REVIEW OF "Antarctic ice sheet grounding line discharge from 1996 to 2023" *by Davidson et al., 2023*

<u>Summary</u>

This manuscript presents a 1996-present record of Antarctic-wide ice discharge at monthly resolution and finds that grounding line discharge increased by about 10% between 1996 and September 2023 (2205 Gt), mostly due to increasing flow speeds in West Antarctica. Several velocity and DEM products, at varying spatial and temporal coverage, are combined and iteratively gap-filled to create full reference maps. DEMs are differenced with multiple single (BedMap2, BedMachine v2) and hybridized ("FrankenBed") bathymetry datasets to compare the range of ice thickness estimates and net impact on ice discharge volume. In addition, a fourth reference bed, termed "FrankenBedAdj" represents the adjusted topography necessary to yield discharge volume changes compatible with altimetry-derived mass losses, when correcting for SMB. Grounding line discharge is calculated for a large variety of input variables, including bathymetry, as described above, multiple (2) firn compaction models, and flux gate location (16 equally spaced gate options plus the gate-average, for a total of 136 variations of ice discharge per drainage basin.

Overall, this is an interesting and both well written and executed study. The methods presented are robust and thorough – and the authors account for a variety of inputs and uncertainties to yield a comprehensive overview of grounding line discharge and its sensitivity to modeled + observational data and methods used. The manuscript will be valuable to the community and is thus deserving of publication in ESSD with minor revisions. However, I have also included suggestions for justification on several approaches, and a request to strongly consider a first order comparison to GRACE. Given the range in net discharge values discussed under various conditions in the manuscript, and regional discrepancies between these and previously published estimates, a comparison to gravimetry would provide valuable context for assessing sources of remaining error and uncertainty. My substantial comments are listed first, followed by minor comments and suggestions.

<u>Main:</u>

I would encourage the authors to provide useful context by comparing large basin mass balance estimates to GRACE. Given that a multi-model SMB average has already been incorporated into the study, combining these data with discharge for a mass balance time series for comparison to GRACE seems feasible and important. Offsets between GRACE/Input-Output time series, and their differences with respect to mass loss magnitude, long term trends, and seasonality would be valuable for better understanding sources of uncertainty and uncertainty in bed topography.

Section 2.5: Thickness change between flux gates and grounding line.
Please add more detail on this section. For example, on line 180:
"*For each gate pixel where ice flow is greater than 100 m/yr we calculate the number of years of ice flow between each flux gate pixel and the MEaSUREs grounding line (Mouginot et al., 2017c), to convert this rate of thickness change to a total thickness change*."

Is the climatological SMB mean taken at the initial flux gate location, or an integrated average between the gate and MEaSUREs grounding line? Similarly, how is time of ice flow between gate and grounding line calculated? Lastly, is this correction applied to the mean gate, or each of the 16 gates?

I also struggle to understand the choice to compute the SMB-corrected ice thickness to better represent grounding line flux, but not also use the velocities at the grounding line. I may have misinterpreted the text, but the flux gates are placed three years of flow distance away from the grounding line, iterated every 0.1 years to account for variable velocity along the migration path. This implies that the velocity is different at the grounding line than at the most seaward flux gate. Why not use this velocity along with the corrected grounding line thickness to calculate grounding line discharge?

Figure 10.
This figure is really interesting, and Line 328 of the manuscript notes that "*The differences between flux gates primarily reflects the difficulty in conserving mass with imperfect ice thickness, velocity, and surface mass balance data, rather than algorithmic errors.*"

Do the values shown in Figure 10 reflect the location effect on discharge before or after the thickness adjustments (from surface processes, etc.) are applied? If the former, do these thickness adjustments account for the range in values seen across gates?

One recommendation is to apply the same methods discussed in Section 2.5 to the most inland gate, and compare to observed elevations at the downstream gate at the calculated between-gate flow time later. The difference between observed and calculated ice thickness change would provide uncertainty for the ice thickness adjustments discussed in Section 3.4.

Lastly, can you provide some discussion on the source of the seasonal "dimming" of inter-gate variability at the Peninsula (Figure 10, panel d). White patches reflecting similar discharge values across all gate locations seem to coincide with seasonal acceleration in ice flow (from Figure 9). However, the source of these patches prior to the availability of seasonally resolved dynamics (such as in 2006 through 2014) is unclear.

On FrankenBedAdj
On deriving an adjusted bed topography by "*proportionally adjust(ing) the pixel-based ice thickness based on the difference between our calculated basin*"
First, if this is an iterative process, what is the precision or threshold value used to determine satisfactory agreement? Second, does "proportionally" imply that every pixel is adjusted by the same +/- %? In instances where ice streams rest on deep troughs, this type of correction would tend to increase the cross-flow gradient in bed slope. Does the type of cross-flow pattern in bed shape calculated from the FrankenBedAdj appear realistic, given available direct observations from ice penetrating radar? It would be useful to see how these adjustments (along with the other three bathymetry estimates) compare at several select sites where direct observations of the bed are available. If FrankenBedAdj performs poorly at these locations compared to the other models, that would suggest the error likely lies in SMB/firn models.

<u>Minor</u>

Line 159

"*For gate pixels with no data at any time and more than 300 m from neighbouring finite pixels (after outlier removal), we use our reference ice velocity estimate which has no gaps by definition*."

What percentage of flux gate pixels fall into this category?

Figure 9.

Consider using larger markers for FrankenBed for panel (b) to avoid other lines completely obscuring the time series. I am also confused by the caption text "Note that FrankenBed and BedMachine are identical for all displayed basins except West." However, basin "Dryg" also indicates BedMachine (green) deviation from FrankenBed. How, if the beds are identical, do we see some divergence in the black and green time series in East Antarctica, panel c?