Reviewer 2 **Comments to the Author**

General

The article presents a novel quantitative method for identifying stable regions of landfast sea ice and provides an empirical differentiation of bottom fast, stable, and unstable fast ice using Interferometric Synthetic Aperture Radar (InSAR). Landfast sea ice is the immobile ice that is anchored to the land. In the Arctic during winter, this ice connects coastal communities. The authors utilise coherence and the phase gradient of various InSAR pairs over the Chukchi and Beaufort Seas in the Arctic. Their research encompasses data gathered from 2017 to 2021, specifically during the winter months when the sea ice forms.

The article highlights two main points: First, it delineates the width of landfast sea ice areas based on the coherence of the InSAR pairs. While this concept is not entirely new, the novelty lies in the comparison with a new dataset to benchmark the results. Second, the authors employ the phase gradient of the interferometric signal to assess the stability of landfast sea ice, focusing on the apparent strain in the satellite's line of sight.

The most significant finding of the study is the differentiation of bottom fast, stable, and unstable landfast sea ice through InSAR apparent strain, along with the mapping of its evolution over time and space. Overall, this article advances the interpretation and analysis of landfast sea ice using radar remote sensing techniques.

This article is interesting, well-written, and clear. It enhances our understanding of the stability of landfast sea ice and offers an alternative perspective on its progression throughout the season. It would be intriguing to explore whether this methodology could be applied in other regions and if varying viewing angles could provide additional insights into sea ice deformation.

Comments regarding the overall text

Overall, this is an interesting article that deserves to be published. However, a few issues need to be addressed before it is ready for publication.

All figures, except for Figure 11, have been utilised in Mahoney et al. (2024), which is a report to the US Bureau of Ocean Energy Management. Since this report is not a peer-reviewed paper, it presents a missed opportunity to provide a more in-depth explanation of the EM2024 methodology. This could be accomplished by either enhancing the text in section 2.2 or including it as supplementary material. The EM2024 dataset and its methodology could greatly benefit the scientific community studying Arctic regions.
The EM2024 dataset, creation and analysis, is more thoroughly described in a "The Evolving Decline of Landfast Sea Ice in Northern Alaska and Adjacent Waters: from an Updated Climatology" by the same authors of this study. At the time of submission, the paper detailing the EM2024 dataset had not been submitted and was not citable. Since then, the paper has been submitted and is under review.

The article presents solid results that are compared to other datasets. However, comparing these datasets quantitatively and statistically, when possible, would be beneficial. For instance, how do the EM2024 and InSAR-based datasets differ in terms of distance or area?

What are the percentage differences, and how do these differences evolve throughout the seasons? Are these two datasets statistically comparable? While they likely are, providing these numbers would strengthen the case for using one or the other to define the Landfast sea-ice area in the future. The same applies to the areas of bottom fast, stable, and unstable fast ice when comparing apparent strain rates to those reported by Dammann et al. (2019) in Figure 9. Although comparisons are made and conclusions drawn, statistical values are lacking. Presenting these numbers would reinforce the argument for using relative strains rather than solely relying on the InSAR fringe approach. For example, in section 4.3, the first statement claims that the apparent strain thresholds align well with those of Dammann et al. (2019). Please include a statistical comparison to support this. Additionally, it would be interesting to explore the quantitative behaviour of stabilised versus sheltered and non-sheltered areas; a simple table could help visualise this information.
In response to this comment, we can add a more qualitative analysis of the difference between the EM2024 dataset and the InSAR-derived fast ice. Instead of using area we will opt to use the fast ice extent, defined as the distance along coast-normal vectors.

The idea to do a similar analysis for the bottomfast, stabilize, and not stabilized fast ice classes is a great idea. We will attempt to implement some qualitative analysis describing the evolution of the amount of each stability class of landfast ice exists from each SAR pair.

We plan to create a confusion matrix which will compare the classes defined by Dammann et al. (2019) and our stability classes on a pixel-by-pixel basis.

Finally, comparing the apparent strain data with a bathymetry map of the region would be valuable.
We can include some analysis analyzing the apparent strain values in each 10 m isobath. We would expect fast ice in waters deeper than 20 m will be classified as not stabilized as grounded ridges typically do not form deeper than 20 m (Mahoney et al. 2007).

Comments on the methods:
The data section states that 14 reference scenes were used to derive the data. Was there an effort to utilize different SAR geometries (ascending and descending paths) over the same area to compare the relative strain results? What criteria were used to select those 14 IW reference scenes? Were they chosen solely for their coverage, or was there prior knowledge about the area involved.
The 14 reference scenes were chosen purely for their coverage of the study area. Through the Alaska Satellite Facility Vertex Portal, we designated criteria including the temporal baseline, IW mode, and spatial baseline and were presented with references scenes where we could choose pairs of SAR acquisitions to process using the HyP3 algorithm. We will add a figure which depicts the reference scene coverage in the supplementary material.

For instance, could the different regional behaviors observed in Figure 10 be partially attributed to the geometry of the scenes? Would it be more effective to identify the optimal line of sight (LOS) for assessing the stability of landfast sea ice?
We acknowledge that the acquisition geometry can influence the direction of motion that InSAR is sensitive too. In our study, we did not explicitly control ascending vs descending orbits. However, we believe that we cannot assume all surface motion occurs in the same direction with

respect to the coastline. This assumption is what led to the creation of the term apparent strain where we recognize the strain, we are measuring is the minimum amount of strain that has occurred over the 12-day period. InSAR is not sensitive to along-track deformation which for both ascending and descending orbits is approximately north-south.

If we were to assume all surface motion happens in a perpendicular direction to the coastline, compression or expansion, then we would not be able to resolve the deformation for the subregions with predominantly north or south aspect. We assume the deformation is occurring in all directions including vertical.

Comments on figures:
In general, the figures are well done and have all the necessary components. However, for someone unfamiliar with the area, it takes some time to orient themselves between the figures and the corresponding names.
We will make efforts to better orient readers to the study area. We will add inset maps to certain figures and labels of villages and some geographic features.

Figure 1 - Since this is the first figure and shows the study area, it would be helpful to add a rectangle that outlines the area related to Figure 2. This can be done with a dashed line to avoid interfering with the other information displayed in the figure. The caption should clearly state that the different shades of blue represent various contiguous areas as defined in the figure. Additionally, instead of "coast vectors," I recommend using "coast normal vectors."
We will improve this figure in multiple ways. Instead of having the coast normal vectors colors in alternating shaded of blue and cyan to differentiate each subregion from the adjacent ones we will adopt a color scheme that has a unique color associated with each subregion. We also plan to adopt the term coast normal vectors for this figure and in text.
We also plan to use this figure as a general orientation for other figures by including dashed lines indicating the boundaries of other figures and how they fit into the study region.

Figure 2 - Is "Utqiagvik" the same as "Point Barrow"? Utqiagvik is not mentioned in the text, so it would be better to remain consistent with "Point Barrow." This figure illustrates the masks used to define the different landfast sea ice areas, which should be stated in the caption. It is important to geo-reference this area with the larger study region. One way to do this is to add a rectangle in Figure 1 that overlaps the same area, and the other option is to include an inset that showcases the larger region alongside the example area.
Utqiagvik is the traditional name of the village formally known as Barrow. We will include text to differentiate Utqiagvik (Barrow) and Point Barrow. We will orient readers within the study region by including a dashed line within Figure 1. We will also update the caption to describe what these regions are used for and ensure that the text describes how and why these regions were defined.

Figure 3 - Please add reference names such as Chukchi Sea, Beaufort Sea, Point Barrow, Prudhoe Bay, Kotzebue Sound, and/or others.
We will add geographical markers such as villages or named coastal features to orient the readers.

Figure 4 - "Kotzebue Sound" appears twice on the x-axis, which seems like a typo. If

intentional, it should be defined differently (e.g., "Kotzebue 2") and indicated on the map in Figure 3 or 1.
Figure 4 is going to be reorganized, and the x-axis labels will be associated with the subregion names instead of villages.

Figure 5 and 6 - Add a star or another marker to show where the transect in Figure 11 is located. In the caption for Figure 11, only the area near Prudhoe Bay is mentioned. Please clarify what the dashed oval in Figure 6b represents. Is that "Elson Lagoon," as referred to in line 630?
We will add geographic markers to these figures to orient the reader. We will opt to add an inset map to Figure 11 to indicate where in the study region the transect is located.

Figures 7 and 8 - Are the y-axes in Figures 7 and 8 the same in terms of percentages? It is unclear whether they represent distributions of the same total. Would it be possible to plot the total distribution of landfast sea ice for April (as shown in Figure 7) in a light color or with 50% transparency in the background of Figure 8? This would help illustrate the 10th and 90th percentiles, that comes from April overall data, correct?
Figures 7 and 8 have different bin sizes where Figure 8 has 10 times the number of bins. We found that using the same number of bins as Figure 8 in Figure 7 cluttered the figure. We also found that including grouping the distribution in Figure 8 into the smaller bins has value.

We are planning on adding the total distribution for the Beaufort region during April to Figure 8.

Figure 9 - It is unclear whether the apparent strain values used in this figure are derived from April 2017 data or represent an average of April data from all years, as seen in Figure 8. Please clarify in the caption.
Thank you for pointing out the need for improved clarity with Figure 9. Figure 9 is meant to provide a visual comparison of the spatial extent of the stability regions defined by Dammann et al. (2019) vs the quantitative defined regions on the same SAR pairs. To provide improved clarity we will add the dates of the SAR pair acquisitions and the spatial extent for each of these SAR pairs. The SAR pairs are not all from the same dates, thus we generalized the SAR pairs as having occurred during April of 2017.

Figure 11 - The transect used in this figure could be added to Figure 9 to provide a spatial understanding of its location.
To orient the readers within Figure 11 we are going to add inset maps of Alaska with boxes indicating where the transect is located. We believe adding the transect location onto Figures 5,6, or 9 would be misleading as the transect does not use the apparent strain maps depicted in those figures.

In-text comments:
Overall, the article is well written, and I have only a few minor comments:

Throughout the text, "Landfast sea-ice" is referred to either as "Landfast sea-ice" or "Landfast Ice." I recommend using "Landfast sea-ice" consistently or, after the first introduction, switching to "fast-ice," with a phrasing such as: "hereafter referred to as fast-ice.

We will use the consistent term of either fast ice or fast-ice when refereeing to landfast ice within the text.

Line 89 - Please provide examples of processes that could reduce coherence, such as snowfall, surface reworking by wind, or melting.

We will include other examples of processes which reduce coherence not associated with sea ice drift.

Line 102 - The assumption that variation of the phase gradient in LOS dominate the surface motion is key for the developed of the apparent strain methodology. However, I am not completely sure if this can be said so bluntly, a more extensive explanation is needed here. Please rephrase this sentence, talk about the importance of the relative surface motion of landfast sea-ice and explain how this relative measurement can be a pertinent way of defining stability in Landfast sea-ice.

We apricate the reviewer's suggestion to clarify a key assumption of our methodology. We will rephrase the original sentence and add additional text to enhance clarity. The Line-of Sight-phase is directly proportional to the amount of line-of-sight strain which has occurred between the satellite acquisitions. For a medium such as landfast ice the relative motion (i.e. the differential displacement between neighboring areas) is indicative of mechanical instability and strength. For example, if the surface of one area of fast ice is moving differently than an adjacent this will result in internal strain and produce cracks potentially causing detachment of the fast ice. The build up of internal strain and creation of cracks resulting in detachment are all signs of instability and unsafe fast ice.

Line 130 - Please rewrite, the last part of the sentence, "...bottomfast ice will be found in waters up to approximately 1.5 m deep", to something like "..bottomfast ice is normally found…"

We will rewrite the sentence to "This depends on the ice thickness (or, more precisely, the draft of the ice), but in our study region bottomfast ice is normally found in waters shallower than 1.5 m (Pratt 2022)."

Line 131 - Please add the citation (Dammann et al., 2019) to the sentence that defines bottomfast sea-ice mapping from InSAR fringes.

We will add the citation to this sentence

Line 155 - Please check that the sentence is correct, "from these" looks out of place.

Thank you for pointing this out. This is a mistake made by the authors. "from these" will be removed.

Line 239 - The word "the" is repeated after "average".

This is a typo. Thank you for making the authors aware of this mistake.

Line 242 - Add Point Barrow and Katkovik to Figure 3 and reference here. This applies to other significant areas mentioned in this section as well.

We will add annotation to Figure 3 which highlights the area mentioned in addition to geographic markers within Figure 3.

Line 268 - Change “.. in May in..” for “...in May is…”
We appreciate your diligence and catching our grammatical mistakes.