**Virtual radar ice buoys – a method for measuring fine-scale dynamic properties of sea ice**

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**Review by Andy Mahoney**

## Summary

This manuscript presents preliminary results of a feature-tracking algorithm applied to surface-based radar imagery of sea ice. The high temporal resolution and weather independence of radar makes ship-mounted and coastal systems ideal instruments for operational monitoring of sea ice as well as the study of small-scale ice dynamics. The results described by the author are highly promising and personally I am very pleased to see them, but I feel the value of the work (and its suitability for publication in The Cryosphere) would be greatly improved with an expanded, quantitative discussion of the observed ice kinematics. The results illustrated in the generally well-produced figures indicate the potential to derive some geophysically interesting analysis of small-scale ice kinematics, but unfortunately I feel the discussion of ice motion and deformation observed in each of the test cases is too brief and qualitative. In my opinion, the quantification of small-scale ice motion represents the primary scientific contribution of this work and without such I agree with the first reviewer that this manuscript may be more suitable for a technical journal like one of the IEEE publications. I also feel the author may be overstating the novelty of the approach and appears to be overlooking a quite extensive body of literature regarding the use of coastal radar to monitor ice dynamics in Barrow, Alaska.

## Major comments

### 1. Missing details regarding radar system and data acquisition approach

I for one would be interested to know the make and model of the radars used in this study and how the imagery were acquired in the form used for analysis. This information is also a consideration for reproducibility

- Was the imagery reproduced from the raw video signal, or did the authors use some kind of screenshot of the radar display?
- In section 4.1, the author refers to 8-bit imagery. Is this the full bit depth of the raw data, or was the dynamic range of the data reduced for analysis?
- Was any additional hardware necessary to obtain the imagery?

### 2. Missing references to and discussion of other relevant literature

The authors make reference to one paper discussing the tracking of ice using land-based radar in Barrow, Alaska (cited at Rohith *et al*., 2013, but should be MV *et al.*, 2013; please see my minor comment below) but they miss a much broader body of relevant work extending back to the 1970s [e.g., *Shapiro*, 1975; *Shapiro and Metzner*, 1989; *Mahoney et al.*, 2007; *Druckenmiller et al.*, 2009; *Jones*, 2013; *Mahoney et al.*, 2015].

The two most recent of these are probably the most relevant as they use the methodology described by MV *et al.*, which has notable similarities to the approach described in this manuscript. Jones (2013) presents an analysis of landfast ice deformation observed by coastal radar in the context of landfast ice stability, while Mahoney et al (2015) include a discussion of errors and a comparison with independent observations of ice motion.

**3. Sensitivity / limitations of VB identification and tracking**

The text states that the number of VBs populated in any image sequence can be controlled by the search radius parameter, $R_s$, but I feel it would be helpful to have some discussion of the limitations of the number of VBs that can be identified and tracked. This important for any subsequent analysis of ice kinematics as it controls the effective spatial resolution with which the ice velocity can be resolved. It would also be important to discuss other factors (such as image quality and atmospheric noise/artifacts) that control the number of VBs can be tracked. In particular, can the author use information from cases where the correlation of a VB was lost to better understand trackability of ice features?

**4. Expanded discussion of results required**

The discussion of ice motion in each of the test cases is highly descriptive. The ice drift data shown in the figures ought to allow the calculation of range of drift statistics such as acceleration, divergence/shear, rotation, dispersion, correlation length, etc, but instead the text contains only highly qualitative descriptions of the ice motion such as "very slow" and "rather coherently". Tantalizingly, the author states that acceleration could be calculated "if necessary", but I was disappointed to see that it was not deemed to be so. Figures 10 and 14 provide timeseries of estimated divergence derived from triplets of VBs, but there is only minimal discussion of these results and Figure 10 is not actually cross-referenced in the main text. Moreover, understanding and quantification of errors becomes increasingly important when calculating differential motion and without any such analysis it is difficult to assign significance to these results.

**Minor comments**

- in typical usage, "landfast" is a single word. Please correct throughout

p 4703, line 15: Please correct "Barrow Sea" to read "the Chukchi Sea near Barrow, Alaska"

p 4703, line 17: Rohith is the first name of the first author of this paper. For publication, his last name is abbreviated to MV, so this citation should be (MV *et al*., 2013). Please also correct the full citation in the reference list.

p 4703, line 15-17: I think this section of text could be rephrased to make it clearer to the reader that it was MV et al. who examined radar data in Barrow. To the casual reader, it might appear that Lucas and Kanade did this work.

p 4712 line 19: please correct "floats" to "floes"

**References**


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Mahoney, A., H. Eicken, and L. Shapiro (2007), How fast is landfast sea ice? A study of the attachment and detachment of nearshore ice at Barrow, Alaska, *Cold Regions Science and Technology*, *47*(3), 233-255.

Mahoney, A. R., H. Eicken, Y. Fukamachi, K. I. Ohshima, D. Simizu, C. Kambhamettu, R. MV, S. Hendricks, and J. Jones (2015), Taking a look at both sides of the ice: comparison of ice thickness and drift speed as observed from moored, airborne and shore-based instruments near Barrow, Alaska, *Annals of Glaciology*, *56*(69), 363.

Shapiro, L. H. (1975), A preliminary study of ridging in landfast ice at Barrow, Alaska, using radar data, paper presented at 3rd International Conference on Port and Ocean Engineering under Arctic Conditions (POAC), University of Alaska, Fairbanks, Alaska, 1975.

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