Dear Dr. Brucker,

We have responded to all the comments/suggestions provided by Reviewer #1 and Reviewer #3. We implemented almost all the suggestions from both Reviewers. In fact, Reviewer #3 had some excellent points that in our opinion significantly improved the manuscript.

Summary of changes:

- Removed Table 2
- Added text and new Figure (Fig. 12) concerning image sampling and high resolution time series construction in Section 4
- Added more text and additional references concerning uncertainty in Section 5

Steve, Alex, and Mike

**Reviewer #1**
The manuscript and, more importantly, the dataset have been significantly improved. The authors generated a new sea ice motion product at higher temporal and spatial resolution and extended the temporal coverage until October 2021. The manuscript now clearly presents the potential users of the product and the scope of its application. The decision for selecting spatial and temporal resolutions and not mixing S1 and RCN imagery is now clearly justified. The high-quality maps of SIM at lower and higher resolution show the advantages of the proposed new dataset. The methodology for uncertainty computation was simplified and made more robust and versatile. Accuracy of the S1+RCM SIM product is computed by validating against IABP buoys and pixel-by-pixel comparison with NSIDC and OSI-SAF
products. The manuscript consistently documents the ECCC automated sea ice tracking system and the generated sea ice motion product and as such can be recommended for publication after a minor revision.

**Howell et al.**
We thank the Reviewer for their comments, which have improved the manuscript considerably.

**Reviewer #1**
Minor comments
Table 2 seems to provide too many numbers that are not very relevant for most readers. I would suggest, first, to replace the absolute number of grid cells with a number relative to ice covered cells, or at least to provide the average number of ice-covered cells for the lowand high resolution products. Second, as seasonality seem to repeat in 2020 and 2021, the number of cells can be averaged for each month, or even each season. Thus, the table can contain just 8 numbers: relative coverage by the low- and high- resolution product in winter,
spring, summer, and autumn.

**Howell et al.**
We just decided to remove Table 2. Reviewer #3 pointed out they did not find it useful either.

**Reviewer #1**
Technical comments

L107. ECCC-ASITS is spelled as ECCC-ASTIS in several places.
L167: between images pairs
L221: What is the average number of grid cells for the high-resolution product? What is the average number of grid cells covered by sea ice?
L222: are is shown
L223: “especially, during” – the comma doesn’t seem to be needed here
L275: “because of its narrow”
L278: “increased

**Howell et al.**
Re: average number of grid cells → This information is contained in the each product.
All the other comments have been addressed.

**Reviewer #3**
First, I apologize to the authors and editors for being so tardy in my review.

Review, Howell et al, Generating large-scale sea ice motion from Sentinel-1 and the RADARSAT Constellation Mission using the Environment and Climate Change Canada automated sea ice tracking system, Cryosphere tc-2021-223

This is a good summary of the SAR-derived ice motion product using two different C-band SAR sensors on 5 different platforms. I reviewed the revision made after comments provided by Reviewers 1 and 2 but I did not read the reviewers comments or response until after I read the revision. I certainly agree with many of these reviewers’ comments and revisions, specifically the inclusion of the 6.25 km product and the buoy comparisons. I also appreciate the revisions made by the authors, to emphasize the primary purpose of these two products which is for marine stakeholders. I believe it is very important to have papers such as this on describing approaches and algorithms for new products, especially those derived from satellite, particularly in journals where the papers will be read by the sea ice community in this case. I assume the editors of TC believe this paper and such related papers on products/algorithms are appropriate, once approved for submission of course through the review process.

I follow now with my review. In general, I found the paper well-written and worthy of publication after my relative minor suggestions are evaluated and commented on. I appreciate the scale of this effort to provide SAR ice motion products. I believe the paper could use some more discussion on some figures which I will mention. I am a little surprised that the buoy comparisons seem quite large especially on the basis of the selected grid size used for 6.25 km product and suggest that more description be included on the multiple sources of the errors (Section 5). The offsets are actually pretty large compared to previous publications using coarser resolution SAR imagery. Also, in comparing the SAR 7-day product with PM results (Section 6), it's understandable that the SAR product is better. I think this section could benefit from more discussion especially on why stakeholders might be more interested in using the SAR product vs. the PM, aside from the improved accuracy.

**Howell et al.**

We thank this reviewer for their comments which have further improved the manuscript. We have implemented almost all of their suggestions.

**Reviewer #3**
Detailed comments
1. Lines 61-62. Please rephrase this sentence to include the thought that the SAR data limitations prior to S1.

**Howell et al.**
Good suggestion. Rephrased as follows:
Prior to S1 there was a lack of widely available SAR imagery for pan-Arctic SIM generation and as a result, this is perhaps the first time such an extensive processing of SAR imagery at the pan-Arctic scale has been undertaken to generate SIM.

**Reviewer #3**
2. Line 65. Please add a sentence that mentions the rationale for near-real time SIM processing and derived products. The processing scenario would be more seamless without the need for near-real time processing. Helps explain need for Figure 7 discussion too.

**Howell et al.**
Good suggestion. Rephrased as follows:
Here, we focus primarily on the latter applications by first describing the ECCC-ASITS workflow that produces SIM from S1 and RCM SAR imagery (hereafter, S1+RCM) in close to near-real time and combines the output into S1+RCM SIM products. A close to near-real time workflow is required given the considerable amount of incoming SAR imagery together with the computational time to generate SIM.

**Reviewer #3**
3. Table 1. I suggest adding the PM sea ice products to this table or making an equivalent one, including pixel size and grid size, temporal spacing (not image count).

**Howell et al.**
Considering the PM SIM products are relatively simple to describe, dedicating another Table to them is not warranted. This information is easily communicated to the reader (simply) in text form. We did note that the pixel size for the NSIDC product was missing in the text, which is now added.

**Reviewer #3**
4. Sampling. From Figure 3, it seems pretty clear that the RCM mapping strategy in general is different from S1 for the Arctic. RCM has a more spatially/temporally distributed consistent sampling approach for the entire Arctic, while S1 has more intensive coverage in certain areas. Each mission is set up to meet its science/stakeholder requirements. Given the overlapping coverage shown in Figure 3C, which shows a major central portion of the Arctic with over 9 images per week, I am surprised at the sparse results shown later in Figure 10, since 5 sensors are being utilized. The enlargements shown in a-d suggest more extensive results than the large figure but I don't find these that useful. I wonder if an additional large figure or two showing

sequential results, say from March 15-17, then March 18-20, would be beneficial to show. Such additions might highlight some of the issues with uneven spatial sampling that both acquisition plans may have, perhaps, and would also indicate how a regional time series could be developed for further study.

**Howell et al.**

The RCM image sampling strategy is based on our ordering from ECCC. That is, we aim to cover the majority of the pan-Arctic domain every 3-days specifically for SIM generation. However, RCM coverage is not systematic so consistent coverage across the entire Arctic is not always achievable week to week. S1 on the other hand is systematic and provides consistent coverage. Figure 3 is an average of the entire record (March 2020 to October 2021) so there is some variability that is masked at 3-days. For example, the gap in the Laptev Sea, Hudson Bay, and Beaufort Sea are often present at 3-days but not 7-days. The other point to remember is just because imagery is available, does not mean automatic SIM detection will be successful uniformly across the image. To this end, we understand the Reviewer's point and suggestion as this ultimately highlights the difficultly in generating spatially consistent 3-day products from these image sources. We have added another Figure (Fig. 12) as suggest and added some text related to sampling. We have decided to keep the insets because we feel they highlight the spatial resolution of the actual product, not reduced for presentation clarity.

New and revised Section 4 text:

The spatial distribution of 6.25 km 3-day pan-Arctic S1+RCM SIM for selected periods during the winter and summer are is shown in Fig. 10 and Fig. 11, respectively. The insets of both Fig. 10 and Fig. 11 illustrate the level of SIM spatial detail captured at 6.25 km. More spatial gaps across the pan-Arctic using higher spatiotemporal resolution especially during the summer months. These problems relate to the challenge of constructing a complete picture of pan-Arctic SIM every 3-days using available SAR imagery because of their different acquisition scenarios. Specifically, RCM acquisitions are more spatiotemporally distributed across the Arctic whereas, S1 are more intensive in certain regions (Fig. 3) and as a result, regions can be missed on certain days. This uneven spatial imaging problem is illustrated in Fig. 12 where it is apparent SIM is captured in the Beaufort Sea, Chukchi Sea and Hudson Bay from March 12-14, 2021 but absent from March 14-16, 2021. Also, just because SAR image pairs are available over a region it does not imply automatic SIM detection will be successful, especially during the summer months. Despite this, there are still many regions across the Arctic where high spatial and temporal SIM can be resolved using S1+RCM but the aforementioned problems need to be taken into consideration with respect to regional time series development.

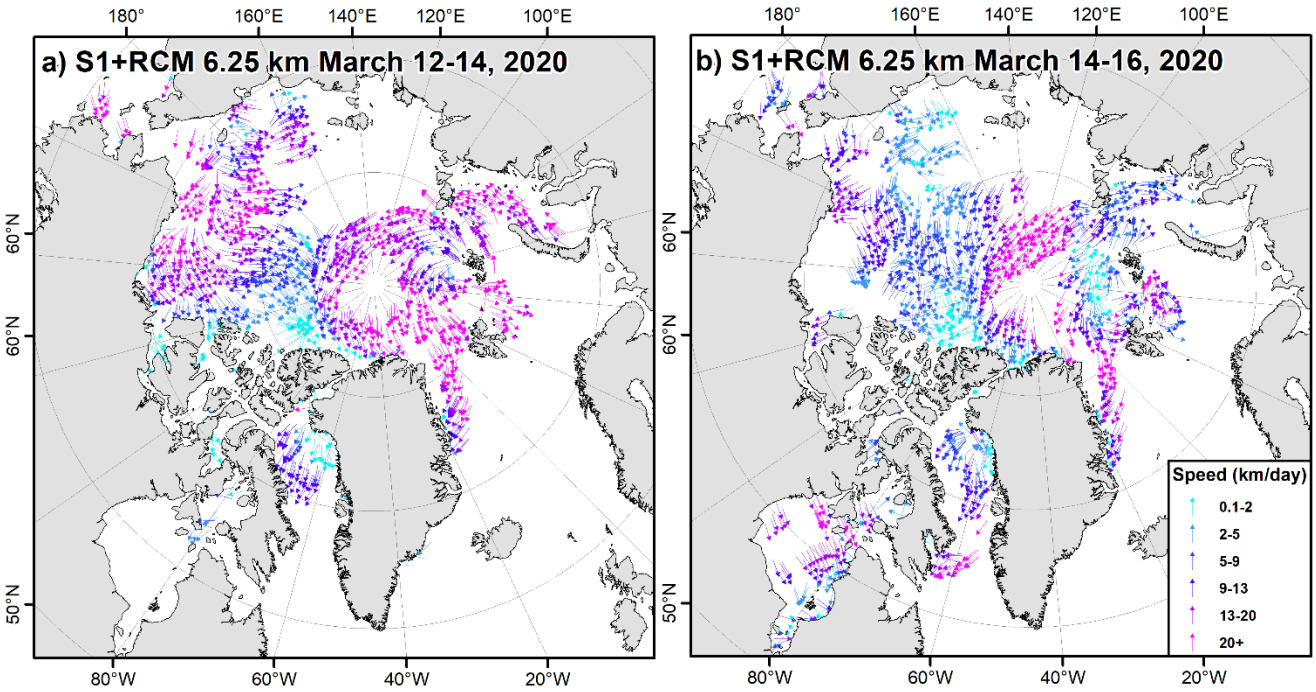


**Figure 12. The spatial distribution of 6.25 km 3-day S1+RCM sea ice motion on a) March 12-14, 2020 and b) March 14-16, 2020. Note that the white areas in the figure indicate either zero ice motion for the landfast ice or no ice motion information extracted (because of no SAR data, no ice, or no stable ice features).**

**Reviewer #3**
Continuing on about sampling, as Reviewer 1 mentioned, and has mentioned in Lines 193-194 and paragraph starting with line 195, I too would be interested in hearing whether they tried mixing RCM and S1image pairs to derive a motion product and what the results were.

**Howell et al.**
Stay tuned. This is a work in progress given the recent problems with S1B. Since late December 2021, S1B is not available and SIM is "gapy" across the Arctic. Our strategy is to keep the near-real time processing chain going but run scenarios that mix S1B and RCM to back process SIM from January 2022 onward to see if we can improve coverage. If successful, this "mixing routine" will be used to generate a more research based SIM product. If we are able to increase computational capabilities and receive the imagery from the ground stations more consistently, we will work this into the processing chain. This will be a considerable amount of work.

**Reviewer #3**
Also, regarding use of stacks, perhaps I missed this but for high coverage areas, say within the central Arctic, how do they handle more than one image pair within a 3-day period- are multiple pairs averaged together to make a single 3-day product?

**Howell et al.**
Yes.

**Reviewer #3**
5. Section 4

I assume ‘resolvable’ means grid cells with derived vectors that passed quality check. Please clarify.

**Howell et al.**
Passed the quality check and detected by the algorithm. This is pretty clear.

**Reviewer #3**
The availability of 5 sensors collecting Arctic sea ice imagery has enabled the most complete picture of Pan-Arctic SAR-derived ice motion. Please clarify sentence starting on Line 214. Its long been desired.

**Howell et al.**
Revised a follows:
The 7-day 25 km spatiotemporal scale is able to provide the most complete picture of SIM across the pan-Arctic from SAR imagery alone, this has long been desired.

**Reviewer #3**
Neither Table 2 or the text really addresses the point about the most complete pan-Arctic SAR-derived maps, at least in terms of numbers.

**Howell et al.**
We decided to remove Table 2.
**Reviewer #3**
6. Section 5
In the first paragraph, the authors should include the reference Lindsay and Stern, 2003 on RGPS offsets, where a mean displacement of 323 m was found for Radarsat-1

Paragraph starting line 309. As mentioned errors of 2.78 km seem quite large to me, basically since its about half of 6.25 km grid cell for winter, also in comparison to the above Lindsay/Stern results. I strongly suggest the authors add a paragraph that describes in more detail the sources of error- buoy, interpolated time to SAR image, spacecraft and SAR image location accuracy, identifying matchups between image pairs and so forth. This would at least enable readers and authors to point to major error sources which may be improved upon.

**Howell et al.**
This is a good suggestion. Briefly, we considered all buoys north of 40N and not just the Central Arctic like Lindsay and Stern (2003). As a result, considerably more ice regimes where taken into consideration during the winter and summer. Our RMSE is half of Wilson et al. (2001) who looked at the dynamic region of Baffin Bay but the Wilson et al. (2001) tracking algorithm is not as sophisticated as ours. Indeed geolocation errors and methodological choices contribute to uncertainty and both need to be acknowledged.

We have revised this section as follows:

…"The only restrictions placed on the buoys where that they were located north of 40N and the distance between the starting point of a given SAR ice motion tracking vector and the starting point of the corresponding buoy trajectory did not exceed 3 km."…

Our RMSE is higher than the value reported by Komarov and Barber (2014) likely because the initial validation assessment of the automated tracking algorithm only used 35 sample points in the Beaufort Sea during the winter and the vectors were at a higher spatial resolution (i.e. 100 m). Our RMSE is slightly higher than reported by Lindsay and Stern (2003) who compared the RGPS SIM to buoys in the Central Arctic and reported an RMSE of ~1 km for the winter and ~2 km for the summer. However, our RMSE estimates are much lower than Wilson et al. (2001) who compared RADARSAT-1 SAR estimates of SIM to buoys in Baffin Bay and reported an RMSE of 3.8 km for the winter and 6.8 km for the summer. The differences in RMSE's can be attributed to numerous factors including the geolocation errors of the different SAR satellites, differences in the methodology for buoy comparison, and different tracking algorithms. Overall, our validation is certainly representative of large-scale SIM uncertainty because we considered a wide-range of ice conditions during both the winter and summer months.

**Reviewer #3**
Figure 15A- the date on figure and in caption are mislabelled. For Figure 15B I found it interesting that a couple of locations within the CAA showed higher velocities (yellow) than surrounding areas. This figure warrants additional discussion.

**Howell et al.**
The date is correct and is meant to be the same in both panels. Panel (a) illustrates what the uncertainty would look like for dry conditions and the right (b) for wet conditions. SIM is very heterogeneous within the CAA so this is to be expected. However, discussion of this Figure would be related to regional SIM in the CAA and that is not the topic of this paper.

**Reviewer #3**
7. Section 6
I too am a little puzzled by comparing SAR with PM, including down-sampling the SAR results. But the PM products do at least have similar spatial scales to the weekly product. I am uncertain as to the meaning of the colors in Fig 16 and 17. Both appear to be heat maps. Both figures warrant additional discussion beyond lines 371-2.

**Howell et al.**
We wanted to do this comparison because the PM products are so widely utilized. This also gives confidence to all products should they achieve similar results. More importantly, we wanted to quantitatively demonstrate the speed bias inherent with PM sensors versus SAR. Admittedly, this was not well articulated in our initial text and some was incorrectly placed at the end of Section 5. The Figures are heat maps and this is now described in the Figure Captions. We do not feel a detailed analysis of this topic is warrant as it has already been done by Kwok et al. (1998).

We have added an introduction to Section 6 as follows:

Given the difficultly in quantifying SAR image pair coverage on S1+RCM SIM uncertainty, we now compare S1+RCM SIM to the NSIDC and OSI SAF SIM products that are widely utilized by the sea ice community. Such a comparison provides additional quantitative confidence metrics to assess the quality of the S1+RCM SIM estimates.

**Reviewer #3**
Details:
Line 33- Torres is misspelled
**Howell et al.**
Changed.

**Reviewer #3**
Line 41- Kwok 2015 paper is not listed in the references
**Howell et al.**
Added.

**Reviewer #3**
Lines 122-123 not a sentence
**Howell et al.**
Finally, different orbit characteristics of the satellites contribute to timing differences between when the images are acquired compared to when they are received by ECCC.

**Reviewer #3**
Line 122. How much computer time does it take to analyze 160 images per day?
**Howell et al.**
The system is constantly running ever hour. We don't have those specific metrics.

**Reviewer #3**
Lines 153-155 shouldn't the overlap be greater than 30%, for retention?
**Howell et al.**
Yes. Changed.

**Reviewer #3**
Line 156- you might mention that 32,000 km/2 is about 178 km2 or a little less than 1/2 a frame.

**Howell et al.**
We are OK with 32,000 km^2. The frame can be variable depending on the sensor. Further, some imagery we receive via the Canadian Ice Service is not a complete frame!

**Reviewer #3**
Line 191 – spatially complete
**Howell et al.**
Changed.

**Reviewer #3**
Line 198-199 – insert: …less representative results, often due to higher wind speeds.

**Howell et al.**
Done.