

Response to Reviewers

Thank you to both reviewers who took the time to give feedback again. We appreciate the attention to the responses and edits. Below, we have responded to the additional comments.

Reviewer #1

I thank the authors for replying to my first review. However, I feel that some of the major concerns I raised were not addressed in enough detail.

For me, the main issue is still about the aim of the paper and what we actually learn from the study. In the response document, the authors write:

“the purpose of this study is to demonstrate the PM biases relative to the optical imagery sea ice concentration and to suggest that we may take advantage of ICESat-2’s narrow footprint to better resolve leads and reduce some uncertainty and biases of PM SIC in high ice concentration areas.”

But when I look at the results, it seems that the higher-resolution ASI product has a similar level of agreement with the optical imagery as the ATL07 product. Only the more theoretical “IS2 Best” case shows clearly better performance to ASI. Since this result is used to justify a Part 2 study that produces a full basin-scale SIC estimate using ATL07, I think this connection should be explained more clearly. My impression is still that ICESat-2 data could be useful for SIC, but only if the lead classification is more reliable. I feel this concern was dismissed too easily by saying that it is outside the focus of this paper. But in my opinion, it is important for the goals you are trying to achieve.

We acknowledge that improvements to the lead classification is important around line 270:

“Still, there remains substantial room for improvement in ATL07 surface classification - a further 60% improvement above the ATL07-based LIF is possible, to a “best” bias of just 1.0%, in these imagery. This “best” bias is determined by the correlation between IS2 ground tracks and the crack features of the sea ice. Although there may be a general correlation between lead geometries and IS2 ground tracks, we show in Horvat et al. (2024) that the expected value of this bias in the Arctic is effectively zero. Therefore, the difference between the “best” and the “ATL07” scenario indicate some error in either the drift correction or the ATL07 classification. Regardless, it is clear that improvements in ATL07 classification could lead to an IS2-based SIC product that improves substantially upon the error characteristics of PM-SIC data in high-concentration ice regimes.”

And we have added a sentence to acknowledge the relative accuracy of the ASI product in our examples and that LIF may not be an improvement in all scenarios.

The ASI 6.25 km resolution SIC performs similarly to ATL07 products in the four sample images (see Table 3). Although the LIF may not outperform all products in all scenarios, it provides a

new metric worthy of further consideration and comparison.

I also want to question the following point in the response:

“As a point of clarification on the ATL07 product, dark leads are no longer included in the sea surface height retrieval, but are still included as leads and thus fall in the category of open water in the LIF determination.”

After reading the ICESat-2 ATBD again, it seems these dark leads are only identified by the radiometric algorithm, and the ATL07 team no longer uses them to estimate sea surface height or freeboard. So I am not sure why they are used here. Also, the ssh_flag variable in ATL07 seems to be used to filter open water points based on height, why is that not used in this analysis? I think this could be explored, especially to see how it affects the LIF classification. This would be important to understand before moving on to the next part of the study.

That is correct that dark leads are identified through the ICESat-2 radiometric algorithm and are no longer used by the ATL07 team for sea surface height (SSH) or freeboard estimation due to known biases in their surface heights (Petty et al., 2021; ICESat-2 ATL07 Known Issues). It is not that they are not leads, but their heights are potentially biased due to the presence of clouds. Our analysis does not rely on these heights. Instead, we categorize segments as leads based on the ATL07 surface type classification, which still includes dark leads as “leads.”

The ICESat-2 SSH flag is specifically intended to select the highest-fidelity specular lead returns for accurate freeboard estimation, not for comprehensive identification of all open water areas. For our purposes, calculating LIF, excluding dark leads would systematically undercount leads and bias our LIF and sea ice concentration (SIC) estimates low. Our goal is to account for all leads as classified by ICESat-2, regardless of their suitability for SSH retrieval. However, in Part 2 of this two part paper series, we create a product that includes dark leads, and a product that does not include dark leads.

Reviewer #2

Thank you to the authors for their thorough consideration of my previous comments. I'm very happy to see this paper being published. I just have two minor points prior to that:

L230-232: With such a strong emphasis on the IS2 LIF being an independent measurement, the authors should finish this section by discussing how they would mask their data in the absence of any SIC data from PM. This is more important now than ever.

Conclusions: I'd also like to see the above point raised in the conclusion, with some clarification of how "independent" the product can truly be over lower concentration regions.

The ICESat-2 ATL07 mask based on sea ice concentration is applied in the ATL07 algorithm to reduce errors in the reference sea surface height that arise in low sea ice concentration regions. Near the ice edge, the sea surface can be strongly influenced by wave activity. This can result in reference heights being tens of centimeters below the local mean sea surface (ATBD), which

would bias freeboard estimates. For this study, we are not interested in the ATL07 freeboard height, just the characteristics that help define the surface type classification. Without the PM SIC mask, we would need to inspect whether wave influence affects the return characteristics used to determine surface type. However, we expect that even without this mask applied in the ICESat-2 ATL07 algorithm, the LIF product would be effective in regions of low sea ice concentration.