Review of tc-2023-142

Updated Arctic melt pond fraction dataset and trends 2002–2023 using ENVISAT and Sentinel-3 remote sensing data

By Istomina and others

<u>**General Comments**</u>

The authors update a previously developed and published algorithm called MPD for the estimation of melt pond fraction (MPF) from satellite optical data, here showing its application to OLCI sensor data from Sentinel-3. The rationale is to provide continuity with the earlier dataset from the MERIS sensor aboard ENVISAT, which is no longer available, but technologically similar, making a 17-year dataset spanning 2002-present with a gap from 2012-2016. The quality of the dataset is evaluated in the current work by comparison to higher resolution optical data from Sentinel-2, to which a different MPF retrieval algorithm is applied (classification algorithm by Niehaus et al. (2023)). The MPD algorithm had been previously compared to ship-based, surface, and airborne data and as such its limitations are fairly well documented. The authors also do an analysis of trends in MPF, analyzing hemispheric trends and regional trends for the period 2002-present. Of note, an updated and more robust cloud screening technique is presented and applied to both the historic (MERIS) and current (OLCI) derived datasets.

Overall the MPD provides a reliable estimation of MPF based on assessment of agreement with other datasets, here (r=0.86) and in previous studies (Istomina et al., 2015). The characteristic nature of the MPD is to overestimate small MPF < 0.1 and underestimate large MPF >0.7. For the small MPF problem, in this paper the authors use spectral mixing simulations to effectively outline the limitations in the algorithm that are imposed by the sub-resolution mixture of surface types and especially the influence of open water. Using Sentinel-3 provides a consistent dataset that offers much potential for use in ocean-ice-atmosphere studies and for analyzing processes that might inform model parameterizations. MPF is also of concern to biological studies due to the importance of melt ponds on light transmission and primary production. The paper should be of interest to TC readership provided the authors address the comments provided here and by others.

1. The treatment of Sentinel-2 derived MPF as ground truth raises its own potential problems since this is another satellite derived dataset (although at higher spatial resolution) and is subject to its own retrieval limitations. Despite referencing the Sentinel-2 algorithm, the authors do not provide enough information on the algorithm and its limitations in the current paper to enable an effective intercomparison of the two products, or to build confidence that it should be assessed as a "truth". More detail needs to be provided. As well the Sentinel-2 MPF should not be identified as ground-truth.

2. Similarly, the comparison between Sentinel-2 and 3 done in Section 3.2 is too cursory in that it is a global comparison of the all overlapping data from the two datasets. The authors should provide a more detailed analysis that considers the ice condition (ice type) and some indication of the temporal component, i.e. how OLCI and MSI MPF compare in different seasonal phases of melt pond coverage when the spectral properties of the snow, ice, and ponds are different (but perhaps typical to some degree). In this context, is good performance of the MPD MPF product realized for first half of the melting season (June–July), as speculated on Line 360? The authors could use one or more of the already cited papers on melt pond evolution, to provide some structure to seasonal component of MPF evolution, e.g. as opposed to calendar months (Eicken et al., 2004; Polashenski et al., 2012). On the other hand, the spectral mixing analysis in Section 3.2 is lengthy and hard to follow in parts, and

should be improved. It important to be clear as to what observations from these results were used to make changes to the current MPD, versus what are being used to highlight possible error sources or identify areas for future iterations of the algorithm.

3. The authors use terminology regarding seasonal stage that isn't consistent with the literature, especially melt onset, which most often likely means pond onset i.e. formation of melt ponds that occurs some time after melt onset, when there is enough meltwater that flooding is possible. This will need to be addressed throughout the paper.

Minor Comments

L17-19: Clarify the ranges ("small" and "middle" are ambiguous).

L18: The snow would not be saturated if it is before melt onset. Is this supposed to pond onset?

L28: Again the term melt onset is confusing here as it was not analyzed, but the onset of ponds was, so perhaps "pond onset" is more appropriate.

L34: 2016-2023.

L35: "…world (Rantanen et al., 2022), the…" (delete "and")

L38: It would be better to say that it is due to the ocean being darker than the sea ice, not the other way around.

L43: What is meant by surface melt in the context of a sea ice ECV? How would it differ from the albedo, which changes due to melt?

L46-54: Briefly provide some detail on what is affecting the different remote sensing methods (e.g., PM emission is affected by the presence of open water from melt ponds on sea ice, etc.).

L51: "A PM based sea ice drift product…"

L55: "GCMs"

L59: "forecasts"

L61: Update the references (e.g. MOSAiC melt pond studies).

L62: Do you mean "climate conforming"? It is unclear.

L64: Use "MPF" instead of "melt pond" for consistency.

L69: delete "of"

L79: add space after "1.4 GHz,"

L80-84: The link between penetration depth and MPF estimation is unclear. Is it not more-so the emission differences between ice and melt pond that enable MPF retrieval, and the presence of open water along with melt ponds that confuses the MPF retrieval because melt pond and OW have similar emission characteristics (regardless of penetration depth)?

Line 86: Add "synthetic aperture radar"

L88: Melt pond and open water could have equally high backscatter in windy conditions.

L93: Clarify what Terra and Aqua are (platforms each with MODIS sensors).

L93: data "are"

L94: Start a new sentence at "important …"

L99-102: Sentence "In addition, …" is not clear and could probably be broken up into two sentences.

L103: "…a MPF dataset"

L105: "…of an earlier…"

L120-123: The information listed should be written out and presented more clearly or summarized in a table.

L134: "…and the absorption coefficient…"

L137-139: Provide some more information on the ice sampled here, given the importance of the dataset (types, melt pond conditions e.g. depth, etc.).

L142: "The MPD has been…."

L159: change to "swaths" and change "overflight" to "overpass"

L175: change to "swaths"

L183: acronym SIC should be defined earlier

L183: "Examples of the daily …."

L184: "…are shown"

L186: Use "SIC"

L189: See general comments. It is not correct to call the Sentinel-2 data "ground truth".

L190: In Fig. 1 it is confusing to have 0% MPF and no-data as both white color.

L202: Use italics for "*in situ*"

L205: "mixtures"

L210: Clarify what is meant by "within ice surface types".

L219: "MPF"

L229: As mentioned before, this should be pond onset not melt onset.

L242: "… a high fraction of ridges…"

L259-260: "darker water saturated sea ice" could be better described. Is this blue ice and/or optically thin ice?

L274: "…a translucent scattering"

L292: Clarify what is meant by typical MYI. There is MYI north of the Canadian Archipelago, even within the Archipelago, due to it ending up there after drifting in the area during summer. Depending on

where the ice transitioned to MYI before drifting to its imaged location, it may be typical (which also depends on the authors' definition of typical).

L316: Insert comma after Fig. 5

L317: "…in (Fig. 7)" doesn't need brackets around Fig. 7 as done on Line 320. Note on Line 323 the text "Figure 7" is used. Be consistent with style used for identifying figures in the text here and elsewhere.

L323: "…melt pond type…"

L330: "… favorable condition"

L332: "…MPD MPF"

L334: "… SIC is shown as color-coding of the data points"

L335: "…bright sea ice surfaces"

L338-343: It is hard to follow if these solutions are implemented in the current algorithm or not. Use of text "can still be accommodated" and "can be accounted for" makes it unclear if these ideas are for future consideration or not.

L343-344: pluralize "version" and use MPF for "melt pond fraction"

L355: There is not water saturated sea ice before melt.

L366-367: Used "averaged" and "analyzed" i.e. past tense for methods implemented.

L385-390: change descriptions of past methods to past tense

L397: See general comment about melt onset (above).

L451: Add spaces each side of "–"

L453: "A significance hemispheric…"

L454: "The last three weeks…"

L456: Add spaces each side of "–"

L483: "…for the middle MPF range"

L533: Is there a statement regarding the Sentinel-2 MPF dataset?