Wintertime Evolution of Landfast Ice Stability in Alaska from InSAR
Author(s): Andrew Harrison Einhorn and Andrew Richard Mahoney
Egusphere-2025-567

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 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.

Finally, comparing the apparent strain data with a bathymetry map of the region would be valuable.

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?

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?

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.

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."

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.

Figure 3 - Please add reference names such as Chukchi Sea, Beaufort Sea, Point Barrow, Prudhoe Bay, Kotzebue Sound, and/or others.

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 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?

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?

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.

Figure 11 - The transect used in this figure could be added to Figure 9 to provide a spatial understanding of its location.

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.

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

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.

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…”

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

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

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

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.

Line 268 - Change “.. in May in..” for “...in May is…”