warmer and colder events defined?

  Ans:
  Thanks, to the wind being highly dominated by the east component, here we used the wind-stress magnitude which is also already indicated on section 3.4.1. The warmer /colder events were defined connecting the wind maximum events (over percentile 90 intensities) with the Temperature event, every stronger peak in wind during summer was related with high temperature event, in autumn/winter stronger peaks were related with a descend in the Temperature. We already describe that in detail that in the Discussion at the ends of the section 4.3.

- Line 425 – A negative trend of -1.212C per day isn't correct

  Ans:
  Thanks we have an error on those estimation and now were corrected.

- Line 426 – A seasonal trend of 557 g/kg per day isn't correct

  Ans:
  See the response above.

- Figure 8 – I think there needs to be some explanation as to why the oxygen concentrations at the bottom are greater than the surface in Figure f) – ie why are the numbers all negative?

  Ans:
  Thanks, we changed to only report △DO here negative gradient imply that surface DO is greater than bottom DO which is what we expect when DO was near cero imply mixing of the water column and that response to the wind influence seem to be observed on the short-time series.

- Line 629 – How does the plume gain heat?

  Ans:
  We don't make estimation of heat budget, but short measurements taken during the traditional CTD measurements indicates high air-temperature during January (> 14ºC) and colder during June (< -13ºC). Surface water was colder than air-temperature in January, and warmer than air-temperature during June. We don't have air-Temperature time-series for the region to accomplished that but is a question to be assess in future studies in the region. We know that reanalysis has several products that could be useful to test that hypothesis, but we decide to focus in the hydrographic and time-series variability for that this is a possible explanation maybe plausible and is part of the Discussion.

- Line 631 – What proof is there of mixing in the upper freshwater that increases DO?

  Ans:
  Thanks, like the above response this is part of a Discussion and part of a possible explanation for the variability observed in the time-series.

- Lines 692-694 – This is a bold statement. If the authors using data in 30 m of water near the head of the fjord to prove this statement?

  Ans:
  Thanks, the new version of the manuscript now is focused only in the exchange of the upper brackish layer, we discard any analysis from the deep basin and focused on the upper layer where we have more evidences an less assumption to support the estimations.

- Lines 696-697 – Were the seal data and wind-driven mixing examined together?

Ans:

Yes, we have made a comparison between the two sets of data. We include in Discussion a paragraph about the comparison of these two sets of data.

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)
Inside Fjord	Summer	Temperature	0.24	**0.99**	0.09	**0.96**
	Summer	Salinity	1.88	-0.09	0.2	**-0.95**
	Winter	Temperature	0.81	**0.80**	0.2	**0.64(*)**
	Winter	Salinity	1.17	**0.95**	1.13	**-0.68**

Outside Fjord	Summer	Temperature	0.48	**0.99**	0.32	**0.99**
	Summer	Salinity	0.22	**0.91**	0.03	**0.98**

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.