Reply to Referee Comment RC1

(review in black, author response in blue)

Review of "Mapping of sea ice concentration using the NASA NIMBUS 5 ESMR microwave radiometer data 1972-1977" by Kolbe et al.

Summary

This paper presents a new sea ice concentration product from the Nimbus-5 ESMR sensor that operated from 1972 to 1977. Earlier sea ice products have been created from ESMR, but the sensor is under-utilized because of limited data quality and substantial amounts of missing data, plus the fact that it is a single-channel sensor while subsequent sensors are multi-channel and there is no overlap between them. The method here uses several filters to remove bad data, implements dynamical tie-points and uses a radiative transfer model with NWP data for atmospheric correction. Comparisons show good consistency with the NSIDC ESMR data product, but with extent values that are generally higher due to the different methods.

General Comment

This is a valuable new dataset that makes the ESMR data more useful for long-term timeseries analysis and extends the passive microwave sea ice record another 7 years. The filtering methods are well thought out and remove much of the bad data and the RTM with NWP help correct weather effects. It is clear that great care went into the product and that the output is as good as can be expected given the nature of the data. The comparisons with the NASA/NSIDC product are useful and highlights key differences in the methodologies. The paper is well-written and thorough. After revision in response to the very minor comments below, this is acceptable for publication.

The authors would like to thank the referee for reviewing the manuscript and providing constructive feedback.

Specific comments (by line number): I think of science as a process of gaining knowledge through the accumulation of evidence to continually get closer to knowing the truth.

95-113: The filter discussion is a bit jumbled in my view. In Line 97, "The first filter" is mentioned, but then in Line 101, it says "The following set of filters are applied…", which is then described as "the second filter" even though it reads to some degree that it is the first filter. I guess I see that the first one is a bit different, but I would just say something like, "The following filters are used…" and then go one-by-one. Or if you want to separate out the analog filter, maybe say something like, "An initial analog filter is used…" and then say something like, "Next, several other filters are employed…."

This is a good point, and we agree that this section needs revision. Since we want to distinguish between the analog filter and the four following filters, we have rewritten the paragraph following your second recommendation:

L.100-123 : “ An initial analog filter is used for filtering erroneous TBs and scanlines. The filter is based on the 16 analog voltage entries in the data. […]

Next, several other filters are employed using the processed TB (in Kelvin) from the previous step. The filters are applied in the following order:

Data that are non-physical and outside the expected range for sea and ice surfaces are removed. Only data points that lie inside the range specified in Eq. 1 are kept: [...]

The next filter removes erroneous scan-lines (across track rows). Consecutive scan-lines should not differ by more than 50K as shown in Eq. 2. The threshold of 50K was estimated experimentally. [...]

n is the maximum across track index of a row, i.e. for a complete row with valid data points for all 78 incidence angles n = 78.

Afterwards, single TB outliers are removed, if they cannot satisfy Eq. 3:[...]

The threshold of 150K was selected manually after identifying erroneous single pixel outliers in the data.

The last filter in Eq. 4 removes neighbouring TBs which are locked on the same value, i.e. TBs for which the following equation equals zero:[...]

where p is again a single pixel TB with an along track index i. The choice of comparing 7 consecutive TBs is based on qualitative experiments. Since the filter is used universally for all incidence angles, the search window varies but covers a minimum distance of 175 km.”

103-113: Another issue is that the equations for some of the filters are used to describe included data and some are to described excluded. For example, Eq. 1 shows the range of valid values, while Eq. 2 and Eq. 3 describe thresholds to remove invalid values. It would be better to be consistent and have each equation describe valid values or each describes invalid values. Eq. 4 I’m not quite sure about- does “not equal to zero” mean remove or keep?

Thanks for pointing this out, we have changed the equations and descriptions to be consistent, so that only valid values are described in the equations. Regarding the last filter, if Eq.4 is satisfied, i.e. not equal to zero, the data is kept.

L.112-119: “

$$\frac{\sum_j^n |T_{B_{j,i+1}} - T_{B_{j,i}}|}{n} \leq 50K \tag{2}$$

$$|p_i - p_{i-1}| + |p_{i+1} - p_i| \leq 150K \tag{3}$$

[...]

The last filter in Eq.4 removes neighbouring TBs which are locked on the same value, i.e. TBs for which the following equation equals zero: ”

121: Section 3 is labeled as “The radiative transfer model”, but the sub-sections seem to go into other areas. I guess the RTM affects the subsections, but it seems like only the first part of Section 3 is specifically RTM and then the subsequent subsections are actually about the

process of deriving SIC. I would suggest putting 3.1 to 3.3 into a Section 4 “Derivation of sea ice concentration”, or something along those lines.

The RTM is an essential part of the SIC derivation (the geophysical noise reduction, specifically), as described in 3.1, but we agree that the first part of section 3 is a more general introduction to the RTM, so we have now organized the sections as you propose.

L.131 “3 The radiative transfer model”

L.182-186 “4 Derivation of sea ice concentration

The RTM is an essential part of the SIC derivation for applying an atmospheric noise reduction. The following section presents the calculations of dynamical tie-points and the SIC algorithm, along with uncertainty estimations. Lastly, the post-processing, including land-spill-over method and data flags assignments, is described. A flow-chart illustrating this processing chain can be found in the ESA CCI ESMR product user guide (PUG) (ESA CCI, 2022).”

L.187 “4.1 Tie-points and geophysical noise reduction”

L.241 “4.2 The sea ice concentration (SIC) and its uncertainty”

182: What is the source of the SIC in ERA5? I think this is worth noting since it is an important element in deriving the tiepoints.

We agree that this is important information, and have included it to the tie-point section of the manuscript:

L.195-199 “The ERA5 SIC prior to 1979 is based on the HadISST2.0.0.0 data set (Bell et al. 2021), which mainly utilizes digitized sea ice charts for this period (Rayner_et_al_2003). The two main data sources are the Walsh data set (Walsh, 1978; Walsh and Johnson, 1979; Walsh and Chapman, 2001) and National Ice Center (NIC) charts (Knight, 1984). The data sets also consist of several data types besides ice charts, e.g. ship observations and satellite data, both infrared and microwave observations, including data from ESMR. ”

Sources:

[Bell et al. 2021] https://doi.org/10.1002/qj.4174 Describes the ERA5 preliminary back extension and states that the used ERA5 utilizes SIC from the HadISST2.0, which is similar to HadISST1.1 described in [Rayner et al., 2003].

[Rayner et al., 2003] https://doi.org/10.1029/2002JD002670 describes HadISST1 and its data sources, which mainly consists of the digitalized sea ice charts of the Walsh dataset [Walsh, 1978; Walsh and Johnson, 1979; Walsh and Chapman, 2001] and National Ice Center (NIC) charts [Knight, 1984].

[Knight, 1984] https://doi.org/10.3189/1984AoG5-1-81-84 talks about NIC/JIC data, which also uses satellite data in their analysis, both visible/infrared and microwave data, including the ESMR data.

[Walsh, 1978] Walsh, J. E. 1978. A data set on Northern Hemisphere sea ice extent, 1953-76.World Data Center-A for Glaciology, Boulder, Colorado, Glaciological Data Report GD-2, p. 49-51

[Walsh and Johnson, 1979] https://doi.org/10.1175/1520-0485(1979)009%3C0580:AAOASI%3E2.0.CO;2

[Walsh and Chapman, 2001] https://doi.org/10.3189/172756401781818671

184-185: This isn't clear to me. What do you mean by the 15-day averaging period is maintained even at the beginning and end of the data-set and when there are data gaps. I assume this means that wherever there is a gap, valid data would not start until 7 days after the end of that gap so that there is a full 15 days for the average period. Is this correct? If so, maybe slightly rephrasing this to be clear.

We agree that this should be elaborated and have added the clarification to the text. It's good that you raise this point, as it is actually the opposite of how you understood the text, i.e. the 15-day averaging period is maintained, even if there are gaps, the averaging is then done over the days available in the 15-day period. So even in the beginning of the ESMR data-set, where the first 7 days are missing, a valid tie-point is computed. An averaging with a full 15 days only is not possible to maintain, especially for the second half of the dataset, where there is only data available for every other day.

L.204-210 "The 15-day averaging period has been maintained even at the beginning and end of the data-set and when there are data gaps, i.e. if there are gaps, the averaging is done over the days available in the 15-day period, also in the beginning, where the first 7 days are missing.

Figure 2 depicts the 15-day averaged tie-points through time. It shows that the ice tie-points follow a seasonal pattern, while the water tie-points are relatively constant. The tie-point criteria from table 2 ensure that each daily tie-point is based on many observations, which result in stable tie-points. The 15-day interval has been chosen experimentally, so the TB variations seem reasonable and one is still able to identify calibration issues as jumps as e.g. in 1976. "

348-360: I'm not a fan of using bullet points for conclusions in a journal article. Maybe just a personal preference by me, but I think it looks and reads better as paragraphs, especially when the bullet points are complete sentences and not a list.

We value the feedback and have rewritten the conclusions as paragraphs.

L.387-396 "The most important findings can be summarized as:

A comparison to NSIDC's ESMR SIC product and the OSI-SAF CDR was presented. While the seasonal pattern is very similar to NSIDC's ESMR SIC product, our product shows systematic larger SIE values, which can not be explained by differences between land masks alone. For the Northern Hemisphere our SIE values are matching the levels of the 1980s of the OSI-SAF CDR with the same land mask, while values of the Southern Hemisphere have been larger in the 1970s than in the 1980s.

Uncertainty estimates have been included in our ESMR data set for better data assessment and easier comparison to other data sets.

Atmospheric noise has been reduced with the use of an RTM and the ERA5 atmospheric data.

Dynamical tie-points were used to avoid biases from the RTM and NWP data as well as to adjust to seasonal variability and instrument biases."