

Author Response to RC1

General Response: We would like to thank the reviewer for their thoughtful and constructive comments. Here, we provide our responses to all comments, and we explain the revisions that we plan to make to the manuscript. One change that we plan to make that we would like to highlight, in response to comments from Reviewer 2, is that we are going to remove discussion of average glacier speeds. Instead, as suggested in the comments below, if the data is available, we will add a comparison of seasonal dynamic thickness changes to terminus position changes for seven glaciers, each one being representative of a particular seasonal dynamic thickness change pattern. We leave a more comprehensive comparison to future studies, once there is more data collected by ICESat-2 that can provide seasonal dynamic thickness change patterns for more outlet glaciers around Greenland.

Major Points:

1. My primary concern with the presented analysis is the use of the GIMP DEM as the reference surface. If I follow the methods correctly, the authors subtract the GIMP DEM from the ICESat-2 elevations so that the ICESat-2 elevations are effectively converted to anomalies and slope effects are removed. Why use the GIMP DEM which, as the authors state, represents the mean ice sheet surface from 2003-2009? The ice sheet has evolved considerably since that time and the ArcticDEM should be more accurate and closer in time to the ICESat-2 observations. Thus, if the ArcticDEM is used as a reference, the vertical offsets due to imprecise repeats over a sloping surface should be more accurately removed from the analysis.

Author Response: We agree with this change and we have changed our reference DEM from GIMP to ArcticDEM. The reviewer is correct in that this change will allow for a better representation of the current ice sheet, and the error on each seasonal dynamic thickness change measurement in the plots (Figure 1, Supplementary Material Figures) decreased for many glaciers. Using ArcticDEM also allowed for the analysis of three new glaciers, Kakivfaat Sermiat (27), Alison Gletsjer (35), and Midgard Gletsjer (173) because the dynamic seasonal thickness change for these glaciers now falls within the 50m threshold that we used to discard bad data (this threshold was previously 25m but has been increased, based on a comment from Reviewer 2).

2. I appreciate the transparency in the process by which the glaciers were selected, but I find it curious that the glaciers were selected in part based on their inclusion in the CALFIN detailed terminus position dataset yet these data were not included in the analysis. Why were the CALFIN data not included in the analysis? The authors state that the inclusion of terminus position time series in such an analysis would be beneficial and it seems as though those data are available, but simply not included here. I do not think a detailed inter-comparison is necessary but it would be helpful to know if seasonal patterns in terminus position and thickness are correlated. The preliminary analysis could focus on centerline terminus change and could aggregate the changes across all glaciers to determine if there is any hint of a relationship between the variables. A more detailed analysis could then be presented in another paper.

Author Response: As stated by the reviewer, a comprehensive comparison between terminus changes and thickness changes would be a better fit in a future study. Part of our reasoning for not including a comparison between our results and the CALFIN dataset is that there is limited overlap between ICESat-2 seasonal thickness change patterns and CALFIN, which currently provides data through mid-2019. In the future, as additional ICESat-2 is available to characterize seasonal thickness change patterns for more outlet glaciers around the ice sheet, a more in-depth study could be conducted.

However, we agree that a qualitative discussion of seasonal centerline terminus changes would fit well within this paper. To address this, we will add time series of the centerline position change for one glacier from each of our characterized patterns to qualitatively investigate the relationship. Using these data, we will discuss the magnitude and timing of terminus change in comparison to dynamic thickness change. Currently, we are investigating new data from a recent paper (Goliber, et al., 2021) released after we had submitted our manuscript. While this TermPicks dataset, which combines the CALFIN data with many other sources of terminus positions, also does not provide sufficient temporal overlap with our results to compare with our seasonal thickness changes, it is our hope that the creators of CALFIN or TermPicks can provide us with additional data to extend the terminus position time series past mid-2019.

Reference:

Goliber, S., Black, T., Catania, G., Lea, J. M., Olsen, H., Cheng, D., Bevan, S., Bjørk, A., Bunce, C., Brough, S., Carr, J. R., Cowton, T., Gardner, A., Fahrner, D., Hill, E., Joughin, I., Korsgaard, N., Luckman, A., Moon, T., Murray, T., Sole, A., Wood, M., and Zhang, E.: TermPicks: A century of Greenland glacier terminus data for use in machine learning applications, *The Cryosphere Discuss.* [preprint], <https://doi.org/10.5194/tc-2021-311>, in review, 2021.

Minor Points:

- line 63: Are the units on discharge correct? Normally discharge refers to mass or volume per unit time, not a unit of length per unit time.

Author Response: We will replace “discharge” with “velocity”. This was a typo.

- line 84: Instead of “vertical component of surface elevation change”, I recommend “vertical component of surface elevation differences” since the word change has the connotation of differences over time and the removal of slope effects is meant to isolate the vertical component of the full difference (both due to spatial offsets and temporal changes) in surface elevation observations.

Author Response: We will make this change.

- line 94: Add a space between numbers and units (“25 m”).

Author Response: We will make this change.

- lines 118-122: No statistical seasonal change is the first in the long list of categories and is also listed in the following sentence.

Author Response: We will change the wording to ensure this is clearer and avoid repetition.

- lines 160-171: I recommend renaming “medium-fast speed” and “medium-slow” to “moderately fast” and “moderately slow”.

Author Response: We will make this change.

- lines 196-202: It is worth noting in this section that the variability can be driven by atmospheric forcing even if the variability is unlikely to be directly driven by variations in surface mass balance. The authors point out that the geometry of fjords may be incredibly important in regard to the access of warm waters to glacier termini, but the underlying topography of the glacier may also influence the dynamic response of the glacier to changes in meltwater fluxes and/or driving stresses driven by atmospheric change.

Author Response: We agree with the reviewer and we will clarify the statement that, alongside fjord geometry, subglacial bed topography also plays an important role in how glaciers respond to atmospheric forcing (via changes to surface melt and driving stress).