Full discussion: https://egusphere.copernicus.org/preprints/2024/egusphere-2024-1656/
Referee comments are in black
Authors responses are in blue, with proposed **new text** in bold

Author Response for Referee #2 (Anonymous)

Summary

This work makes a significant contribution to Arctic coastal erosion research, and particularly the use of ICESat-2 for coastal applications. The authors use annual PlanetScope imagery-derived shorelines (NDWI/Otsu) and ICESat-2 backshore and shoreline (manual) locations. Open water days, cumulative wave energy, and other environmental variables are brought in from ERA5 to better understand drivers of erosion. Fine-scale features are visible in the ICESat-2 photon data. A 10.7m/a shoreline erosion rate for Drew Point between 2019 and 2021 was reported, but also contextualized within recent decades of work, the outlier of the 2019 season, and local variability in shore classification. Slope measurements from ICESat-2 are discussed in the context of erosion rates/classifications from other sources.

The key contribution is the novel application of fine-grained photon-level analysis for coastal settings, especially as a complement to optical satellite imagery-based estimates of shoreline change. Importantly, the authors provide a thorough discussion of ICESat-2 uncertainty and leverage the repeating ground tracks in the Arctic for unique measurements of change from elevation profiles, comparing them to imagery-derived estimates. While Drew Point is an outlier for its high change rates, these same rates make it particularly valuable for honing satellite-based Arctic coastal change methods, and this work makes a notable contribution by focusing primarily on satellite data. Features observed in the ICESat-2 data are thoroughly explained and used to explain/compared to erosion rates. In terms of the applicability of ICESat-2 for shoreline monitoring, the upper shoreline is shown to better match the Planet-derived shoreline estimates.

We thank the reviewer for the detailed and constructive review. We've addressed specific comments below:

Section/Paragraph Level Response:

2.3 Overall, this section could benefit from at least some citing of the existing, and especially recent research into sub-pixel shoreline extraction from satellite imagery. I think this method is sound and the thresholds in the Appendix are acceptable, but there's enough variation in the literature I'm curious why you went with what you did. Perhaps existing tools like CoastSat do best with sandy beaches with no sea ice, and a simpler approach does fine here. Or perhaps existing tools were challenging to integrate with PlanetScope? Would this work for other locations along the Beaufort Sea Coast? In any case I think that's worth clarifying to future readers, even if this paper is focusing more on ICESat-2 than rehashing satellite shoreline methods, which is understandable.

We agree that discussion of the existing literature on shoreline extraction would be helpful here. We note that the existing classes used in CoastSat (sand, whitewater, other) may not work properly with images that include sea ice and sediment-rich water as observed here. Although CoastSat may be a good alternative for shoreline detection in this region, we have not tested it. Our ndwi-based thresholding is more straightforward to implement than CoastSat and performed well enough on our test images that there was no need to use CoastSat as an alternative method. We note that while our method worked well on our four images, it may in general be susceptible to blunders due to clouds, offshore sediment, sea ice, and near-shore water. Additional testing would need to be done before we would recommend using it for other locations along the Beaufort Sea coast. We have added the following text:

-L168: "**Historically, shoreline change has been estimated from satellites via manual delineation of the shoreline (Günther et al., 2015; Farquharson et al., 2018; Jones et al., 2009; Irrgang et al., 2018). Recent workflows such as CoastSat (Vos et al., 2019) have been developed to automatically detect the shorelines at sub-pixel resolution, but they have focused on lower-latitude beaches and may not perform well in Arctic regions where sea ice is present. Here, we implement our own shoreline detection method, following some of the same steps as Vos et al. (2019).**"

-**L173**: " **We found that calculating our threshold using all image pixels resulted in an adequate shoreline estimate for all four of our images, such that an initial identification of land and water pixels (as is done in Vos et al. (2019)) is not necessary.**"

2.3. I'm convinced by your argument of the North-South simplifying assumption for this study site. However, this is likely only generally applicable for Arctic coasts, and even then, I'm not sure if the associated uncertainty of this assumption would be a problem for anywhere rates of erosion are much lower than Drew Point. Maybe a sentence here or in the discussion better clarifying why you opted not to go with standard cross-shore transects, or whether this is a valid assumption for Beaufort coast locations other than Drew Point.
Shoreline change was calculated in the north-south direction for ease of computation, and because the majority of the shoreline is approximately east-west oriented, such that the north-south is approximately equal to the cross-shore direction. However, based on feedback from reviewers, we have decided to update our shoreline change estimates to be calculated in the local cross shore direction. Based on our estimates of the difference between shoreline change calculated in the north-south and local shore perpendicular direction (L188-195, Fig. A2), we expect the impacts on our reported results to be small. As a result of this change, we will remove L188-195 and Figure A2.

2.3.P4 More explanation is needed about how and why you used matplotlib contour.
We have updated this sentence to include what matplotlib contour does:

"We identified the sub-pixel land-water boundary from our NDWI images using **a marching squares algorithm** implemented in matplotlib contour in Python"

2.4.P2 (/Introduction) I agree the terrain heights provided by ATL08 are too coarse, but there are ground/vegetation classification data provided at photon resolution, and easily filterable using SlideRule. It's possible that these classifications are over-smoothing coastal features here and shouldn't be used but could be worth showing/saying so if that's the case.
While we agree that the ATL08 ground/vegetation classification may be useful for identifying signal photons, we expect that filtering photons the ATL08 ground classification would produce very similar results to using the ATL03 confidence scores as we did here.

Similarly, why or why not use quality_ph flags that come with ATL03 to filter afterpulsing, instead of manually applying a 0.8m cutoff?
Arndt and Fricker (2024, in review) found that the 0.45 m afterpulse (which is what we observe in Figure 7), is not reliably removed when filtering with the quality_ph flag. Thus, choosing a 0.8 m window (corresponding to 0.4 m above and below the surface) ensures that we are not including photons associated with the 0.45 m afterpulse. We have added Arndt and Fricker (2024, in review) as a reference in section 2.4 when discussing afterpulses:

Arndt, P. S. and Fricker, H. A.: A Framework for Automated Supraglacial Lake Detection and Depth Retrieval in ICESat-2 Photon Data Across the Greenland and Antarctic Ice Sheets, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2024-1156, 2024.

2.4.P2/P3. I am curious about whether signal_conf_ph > 3 is sufficiently including photons from the face of the bluff. I doubt this warrants anything like a new plot, but given the manual inspection/selection of the shoreline features, it makes sense to mention why that threshold was selected, even if cursorily. The custom ATL06 processing you use should help filter out most, if any errors a lower confidence threshold might introduce, while including more photons, potentially improving the accuracy of slope measurements.
While we agree that any analysis of coastal ATL03 data should consider lower-confidence photons, we found that there were very few photons with signal_conf_ph > 3 on the backshore, such that our threshold removes outlier photons without removing useful photons.

2.4.P4 It's not clear when the custom-ATL06 derived heights were used or when the photon data was used. It seems like the photon data was only used to generate the custom-ATL06 heights, and for the discussion of visible features, while the ATL06 derived-heights were used for the upper and lower shoreline detection. Maybe a small clarification here would help. Similarly, if you suspected the photon data was a toppled bluff, how should you address the manual classification of the beach/backshore?
We thank the reviewer for pointing this out, and have added the following sentences to clarify how the photon and custom ATL06 data was used:

-L206: "These photon data were plotted and inspected to provide a qualitative analysis of small-scale features."

-L222: "To estimate shoreline change **from our custom ICESat-2 elevation profiles...**"

Future work would benefit from removing photons that are thought to belong to toppled blocks prior to identifying the beach/backshore boundary.

2.4 Did you consider trying to classify the instantaneous waterline from the ICESat-2 profiles? Perhaps this was beyond the scope of the study, but it's not clear whether the waterline might be detectable from the ICESat-2 photon data. If only because the Planet shorelines are instantaneous waterlines, but the ICESat-2 shorelines technically aren't, I think it may be worth addressing.
This is partially addressed in L223-225:

"The presence of sea ice and snow in three of the ICESat-2 tracks prevents the accurate identification of a land-water boundary. Instead, we identified the boundaries of the backshore, defined here as the relatively steep region between the beach or ocean and the onshore region."

We have added the additional justification on L226:
"**Since beaches in this region are very narrow when present (Gibbs and Richmond, 2015), we expect the lower boundary from ICESat-2 to be similar to the land-water boundary**."

2.4 Please clarify if you are using strong beams, weak beams, or both.
We have updated Table 1 to indicate which acquisitions came from strong vs weak beams.

Figure 5. A 1:1 line would be helpful for comparison.
We will add a 1-1 line.

4.2.P1 It's great to see the incorporation of environmental variables along-side ICESat-2 and Planet-based erosion estimates, and the annual trends are clear. Are these valuable at a finer-scale, either temporally or spatially, for similar or other study areas? I was expecting there would be more analysis of these data compared to the shoreline change rates. For example, are storm events and their corresponding increases in erosion rates measurable within a season from some combination of Planet/ICESat-2? Any numbers regarding the temporal variability of erosion rates with respect to environmental variables might complement the existing paragraph well.
ERA-5 output is available at hourly time-intervals, but its low resolution (~30 km) prevents analysis of spatial variability in shoreline change rates. While it may be possible to examine sub-seasonal shoreline change with Planet imagery, cloud cover makes the amount of images per year highly variable. We chose to limit the temporal analysis of this study to annual intervals because that is the shortest interval that could be reliably measured by both Planet and ICESat-2.

Stylistic comments
The manuscript is well organized, edited, and the points to be made were clear. Figures are clear and well-designed. The following minor typos were found.

L72. Missing space after citation.
We have added a space.

L83. Missing space before citation.
We have added a space.

L155. Needs rephrasing.
We have removed "when retreat", which was a typo

L368. Shoreline misspelled.
We have corrected this typo

L404. Missing space before parenthesis.
We have added a space