

## Review 2 – Author Response

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The following section provides a point-by-point response to Reviewer 2 (Anonymous). The reviewer's comments are shown in black, followed by our response shown in blue.

### 1. General comments

This manuscript presents an ambitious ensemble of datasets in an attempt to weave together a complex story of glacier dynamic change, as potentially driven by mCDW intrusion and sea ice breakup events, in the Porpoise Bay region of East Antarctica. The authors combine time series observations of ice front position, ice velocity, grounding line position, and bed, glacier, and ice shelf elevations with sea ice observations and ocean temperature/salinity observations/objective analysis. The authors are combining sometimes disparate datasets into decades long time series for each process, which they then compare in order to compile evidence for causality between climate drivers and components of dynamic change.

The paper carries two central narratives. The authors argue that the conditions exist for mCDW transport to Porpoise Bay grounding zones, and that best estimates of grounding line retreat suggest it could be occurring. They also separately argue on the basis of timing that sea ice breakup causes calving events, and that calving can precede upstream dynamic changes. Overall, this manuscript has the potential to be good, but as it stands, there are a lot of moving parts that would benefit from careful reorganization and a touch more rigor. Two elements of the paper that needs attention are (detailed in specific comments):

(1) the uncertainty quantification. Currently, this is limited to a brief discussion in the methods section and frequent references to uncertainty without quantitative support.

(2) the narrative organization and logical flow. This needs attention through reorganization and the addition of a supplement to capture supporting ideas and streamline the central narrative.

With the proposed changes, this paper could meaningfully contribute to a growing body of literature concerning the growing importance of the EAIS to Antarctica's mass balance and sea level contribution. [We thank the anonymous reviewer for their positive feedback on the manuscript and constructive suggestions. Please find our responses to the specific comments below.](#)

### 2. Specific comments (in no particular order)

This text combines numerous datasets, which occasionally express uncertainty ranges upwards of an order of magnitude. In order to make it more clear which portions

of the timeline are contributing most to uncertainty, I recommend that error bars be placed in all applicable figures (3, 4, and 8) and reported alongside key estimates in the results. Also, I recommend a scan for any mention of “high uncertainty” (I’ve identified a few) and try to replace with something more quantitative (e.g., percent error). These uncertainties should be addressed when qualifying the hypothesized processes. For example, do upper bounds in uncertain bed topography drastically alter the likelihood of mCDW intrusion? The errors from Figure 3 are digitisation errors which are estimated at 1 pixel depending on the imagery used in the digitisation process. We propose to add a table to the Supplementary Information showing the imagery used in each timestep with the associated errors. Adding uncertainty bars to Figure 3 would make it hard to much harder to read, especially post-2000, where there are more data points close together, so we instead clarify the specific uncertainty with reference to an additional table in the supplementary materials.

Date	Satellite	Scene ID	Resolution (m)	Error (m)
1963	KH-5 ARGON	ARGON mosaic (Kim et al., 2007)	140	210
03/11/1973	Landsat 1	LANDSAT/LM01/L1G5/098107_19731103_20180428_01_T2	60	90
19/03/1989	Landsat 4	LANDSAT/LT04/C02/T2_TOA/LT04_094107_19890319	30	45
13/02/1991	Landsat 5	LANDSAT/LT05/C02/T2_TOA/LT05_094107_19910213	30	45
07/01/2000	Landsat 7	LANDSAT/LE07/C02/T2_TOA/LE07_093107_20000107	30	45
10/02/2001	Landsat 7	LANDSAT/LE07/C02/T2_TOA/LE07_093107_20010210	30	45
21/12/2002	Landsat 7	LANDSAT/LE07/C02/T2_TOA/LE07_094107_20021221	30	45
22/01/2003	ASTER	ASTER/AST_L1T_003/20030122004242	15	45
27/12/2005	ASTER	ASTER/AST_L1T_003/20051227005243	15	45
07/11/2006	ASTER	ASTER/AST_L1T_003/20061107003450	15	45
18/02/2007	Landsat 7	LANDSAT/LE07/C02/T2_TOA/LE07_094107_20070218	30	45
14/09/2007	Landsat 7	LANDSAT/LE07/C02/T2_TOA/LE07_094107_20070914	30	45
08/03/2008	Landsat 7	LANDSAT/LE07/C02/T2_TOA/LE07_094107_20080308	30	45
07/02/2009	Landsat 7	LANDSAT/LE07/C02/T2_TOA/LE07_094107_20090207	30	45
14/03/2010	Landsat 7	LANDSAT/LE07/C02/T2_TOA/LE07_094107_20100314	30	45
01/03/2011	Landsat 7	LANDSAT/LE07/C02/T2_TOA/LE07_094107_20110301	30	45
10/03/2011	Landsat 7	LANDSAT/LE07/C02/T2_TOA/LE07_093107_20110310	30	45
24/01/2012	Landsat 7	LANDSAT/LE07/C02/T2_TOA/LE07_093107_20120124	30	45
18/02/2013	Landsat 7	LANDSAT/LE07/C02/T2_TOA/LE07_094107_20130218	30	45
03/04/2013	Landsat 8	LANDSAT/LC08/C02/T2_TOA/LC08_095107_20130403	30	45
17/03/2014	Landsat 8	LANDSAT/LC08/C02/T2_TOA/LC08_094107_20140317	30	45
29/03/2015	Landsat 8	LANDSAT/LC08/C02/T2_TOA/LC08_093107_20150329	30	45
29/03/2015	Landsat 8	LANDSAT/LC08/C02/T2_TOA/LC08_093107_20150329	30	45
28/02/2016	Landsat 8	LANDSAT/LC08/C02/T2_TOA/LC08_093107_20160228	30	45
04/01/2017	Landsat 8	LANDSAT/LC08/C02/T2_TOA/LC08_094107_20170104	30	45
24/02/2018	Landsat 8	LANDSAT/LC08/C02/T2_TOA/LC08_094107_20180224	30	45
19/03/2018	Landsat 8	LANDSAT/LC08/C02/T2_TOA/LC08_095107_20180319	30	45
27/02/2019	Landsat 8	LANDSAT/LC08/C02/T2_TOA/LC08_094107_20190227	30	45
26/03/2020	Landsat 8	LANDSAT/LC08/C02/T2_TOA/LC08_093107_20200326	30	45
29/01/2020	Landsat 8	LANDSAT/LC08/C02/T2_TOA/LC08_094107_20200129	30	45
24/01/2021	Landsat 8	LANDSAT/LC08/C02/T2_TOA/LC08_093107_20210124	30	45
15/01/2021	Sentinel 2	COPERNICUS/S2/20210115T003509_20210115T003505_T52DDM	10	15
20/02/2022	Landsat 9	LANDSAT/LC09/C02/T2_TOA/LC09_093107_20220220	30	30
11/03/2023	Landsat 9	LANDSAT/LC09/C02/T2_TOA/LC09_093107_20230311	30	30
17/03/2023	Landsat 9	LANDSAT/LC09/C02/T2_TOA/LC09_095107_20230317	30	30
01/02/2024	Landsat 9	LANDSAT/LC09/C02/T2_TOA/LC09_094107_20240201	30	30
12/02/2025	Landsat 9	LANDSAT/LC09/C02/T2_TOA/LC09_093107_20250212	30	30

Similarly, adding error bars to Figure 4 would make the figure far less readable, given many of the data points are so closely spaced. We have followed the approach of Picton et al. (2022) here, which is a similar study also published in the same journal. In response to Reviewer 1, we propose to put a table in the Supplementary Material showing the specific error range for annual velocity measurements within each box and for each glacier and we will mention this in the Figure 4 caption to clarify the uncertainties.

For Figure 8, the grounding line data did not provide uncertainty data on a per-point basis in the original dataset. We had already added data uncertainty where possible (i.e., the two data points we produced). No further change is proposed.

In its current state, there are two competing narratives in this work: (1) dynamic thinning and grounding line retreat from mCDW intrusions, and (2) the interactions between sea ice, calving, and upstream glacier flow. I would suggest taking steps to centralize the narrative, such that these are two functional branches in the broader scheme of glacier dynamic change. This might look like more emphatic statements to link the two processes and some reorganization around those two central threads. Alternatively, suppress or remove (2), since it already seems to be secondary (it does

not appear in the title) and is difficult to support without some modelling effort (see my comment on line 663). This is a useful point, but we would like to clarify that there are two narratives in the paper that explore two different possible controls on the change in Porpoise Bay. We feel that we discuss the importance of these two threads for the behaviour of these glaciers. It is slightly unclear what could be done to 'centralise the narrative.' We treated the two controls separately and we do not know how closely the controls are linked due to data constraints, as the reviewer notes. In order to centralise the narrative along the lines suggested here, we would have to begin speculating about these links and/or use numerical modelling, as the reviewer suggests. Ideally, we would prefer to retain the simple organisation of the two threads, but we do make some attempt to link them in the Discussion, as two potential controls on outlet glacier dynamics in this part of East Antarctica. Furthermore, Miles et al. (2017) focused on the ice shelves/sea ice interaction in Porpoise Bay, and we did not want to reiterate/repeat that study, which is why it may appear as a secondary focus on this manuscript. Nonetheless, we think the manuscript would be weakened by removing this section altogether, especially as we document some more recent evidence of the link between calving and sea ice concentrations.

In line with the last suggestion, some figures don't seem to be essential for the narrative, and thus might be better off in a supplement (e.g., figures 10, 12, 14, possibly 7). We feel these are all important figures to explore the relationship between ocean temperature/potential mCDW, thinning, and sea ice conditions in the region. Therefore, for clarity we propose to keep these figures in the main text rather than making the reader refer to the supplement. We also note that neither of the other two reviewer suggest removing figures.

The argument for mCDW presence relies on two (necessarily) incomplete pieces: EN4 and tagged seal data. EN4 is an objective analysis product, and given the data limitations in this region, some discussion (possibly a supplemental figure) depicting the actual available data points used in this product would provide an honest anchor for the veracity of water temperatures in Porpoise Bay. Additionally, a quick supplemental comparison between the two datasets (such as one plotted on top of the other) would strengthen them both. This is a good point that captures the frustration of working with ocean data in East Antarctica. Due to the paucity of ocean temperature measurements in East Antarctica, the only temperature data that informs the EN4 model within Porpoise Bay would be from seal-tracked measurements, which we show in Figure 12. Regarding plotting the EN4 and MEOP datasets against each other, the MEOP seal data is used to build the EN4, so we do not think it is wise to plot these datasets against each other. Furthermore, the MEOP data is not spatially or temporally continuous and is only available for a narrow time period. We propose to add additional information about the EN4 data in the text and further acknowledge the paucity of ocean data and requirement for more in-situ ocean temperature measurements around Porpoise Bay and East Antarctica generally.

Factors which affect ice elevation changes over time (namely precipitation and firn densification) are never discussed. This should be central to introducing the elevation changes as a metric, so that the reader understands where the ambiguities lie. This is a good point. We will add some introductory sentences to explain the drivers of surface processes in the methodology and discussion sections of the manuscript. However, a full analysis of precipitation patterns and firn densification is beyond the scope of this

paper. We will, however, add some further discussion of this issue in relation to the surface elevation changes in the Discussion.

### 3. Even more specific comments/questions

20: consider dropping the last clause and adding a concluding sentence that widens the scope back to the broader community contribution. This will be amended in the revised document, as suggested.

40-60: Might be worth citing Walker et al., 2024, which captured the first ice shelf collapse in East Antarctica, to highlight that changes are starting to take place. Good idea. Walker et al., (2024) will be added to this section, as suggested.

41: This paragraph could be split in two, talking about EAIS, then about Wilkes Land. Great point. This paragraph will be split in two for ease of reading.

75: Thompson et al., 2024 is another key paper about Wilkes Land dynamics. We have searched for this paper, but we cannot find which study the reviewer is referring to. We would be happy to include this with more information.

110: "identification criteria" would be a bit more clear. "Identifying" will be swapped for "identification" in the Table 1 caption.

129: To which satellites are these errors attributed? Here is an order of magnitude error range that makes the good data look bad. These are the errors published; the following sentence explains that the "altimetry data from Seasat, Geosat, ERS-1, ERS-2, Envisat, ICESat, and CryoSat-2 satellite missions."

141: Maybe specify that it comes from the ATL15 gridded product that is corrected with firn-models and tides. Great point. This will be added in the revised paper.

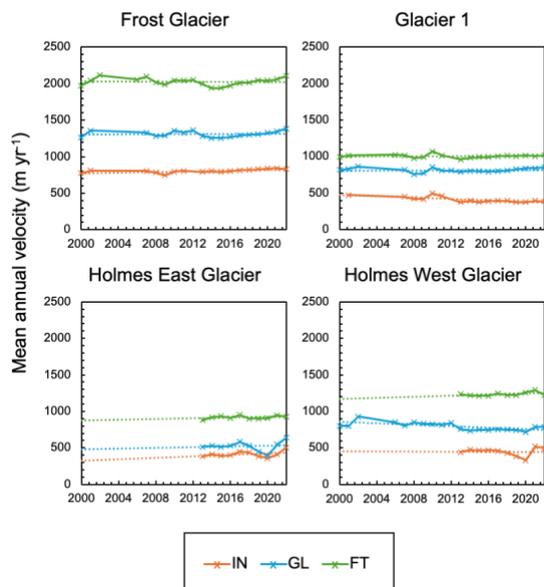
144: Not clear what you mean by compare the datasets. We extracted the data from all three datasets in the timeframe 2003-2017/19 to match the temporal range of the Smith et al. (2020) dataset. This wording of this sentence will be adjusted for clarity.

162: Possible to use a smaller cutoff? 50 percent is quite large, that's 200 m/yr error for some of your upstream velocities. At least warrants an explanation. This follows the methodology from Picton et al. (2022) and it set at a level to minimise the data loss. Most of the magnitude percentage error measurements are below 5-10%. We will add a sentence explaining this choice of cutoff.

Fig. 3: Dashed lines aren't necessary because you have markers too. Also, could consider dropping the 1960-2000 to make the era of interest more clear. You could change the axis label to "change from 1960" and possible include vertical lines to show the 1960-2000 min and max since that is the primary benefit of those points in the first place. The dashed lines for the pre-2000 measurements are to denote that the data is scarce/this is a low-resolution record compared to post-2000 plots, so we propose to keep the dashed lines in the revised document. We will change the Figure 3 axis to read "Change in ice shelf frontal position from 1963" in the revised document. We have considered removing the 1960-2000 ice shelf retreat from the plot, but we think it is

useful to show the range experienced in the past and a valuable indication of window in which the ice shelf length is operating.

Fig. 4: I would recommend aligning all vertical axes, even if the lines get squished a bit. Will help the reader understand the relative significance of each glacier. We considered adjusting Figure 4 to use an aligned vertical axis, but we find this is harder to see the detail of the minor fluctuations (see below), especially since the velocity changes are small as is. We would prefer to retain the original x-axis numbering.



170: Maybe state where grounding lines were found as well as where they weren't. This confused me a bit. Good point. This will be added to this section as recommended.

192: Perhaps MOA would be more clear than manual, since you have DInSAR labelled. It is unclear what the reviewer is asking us to change here. The grounding line mapped from the MOA dataset is manually digitised.

3.1.: "Ice shelf front position." This terminology in particular varied a bit throughout. This use of terminology to describe the ice shelf frontal position will be standardised in the revised document.

230: Might want to explain how EN4 is constructed. We will add the following sentence to explain EN4: "EN4 is constructed by collecting in-situ observations of ocean temperature and salinity (e.g., from Argo programme, World Ocean Database, seal-based CTDs), applying quality control and bias corrections, then objective mapping to produce monthly gridded fields ( $1^\circ \times 1^\circ$ , 42 depth levels) of ocean temperature and salinity (Good et al., 2013)."

233: This sentence is superfluous. Also consider sometimes replacing phrasing of "high uncertainty" with "best estimates". We will edit this sentence to make it less superfluous to explain why we read the EN4 data cautiously.

415: recommend replacing “around” with  $\sim$ . This will be replaced in the revised document.

452: “elevation thinning.” This will be replaced with surface elevation loss in the revised document.

455: “faster (<500 m/yr)” consistent formatting. Parentheses will be added here.

456: A grounding zone paper to cite: Zhu et al (2025). This citation will be added.

Table 3: Maybe add date ranges to the table itself. Great point – data ranges will be added.

3.6: This section could use another look to make sure you are highlighting the results you want to highlight. E.g., sea ice is not mentioned here. Maybe that was on purpose. But I read this section as if it were the intro to your discussion, for what that’s worth. We use this section to summarise the key findings from the glacier parameters that we were using to assess dynamic change in PB rather than the drivers of changes.

474: “face value” said a few times, it has the effect of downplaying your estimates. Fair point. We no longer use this phrase and replace it with more exacting language but remain mindful of the uncertainties associated with the grounding line data which merit further investigation.

482: another “highly uncertain.” We will change this to “are subject to uncertainties.”

511: does EN4 depict the temperature and salinity that can be used to identify CDW? We have mentioned this in Line 420: “The casts record salinity up to  $34.7 \text{ g kg}^{-1}$  on the continental shelf, with many of the values above  $34.5 \text{ g kg}^{-1}$  (Fig. 12b). mCDW in East Antarctica is characterised by high salinity ( $>34.5 \text{ g kg}^{-1}$ ) and temperature above freezing (Schodlok et al., 2016). Our findings suggest the presence of mCDW around the continental shelf break near Porpoise Bay at depths at, or shallower than, the continental shelf edge.”

653: another “high uncertainty.” We will reduce the use of high uncertainty in the paper and will enhance uncertainty quantification using two additional tables in the Supplementary Materials.

663: It could be argued that wind is the force driving both events, and that the sea ice gives in first, then calving occurs, creating the illusion of causality. Recent modelling work by Surawy-Stepney et al, (2024) explores this on the Antarctic Peninsula. This is a great point. We propose to add a sentence “However, we cannot rule out that wind is a driving factor in both sea-ice and ice-shelf break up, similar to the findings from Surawy-Stepney et al. (2024) in the Antarctic Peninsula” to Line 585 in the discussion to mention this.

#### 4. Technical comments

There is a shift between active and passive voice (lots of active voice in the discussion). We will ensure more consistency in tone in the revised manuscript, using the active voice more across the paper.