

Reviewer 1

In this manuscript, the authors assess the performance of the long-term Antarctic sea ice motion product derived from passive microwave (PMW) observations at NSIDC using buoy observations and high-resolution SAR-derived sea ice drift data. The authors show that the PMW-derived Antarctic sea ice drift generally agrees well with both SAR and buoy observations. However, they also identify a systematic underestimation of sea ice drift speed in the PMW product, particularly in regions where sea ice concentration (SIC) is lower than 50%. The authors further suggest that the optimal interpolation procedure is likely responsible for this behavior.

Overall, I found the objectives and conclusions of this manuscript clear and easy to follow. The analyses are generally solid, and the manuscript is well organized. I enjoyed reading this paper. I recommend minor revisions before the manuscript can be accepted for publication.

- Thank you for your positive feedback. Please see our responses to your comments below.

Major comment:

- After carefully reading the manuscript, I feel that the paper focuses more on the evaluation/validation of the NSIDC Antarctic sea ice drift product rather than a comprehensive uncertainty assessment. Therefore, I suggest revising the title so that it better reflects the actual content of the manuscript.
 - Thank you for your valuable feedback. We revise the title to “Pan-Antarctic evaluation of National Snow and Ice Data Center (NSIDC) sea ice drift product using high-resolution SAR and buoy data.”
- Scientists from EUMETSAT Ocean and Sea Ice Satellite Application Facility have also developed a widely used Antarctic sea ice drift product. It would be very helpful if the authors could discuss how the NSIDC sea ice drift product compares with the OSI SAF product, including but not limited to retrieval methodology, spatial/temporal resolution, and more importantly the relative performance against independent observations. Including such discussion would substantially improve the scientific significance and broader relevance of this manuscript.
 - Thank you for your constructive comments about the comparison between NSIDC and OSI SAF sea ice drift products. We agree that this comparison is useful, but it is out of the scope of this study. This study is focused on the pan-Antarctic evaluation of the NSIDC product using high-resolution sea ice drift across the Southern Ocean, which addresses the limited coverage of Antarctic buoys. However, the currently available OSI SAF product has a coarser resolution (62.5 km) than the NSIDC product (25 km), which implies that the OSI SAF product cannot really serve as “validation” data for the NSIDC product. Several inter-comparison studies have been conducted by others, and this

inter-comparison or validation of the OSI SAF product is out of scope for this study, as it may require too much content for another separate paper. Therefore, we would like to focus solely on the pan-Antarctic evaluation of the NSIDC product, using high-resolution SAR images and buoys.

Minor comment:

- P2 Lines 42-44, this statement is somewhat new to me. I wonder whether there are existing studies or references that support this claim.
 - It is widely known that Antarctic sea ice exhibits higher velocities and, consequently, higher deformation rates (Kwok, 2010; Kwok et al., 2017; Heil et al., 2001). These higher displacement and deformation rates have a direct and well-documented impact on PMW-based ice motion retrieval. We add these references in L44. We refer directly to Kwok et al. (2010) for more details: *“However, the quality of the data is somewhat lower than that achievable in the Arctic Ocean: the higher daily displacement and deformation rates in the Antarctic ice cover reduce the spatial coherence of image features (brightness patterns) at a faster rate and this impacts the matching schemes discussed above. It is also difficult to produce ice-drift estimates close to the ice edge where atmosphere/ocean processes modify the ice cover at much shorter timescales than the typical satellite revisit time of 1 day.”*
 - Kwok, R.: Satellite remote sensing of sea-ice thickness and kinematics: a review, *Journal of Glaciology*, 56, 1129–1140, 2010.
 - Kwok, R., Pang, S. S., and Kacimi, S.: Sea ice drift in the Southern Ocean: Regional patterns, variability, and trends, *Elementa: Science of the Anthropocene*, 5, 32, 2017.
 - Heil, P., Fowler, C., Maslanik, J. A., Emery, W. J., and Allison, I.: A comparison of East Antarctic sea-ice motion derived using drifting buoys and remote sensing, *Annals of Glaciology*, 33, 139–144, 2001.
- P12 Lines 231-233, does hypothesis (2) also contribute to the underestimation of sea ice drift speed? Please clarify this point further.
 - Yes. We clarify this further in the manuscript: *“These extensive comparisons between PMW_{raw} and SAR sea ice drift strongly suggest that the PMW-based MCC feature tracking successfully reproduces sea ice velocity without a significant intrinsic speed bias, whereas the optimal interpolation systematically introduces a negative bias (i.e., underestimation of sea ice speed) into the final gridded sea ice motion product. We propose two possible, non-exclusive reasons for the widespread underestimation of sea ice speed caused by the interpolation: (1) Smoothing effect: Optimal interpolation is designed to produce a smooth velocity field, which inherently acts to reduce the magnitude of real ice velocity, particularly in highly dynamic, higher-speed regions. (2) Bias at ice edge: Sea ice*

edges typically exhibit higher speeds than the middle of the ice pack. However, velocity at the ice edge is often estimated through interpolation of lower velocity values from the interior pack ice, leading to a substantial underestimation of the true speed near the ice edge.”

- P15 Lines 253, please check the wording “all seasons”, as it appears inconsistent with the earlier statement that only results from March to November are shown (P8, Lines 193–194).
 - Thank you for pointing this out. Yes, our comparison covers only March to November, so we specify “all months from March to November.”
- Since the optimal interpolation may degrade the performance of the sea ice drift product, which version of the dataset is publicly distributed and recommended for scientific research: the interpolated product or the raw PMW-derived product?
 - Both products are publicly available (<https://doi.org/10.5067/INAWUWO7QH7B>). We would recommend that users select an appropriate product depending on their purposes: (i) Since the interpolated product covers the entire Southern Ocean, the interpolated product is suitable for investigating the overall, multi-year spatiotemporal variations of sea ice velocity. The interpolated product also provides uncertainties associated with the optimal interpolation, so users must account for these uncertainties in their scientific analysis. (ii) If a user wants to focus on accurate ice velocity values, without an estimation bias, the raw sea ice motion product is recommended. We add the final remark in the conclusion section: *“Since the NSIDC sea ice velocity product provides uncertainty estimates associated with the optimal interpolation, users of this product must account for these uncertainties, particularly the underestimation in interpolated areas, in their scientific analyses.”*
- Figure 2, it may be clearer to show only the buoy locations that were actually used for the validation analysis.
 - We revise Figure 2 to show only buoy locations used for the analysis.
- Figure 9, I noticed that even without interpolation, the PMW_raw sea ice drift still shows an underestimation under low-SIC conditions. Does this imply that factors other than interpolation also contribute to the bias? If so, please discuss the possible mechanisms.
 - Thank you for your valuable comment. We agree that this issue should be discussed in more detail. We add a discussion: *“In low SIC areas, the PMW brightness temperature signal becomes increasingly contaminated by open-water emission, reducing the contrast and spatial coherence and making cross-correlation tracking challenging for coarse-resolution PMW images (Kwok, 2010).”*