

**Multidecadal Arctic sea ice thickness and volume derived from ice age  
Liu et al., 2019**

The study of Liu et al. (2019) introduces an Arctic-wide sea ice thickness and volume data product and retrieval method derived from sea ice age. Their product extends all the way back to the early 1980s and presents a data set created with a consistent method, thus providing an interesting novel addition to the existing sea ice thickness products. In addition to complementary information to the more recent satellite altimetry based products, the product could bring additional information about the conditions before the more systematic period of satellite altimeter sea ice measurements.

However, the manuscript currently lacks clarity and detail in explanation of some of the implemented methods. In particular the validation of the product should be improved and justified in order to prove the usefulness of the product. In addition there are some minor cases, included in the review comments below, which should be corrected to accomplish a more finished manuscript.

Considering the novelty and added value in extending the satellite based sea ice thickness records, I recommend this manuscript to be considered for publication in the Cryosphere, after addressing the major review comments.

**General comments:**

1. The data and methods section lacks clarity. There is a great number of data sets used for creating the product and then those used for validation/comparison. And some of the products are used for both purposes. And not really in a chronological order. It would improve the readability if you could structure this section so that it is clear for which purpose the data sets are used, maybe adding separate sections for datasets used in IceAgeDerived creation and for validation data.
2. You seem to use ICESat data as one set of validation data, which is always a bit suspicious if you are using it to construct your data set. The same applies to the draft data. You could either remove the comparisons to these completely from the results or really emphasise and justify more, what comparisonal value these bring.
3. Uncertainties are sometimes painful, but they could be handled more systematically. You mention some, but there is very little analysis. In the data section there are some uncertainty estimates for OTIM, but not really for the other data sets. In results there are brief mentions of ICESat and CryoSat-2 uncertainties. And you mention significance levels for ice thickness and volume trends. Adding more discussion and quantifying the uncertainties in a comparable manner, as well as stating seasonal differences in uncertainties, perhaps adding some discussion on the possible biases

from using submarine vs. laser altimeter in the ice age derived thickness, would add a nice touch to the manuscript.

4. The results, particularly the comparisons with different data sets, should be discussed in detail. Currently the statement about the usefulness of IceAgeDerived is not made that clear. PIOMAS and OTIM seem to be used here as the main comparison sets, and they are good in a sense that both extend to the early 1980s, but to reason the usefulness of IceAgeDerived, you could consider using a satellite altimetry observation based thickness data set with a good temporal extent. I would see some of the main users for the IceAgeDerived being those who are already using altimetry data for sea ice thickness and volume, and thus it would be good to see how these two compare over a longer time period. There are for example datasets combining EnviSat and CryoSat-2, where efforts have been made to bring these to a level of consistency. Such data sets are provided at least by CTOH/LEGOS and ESA CCI. This is only a suggestion for the comparison data, but in case you decide to stay with PIOMAS and OTIM, it would be good to add explanation why you chose these, what are they good for and what do the comparisons really tell about the usefulness of IceAgeDerived.

#### **Minor comments/edits:**

L23: Have declines -> have declined

L27-29: There could be more sources, perhaps making a stronger statement with results based on satellite observations, if possible. And there could be something newer for the model results, as 2002 was almost two decades ago.

L34: The “relatively high quality of sea ice concentration retrievals from passive microwave data”, relative to what?

L39-40: Not mentioning EnviSat? It covers almost a decade of historical data. Of course an exhaustive list might be unnecessary here, but you could consider adding “e.g.” if only mentioning CryoSat-2 from the radar altimeters as now it sounds like CryoSat-2 is the only source.

L52: Maybe a newer source than Wang et al. 2010? In Section 4, Discussion and Conclusions, you mention the new snow products and their remaining uncertainties, so perhaps something from there.

L55: Does Laxon belong here? And rather many references for PIOMAS?

L58-68: Nice paragraph!

L59: Individual sea ice *parcels*?

L79: Masnalik et al. 2007 -> Maslanik et al. 2007

L81-83: Each grid cell is tracked as independent parcel, but age of a grid cell of parcels with different ages is assigned to this parcel? The latter sentence in these lines could be more clear.

L117-123: Confusing section, it is a bit unclear what you mean with the “interannual change with the annual cycle superimposed in averaged ice thickness”. Also, I and A are not explained too well. These equations should be explained better as you mention they will be used in the results section.

L125-126: You reduce 0.29 m from ice thickness of IceAgeDerived when comparing to submarine derived ice thickness e.g. for the statistics in Tables 1 and 2, or which way?

L127-130: Figures 2 and 3 in RK18 are thickness (Figure 2) and volume (Figure 3), so it would be appropriate to refer to “sea ice thickness and volume” in that order.

L132: Key, et al., -> Key et al.,

L160-161: Is the 10 km necessary to mention here?

L167-168: You use age classes only up 4+ years, but Tschudi et al. 2016 (Fig. 5) have up to 5+. How did you choose this? Using the same classes would increase the consistency and comparability.

L168-170: This method needs more reasoning.

L200-203: Did I understand correctly that you go from weekly to daily to monthly. What is the benefit of doing the daily step?

L244-246: Good that you mention this! How about ICESat? That too was used in the development, right?

L269: How is the partial recovery after summer 2008 visible in these DRA mean ice thicknesses? Particularly in IceAgeDerived?

L295: Arctic sea ice volume for what? Is this still for IceAgeDerived? Maybe add more explanation in the figure caption.

L315-328: Interesting analysis! See comment about Fig. 14.

L348-350: This bullet point does not seem as important as the others, as these findings have been shown in other studies. This could be more of a point to state the consistency between methods, IceAgeDerived succeeds in showing this phenomena that the other sea ice

thickness products have captured, which would encourage the users to take on IceAgeDerived.

L360-363: Extremely interesting! I missed the information for which area this was done.

L366-367: Would love to see more analysis on this. Tschudi et al. (2016) seemed to have thicknesses increasing for each age category up to 5 years. It would be a nice addition to see some speculation about the causes.

L410-411: These references are not used (and maybe never will be)

L475: Malanik -> Maslanik

L484, L487: Please add a and b for Tschudi 2019.

Table 1, and others: SCIEEX -> SCICEX

Table 1, Table 2, Fig. 5, Fig. 6, and where relevant: Cryosat-2 -> CryoSat-2

Fig. 1 Consider a different latitudinal cut off, now there is quite a lot of uninformative area in the figures and especially it is hard to see the draft observations. Or if wishing to keep similar cut off to your other figures, consider emphasizing the draft points.

Fig. 2 to1995 -> to 1995 (space). For consistency, consider having the same colorbar as in the other figures, e.g. Fig. 7 [0,4] instead of [0,~4.5]. Consider as well the choice of colormap if 3 m ice, which now stands out with yellow, does not need extra attention. Also, the unit is missing for sea ice thickness.

Fig. 4a v4.0? This maybe refers to the sea ice age product available at NSIDC, but I did not see the version mentioned elsewhere in the manuscript.

Fig. 9 GORE box? And in general, there are a bit too many names for different areas (Arctic Ocean (as in RK18) , SCICEX box, GORE box, DRA). Use only one, unambiguous name for each area.

Fig. 14 I did not see this figure being referred to. If this is correct, please add it somewhere in L315-328.

Fig. A1 t0 -> to