

## Response to Reviewers' Comments

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*Wintertime Evolution of Landfast Ice Stability in Alaska from InSAR*

by Andrew Einhorn and Andrew Mahoney

### **Overview**

Below, we provide our responses explaining how we have addressed each of the reviewers' comments. For clarity and ease of reference, we have broken some comments into individual points. Our responses to all comments are highlighted in blue. Descriptive comments that we feel did not include specific points that required addressing are italicized in grey text.

### **Reviewer #1 comments**

*I believe the authors have sufficiently addressed most of the concerns of the reviewers, and may be suitable for publication after additional modifications.*

*There is one major issue I see, that was commented upon by reviewer #1 in the original manuscript that while clarified, I feel should be further addressed before publication.*

### **Major points**

For the apparent strain threshold for sheltered and not sheltered ice. I am not convinced the Otsu's method is appropriate in this case. Otsu's method is often used to distinguish between background and foreground in an image. As such the assumption is there are two distinct classes that can meaningfully be separated. I do not think this is an analogous situation, as I am not convinced that "stabilized" vs "not-stabilized" is a binary distinction. It is also not clear that a distinct threshold for SHLFI and NSHLFI is justified, as there is considerable overlap between the distribution (they do appear statistically distinct, which perhaps be confirmed). However, because of the shape of the distributions (more on this below), it is not clear that another method would necessarily be better if the goal is to divide into distinct classes. So I suggest that you provide more discussion of this choice of method and the physical significance of the distinction between classes.

Thank you for your careful review of the method which we employed to determine the thresholds for each stability class. We found Otsu's method to be an appropriate method for determining the apparent strain thresholds for the Bottomfast, Sheltered, and Not Sheltered. We performed Otsu's method on each distribution, represented by the vertical dashed lines in Figure 8. We believe that the not sheltered class contains landfast ice which is both shoreward and seaward of a grounded feature. This results in the distribution of the not sheltered landfast ice with apparent strain values corresponding to stabilized and not stabilized classes. In other words, the landfast ice within the not sheltered area displayed in Figure 2 is composed of both the stabilized and not stabilized classes but we cannot delineate them since we do not know the location of grounded ridges. The similarities of the distributions between sheltered and not sheltered in Figure 8 reinforces the idea there is landfast ice within the not sheltered area which is stabilized.

This is why we used Otsu's method on the not sheltered distribution to establish the apparent strain threshold which represents the upper bound of the stabilized class and the bottom bound of the not

stabilized. Similarly, the bottomfast apparent strain threshold was determined under similar assumption, that not all landfast ice in the bottomfast ice area was bottomfast. Thus, we used Otsu's method to delineate the bottomfast from everything else.

We will reenforce these concepts in the text which justify using Otsu's method for determining the apparent strain thresholds for each class.

The distribution of apparent strains do not provide a clear rationale for dividing into two distinct classes. It appears that the choice to do so is based on the prior work of Dammann, who did so. I presume this was done because qualitatively, the two classes indeed look distinct from the interferograms. But the apparent strain distribution does not suggest this is strictly true. I acknowledge the results in figure 9 look encouraging. This may be because the change in phase gradient and coherence is most rapid above this threshold and happens rather sharply spatially. So, I suggest there be more discussion of the choice of threshold and its impact. What would be valuable is a quantitative assessment of the sensitivity of the spatial extent of the stabilized ice to the value of this threshold. This could satisfy the reader that the choice is physically reasonable.

The reviewer is correct that the choice of 3 stability classes was based on the work of Dammann et al. (2019). We believe the way we define the regions and the assumptions represent landfast ice which different physical processes affect stability resulting in different apparent strain values for each class. Bottomfast ice should deform very little as it is in contact with the sea floor and unresponsive to waves and tides. The stabilized class is defined by an offshore grounded feature (bottomfast ice in contact with a barrier island or a grounded ridge). The presence of these offshore stabilizing points contains the degrees of freedom which the landfast ice can deform. Without these offshore grounded features (not stabilized), the landfast ice can sway, yaw, and pivot in response to winds, waves, and currents. The load of stress can also be transferred, at least partially, to the grounded features. This process can be visualized in Figure 11C where the areas we identified as grounded ridges have high apparent strain with low apparent strain values directly shoreward of each grounded ridge.

One question that is never addressed is the physical meaning of stabilized vs non-stabilized granted, there is discussion of where one versus the other may be found and speculation as to why, but it would be better if there was a dedicated discussion of this .

Similar to how Dammann et al. (2019) defined a Landfast ice regime associated with each stability zone, we have now added a description of the landfast ice and the stability regime associated with each of our stability classes. Specifically referencing the proximity to a point feature (grounded ridge or barrier island).

Is the transition indeed rapid spatially? Or is the definition more arbitrary. The former makes some sense to me. I think some discussion of this could help address the concerns noted above.

The transition from stabilized to not stabilized is a spatially rapid transition. We will add text specifically referring to Figure 11 where the apparent strain along a transect is plotted. Specifically, the 2022 example, offshore of the localized low apparent strain associated with the last grounded ridge the apparent strain is within the not stabilized threshold. It maintains these high values until near the edge of the landfast ice.

#### **Minor points:**

A few minor issues to address are listed below

There are numerous typographic errors throughout the document. I have listed just a few of the ones I saw in the first few pages, but please look carefully through the doc as there are more. Line numbers refer to those in the tracked changes document

Line 41 - "landfast ice, and not mobile pack ice, between..."

Fixed

Line 44 – extra "the"

Fixed

Line 59 – extra "the"

Line 60 – extra "in the"

Fixed

Line 67 – "represented"

Deleted the ed

Line 69 – "resulting"

Added ing

Line 94 – what is meant by "?"

Line 96 – "programmability"???

Implying the differences between people's subjective definition instead of this word

Line 97 – "define"

Line 101 – "to", not "too"

Fixed

Line 131 – "were" missing?

The map figures have different lat-lon bounds. It is clear to me that the reason is to highlight more detail in figure 2 versus most of the others. But it is different than figure 9. Since a reviewer requested consistency, please provide a justification for the differences in your response.

The inset in Figures 5/6 and 9 highlight different features and provide greater detail for these features. The reason figures 2 and 9 focus on the Beaufort coast since this is the location which was used to define the apparent strain thresholds. Showing the entire study region in Figure 1 and 5/6 highlights that the method works for the whole study region. We will ensure the extent of map figures is consistent, but we see a need to focus on the Beaufort coastline when discussing the apparent strain thresholding and classification.

Line 296 – by my eye, the distributions resemble lognormal distributions more than normal distributions. It's not so important for this study, since you don't infer anything from that, but it makes some intuitive sense that the distribution should be more lognormal (or some other right-skewed distribution).

We have added some text discussing the distributions of monthly apparent strain values and their right-skewed distributions not normally distributed.

Reviewer #1 suggested examining thickening of ice as a cause of the reduction in apparent strain. In response, you suggested you would examine this by looking at a simple ice thickening model, but you did not do so in the end. I also note that the decrease in apparent strain seems to be stronger later in the season, and I am not even sure monotonic is the best way to describe it. So I wonder if it is not thickening so much (that may play a role), but more a seasonal change in forcing. For example, the apparent strain decreases strongly in spring in some cases when the ice likely has already reached maximum thickness. It would be good to add some further discussion of this and respond to the reviewer's suggestion (not necessarily performing the suggested analysis).

We agree that the term monotonic when referring to the overall distributions of the apparent strain is not accurate. However, we specifically refer to the modal apparent strain values. In the study region we the modal apparent strain values do decrease from December through May, never increasing. This was the concept we were trying to highlight with the phrase monotonically decreasing. We have rephrased it to be clear what variable we are referring to and how that variable changes between months. In addition, we connected the relationship between apparent strain and stability.

Line 375 – is it possible that the stability increases because ice shoreward becomes more stable as it is further from the action of the pack as the extent of the fast ice increases? This should be apparent from maps of the distribution of apparent strain over time.

We have had similar discussions and concluded that the presence of grounded features likely has more effect on the stability of the landfast ice than the amount of landfast ice between a specific piece of landfast ice and the landfast ice edge. While ridging does occur at the landfast ice edge due to interactions with the pack there are more processes which affect the landfast ice stability. To test how the width of landfast ice modulates the apparent strain induced by pack ice interactions we would need to identify the point where the grounded features have a minimal impact on the stability of the landfast ice (i.e., the Not Stabilized stability class).

We agree that at the landfast ice edge, where the pack ice interaction occurs, we would expect to see high apparent strain. It is also possible at the landfast ice edge a loss of coherence occurs due to extreme deformation thus resulting in no measurement of apparent strain. We added some discussion referring to high deformation at the ice edge reducing coherence resulting in an under representation of the landfast ice extent.

**Other:**

Please ensure that the colour schemes used in your maps and charts allow readers with colour vision deficiencies to correctly interpret your findings. Please check your figures using the Coblis – Color Blindness Simulator (<https://www.color-blindness.com/coblis-color-blindness-simulator/>) and revise the colour schemes accordingly. > figures 7+10 The material in the supplement file has an appendix numbering (A1, A2, etc.) but must have a supplement numbering. Please see "Supplements" at <https://www.the-cryosphere.net/submission.html#assets> and number the sections with "S1", "S2", etc., the figures must be numbered as "Figure S1", "Figure S2", "Figure S3", the tables must be numbered as "Table S1" and "Table S2". Please also adjust any references to this material in the main manuscript text.

Figures 7 and 10 have been redone to use colorblind friendly color pallets and have been tested using the link provided. The appendix formatting is now supplement formatting.