

## General Comments

The study provides valuable insights into the seasonal dynamics of sea ice floes in the Weddell Sea using high-resolution data from ICESat-2. The use of altimetry to quantify floe chord and freeboard thickness distributions, as well as lead width and vertical floe roundness, adds a crucial dimension to understanding sea ice behavior and its regional variations. This study contributes to the development of floe-resolving models by offering detailed diagnostics of sea ice processes.

However, I have several concerns regarding the usage of the ICESat-2 datasets and the clarity of the methodology. Therefore, I recommend that the paper undergo major revisions before it can be considered for publication.

### Here are my major comments:

1. I'm not sure if the manuscript presents enough innovative methodologies/findings since many previous publications have already used altimeters, including CryoSat-2 and EnviSat, to derive floe chord distribution (Horvat et al., 2019) and lead-to-floe (Tilling et al., 2019). Additionally, it is unclear whether the results might depend on the specific ATL 07/10 version.
2. The introduction mentions that “The perennial extent of Antarctic sea ice is small compared to the seasonal portion of the pack...” and the manuscript primarily addresses perennial ice. Clarify how the study’s focus on perennial ice informs the basin-wide behavior of the pack as stated in Line 74.
3. I don't quite follow the application of floe-derived metrics for model diagnostic evaluation since ICESat-2 and freeboard ice thickness distribution here is snow freeboard, not directly the ice thickness or ice freeboard. This means the snow freeboard needs to be converted with snow information to have potential sea ice process applications. It’s unclear how we can use this knowledge—is it just a product-based ice diagnostic study?
4. I'm not clear how you define distributions such as floe chord distribution or freeboard ice thickness distribution in which temporal or spatial windows. While the floe chord length is defined by the distance between ice segments by each beam, what exactly is the floe chord distribution?
5. I appreciate the use of different methods in lead detection from ICESat-2 for the sensitivity test, but since the sensitivities are all based on ICESat-2 data, how about using one case to show the lead bias or validate the lead detection from a different data source, such as SAR? How does the systematic bias in lead detection affect the distribution slope changes in the results?

### Detailed comments:

1. Line 89: What corrections were made in the previously uncorrected ice type product?
2. Line 93: How did you complement the daily ice type with monthly ICESat-2 and weekly ice motion data? More details are needed here.
3. Figure 2: Are Figures 2c and 2d calculated based on the Weddell Sea or the Antarctic basin scale?
4. Figure 3: Are the results here based on all seasons during the period of 2018-2022?

5. Line 194: It might not be feasible to describe this as “inter-annual variability” given it is only four years of data. The sample is scarce in terms of defining inter-annual variability.
6. Line 196: Based on Figure 4(b), is there statistically significant anti-correlation? Only sometimes in January and March do they share significant correlation instead of the whole season. How do you explain this anti-correlation?
7. Line 254: How can we trust the lead spacing from lead detection based on ICESat-2? Figure A3 shows huge differences in those spacings from different algorithms, especially over the west region. How does this affect the results in Figure 5b?
8. Figure 6: Where are the ‘plus’ symbols in the plot?
9. Equation (1): What do  $d\hat{x}$  and  $\hat{p}(\hat{x})d\hat{x}$  mean, and what is the temporal/spatial scale you used to derive the vertical roundness values?
10. Figure 7b: I’m curious about how to interpret the differences between the west and south regions in their features of vertical roundness.
11. Line 300: Which basin-scale are you referring to: the Weddell Sea or the Antarctic basin?
12. Figure A2: Should be “‘Freeboard height threshold at 1 cm’ and ‘Freeboard height threshold at 2 cm’.”

### Reference

- Horvat, C., Roach, L.A., Tilling, R., Bitz, C.M., Fox-Kemper, B., Guider, C., Hill, K., Ridout, A. and Shepherd, A., 2019. Estimating the sea ice floe size distribution using satellite altimetry: theory, climatology, and model comparison. *The Cryosphere*, 13(11), pp.2869-2885.
- Tilling, R., Ridout, A. and Shepherd, A., 2019. Assessing the impact of lead and floe sampling on Arctic sea ice thickness estimates from Envisat and CryoSat-2. *Journal of Geophysical Research: Oceans*, 124(11), pp.7473-7485.