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Discussions

Interactive comment on "The EUMETSAT sea ice climate record" *by* R. T. Tonboe et al.

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Thanks for the thorough review and for helping us making this MS a better paper. Please find our reply to all of your comments below.

General comments: The content of this publication can be considered very important contribution to the creation of consistent several decades span of sea ice cover data sets. This article reads like it was written by several different people. Up to the section 2.1 the writing style and terminology used do not explain clearly the data sets properties used in this project. The list of recommendations below will improve the readability of these sections. Thanks for providing these recommendations. We will modify the text accordingly.

Starting with section 2.1 the writing style and the clarity greatly improves and very few minor clarifications are needed. But, very important section 3.3 Ice chart and ESICR

comparison discussion is not easy to read. The comparison should be better organized. The authors should spend some time on deciding what will be the primary use of these long term data sets. The spatial and temporal resolutions, as well as the accuracy of retrievals are usually driven by these applications. The criteria for comparisons with existing data sets and/or ice charts are also dictated by who will be using this new and improved sea ice cover information. Making trend analysis using different sea ice concentration algorithms shows quite different negative trends of the Arctic sea ice cover. This indicates that the geophysical noise sources (including atmospheric water vapor ice types etc.) have climatic trends as well as the ice extent and that the uncertainties are significant and should be quantified. This was the motivation for doing this reprocessing and it has been the aim to create as long a record as possible thus using 19 and 37 GHz channels with the spatial resolution that these channels have.

Algorithms designed for processing spaceborne measurements are developed for specific applications. Some of these algorithms are very simple and set up to provide yes/no indicators to mask ice covered (>threshold value) areas. Some other algorithms, especially to be used in near-real time for navigational support, are more complex and are region and season specific. The regional and seasonal variability of sea ice cover can be partially compensated by using seasonal, regional algorithm parameters and sea ice signatures. These parameters can be derived using RTM. The complexity of the microwave radiation from the sea ice cover must be accommodated. The authors do state that understanding what contributes to the emission from the ocean surface (e.g., snow free ice floes, ice flows covered heavy wet snow, young saline ice, etc..etc„) is very important but do not carry out their evaluations region by region. The "new" hybrid algorithm should have region specific "flagging" to allow global processing. Both the noise reduction using NWP data and and an RTM on every measurement and the tie-points are region-specific so that the distribution of ice types (meaning sea ice with different emissive characteristics) is accounted for regionally. The seasonal variability including melting snow on sea ice is to some extent accounted for using the dynamical tie-points.

The authors should dedicate more discussion time in planning their future work to regional seasonal variability of the ice cover and how that impacts microwave and optical brightness temperatures. We are already in the process of planning the next updates of the dataset and we have already included these plans in the text in 4.1.

The authors have selected a hybrid algorithms that uses fixed coefficients multiplied by observed brightness temperatures. It is not clear how using NWP is incorporated into calculations of these coefficients or in computations of dynamic tie-points. The text has been revised with attention to better explain the use of tie-points and atmospheric correction. The Bristol algorithm is using fixed coefficients only to rotate the coordinates of the plane which is spanned in the space of the three brightness temperatures (19v, 37v, 37h) that the algorithm is using. The coefficients used for quantifying the sea ice concentration are the tie-points (or ice line coefficients) and these are dynamic. The bootstrap algorithm is not using fixed coefficients for rotation only the dynamical tie-points. These two algorithms are used in combination.

All throughout descriptions of different algorithms the authors discuss items they call "uncertainties". It is not clear what this particular quantity represents. Is it a statistical value or derived value related to variability (or accuracy) in measured brightness temperatures or other measured (or derived) parameters? In a real world there are very few instruments that can claim to have accuracy of less than 2%. The sea ice concentration uncertainty is quantifying the sea ice concentration uncertainty on every pixel as an absolute quantity and given in percent. It describes the independent instrument noise, the geophysical random noise and the representativeness error. The total uncertainty is normally higher than 2%.

The sea ice cover data sets generated using MODIS and/or SAR provide higher spatial resolution data but the authors should not forget that the algorithms used to generated ice cover imagery may contain sensor/processing algorithm specific errors, e.g., ocean surface roughness effects on SAR imagery; cloud cover on MODIS The authors have acknowledged the need for the algorithms to accommodate pack ice and marginal ice

regions. It is not clear if the hybrid algorithm will be tested for these diverse ice cover regions. It is also not clear how different coefficients used in this new algorithm can be derived using physical properties of different types of ice and weather conditions.The ice cover in marginal ice zones can change very quickly depending on the wind (e.g., read about icebreakers trapped in Barents ice; ships stuck in Weddell sea) and in some parts of the world the extent of the ice cover is dictated by the thermal currents (e.g., sea ice cover in Labrador and Newfoundland waters). The data used for generating the ice charts such as microwave radiometers, scatterometers, visual/infrared scanners, SAR instruments etc. each have uncertainties and ambiguities. Combining different data in the analysis may to some extent reduce the ambiguities, but the manual interpretation introduces other uncertainties. A discussion of the ice chart uncertainties is included in section 3.1 and the text has been revised to state this more clearly. Ice charts include these different regions mentioned above and we have included a discussion of the uncertainties in ice charts (sections 1.5 and 3.1).

The authors have discussed "smearing" of ice cover location but did not address "smearing" effects of orbital data gridding onto a fixed grid. These effects can be determined by comparing retrievals from ascending and descending satellite overpasses looking at ice edge that was not changed (in 10 to 12 hours between satellite passes) by prevailing winds We have developed a model for the "smearing" for this dataset using an radiometer imaging simulator. The smearing uncertainty is one of the two components in the total sea ice concentration uncertainty. The gridding uncertainty when binning swath data onto a predefined grid for example quantified by the daily grid point STDDEV is not independent from the tie-point uncertainty component and we have not been able to include it here.

The authors should have more systematic plan for testing their chosen algorithm. Signature areas of predominant sea ice type cover (e.g., Sea of Okhotsk for seasonal ice cover; old ice covered areas; mid-winter Labrador Sea ice cover) are ideal for testing algorithms. The algorithm testing is described in separate studies e.g. Andersen et al. (2006), Andersen et al. (2007) and in Ivanova et al. (2015). These references are given in the text. . . Section specific comments: In the abstract 1. Replace: American by NASA, NOAA, or NSIDC depending which agency was responsible for the satellite sensor, satellite launch, and satellite data processing Sea ice area by sea ice covered area OK.

2. Sentence starting on line 16: “The methodology. . .. . .and ending on line 21 is not clear It has been reformulated.

3. Are the authors saying that in preparation of this sea ice dataset : 1) NWP and RTM were used to reduce impact of the atmospheric conditions on the measured brightness temperatures; 2)to reduce the inter-sensor comparison bias dynamic tie points were used in retrieval algorithms, and 3) hybrid algorithm was created using Bristol and Bootstrap algorithms. Yes, that is true. We have tried to clarify this in the text.

This algorithm was used in estimation of the spatial and temporal variabilities in sea ice concentration retrieval accuracy. The algorithm was used for generating the sea ice concentration dataset.

4. Who generated “sea ice charts from the Arctic and the Antarctic” (lines 22 and 23) We have added: “U.S. National Ice Center” as the source. References to the datasets that we have used have been included in the text.

5. What are the “intermediate ice concentration” We have specified that now [between 1 and 99%].

6. Line 32: see comment #1 OK. We have specified the agencies.

7. Pg. 2, line 1: by “Here the sea. . .” The authors are saying In publications referenced above the sea ice. . ... OK. We have replaced “Here” with “Throughout this paper”

8. Pg. 2 line 8: replace “atmospheric parameters” by weather conditions such as wind generated ocean surface roughness and cloud cover OK. we have done that throughout the text.

9. What is “structural uncertainties” We have deleted the term because it is not really needed. Structural uncertainty is different outcome from different methods using the same data.

10. Line 15 Define “noise” OK, good point. Noise is the Tb fluctuations caused by the electronic components in the instrument, ice and water surface emissivity, and weather conditions, or anything which is not the sea ice concentration variability.

11. Why “climatic trends” are “artificial trends” ??? They are artificial trends because they appear as trends in the sea ice concentration but they are due to something else. This has been clarified in the text.

12. Be more specific in “for the properties that we are able to quantify,????? OK. “NWP data: wind, air temperature and atmospheric water vapour” it has been included in the text.

13. Please explain what are the “dynamical tie-points” OK. It has now been explained in the introduction.

14. “residual uncertainties” for which parameters and please, define uncertainty is it - accuracy. It is sea ice concentration accuracy. This has been specified in the text.

In section 1.1 Line 14 after “84°.” Should be replaced by: “SMMR data were acquired every second day” OK. “...because of satellite power limitations” has been added.

In Section 1.2 “The SSMIS data (used in this project?) are from the L2B near real time data-stream” received from??? Received via EUMETCast, initially processed at NOAA. This has been specified in the text.

In section 1.3: Please clarify your statement on lines 7 and 8. Was sea ice coverage included in NWP? If yes, where did that information come from? The sea ice coverage is included in the ECMWF numerical weather prediction model. These data are from the Hadley Centre: a compilation of ice charts from different ice centers and microwave radiometer data processed by J. Comiso, NASA.

In section 1.4 line 15 insert "The coarse resolution of the passive microwave brightness. . ." OK Line 22 and line 24 "Brightness above 220 (units?) 60 (units?) The pixels have brightness values between 0 and 255. These values are not calibrated to a physical quantity for brightness. Here they are used in a relative sense to identify pixels with sea ice and open water. We have included a short discussion of the albedo variability of water and ice. It is short because this is beyond the point here. The purpose of the image is only to provide realistic input data to the imaging simulator in terms of floe size distribution, the distribution of cracks and leads etc. The MODIS image concentration is only used as input to the simulator and not compared to coincident microwave radiometer data or other sea ice concentration estimates.

"We use 6 hourly data at a resolution of 1.25 degrees." Why this temporal and spatial resolution was used? This is the resolution of the model. The NWP data were interpolated to the satellite swath data.

Section 1.4 Line 15" add passive microwave in front of "brightness temperature" OK

Section 1.5 What does it mean by: "The operational sea ice charts from the National Ice Center (NIC) are a relatively independent . . ." this contradicts what you write in the text below these lines. OK, we have rewritten this section and taken your comment into account.

See also in section 3.3 "The NIC ice charts are produced manually on the basis of satellite and reconnaissance data"

Which satellite "pixel grid" are you referring to? This the the EASE grid where the sea ice concentration data is provided. This has been specified.

Section 2.1 The title of this section is misleading. Microwave (and thermal) emission received by satellite sensors is attenuated by the atmosphere. In addition, emission from the atmosphere contributes to the radiation measured by the spaceborne sensors. Over the old sea ice and open water this contribution could be significant in

comparison with the radiation from the sea surface. It is very true that the surface emissivity variability does contribute to the sea ice concentration uncertainty. However, the particular processing step which is described in section 2.1 is only reducing the uncertainty due to the weather conditions which are quantified by the NWP model.

Line 26 What is "wind shear" ? We have deleted "shear".

Liquid water has much greater contribution to the measured passive microwave brightness temperatures than water vapour. The cloud liquid water (CLW) is for sure one of the important error sources. However, it is difficult to correct for using NWP data because its spatial and temporal variability is not quantified very well by the model. We have selected a sea ice concentration algorithm over open water which has low sensitivity to CLW.

For the sake of clarity: Section 2.2 should be placed before section 2.1 Section 2.2 OK.

Brightness temperatures for what type of ice are selected to be considered for a tie-point ? Tie-points are selected for pixels where the NASA team ice concentration is greater than 95% and south of 84N in the Arctic in order to be consistent with the SMMR coverage. This includes both multiyear ice and first-year ice, but not new ice.

Section 2.3 How are the tie-point brightness temperatures are used to derive parameters in the Bootstrap and Bristol algorithms? The tie-points are reference points for 0% and 100% ice. This has been clarified in the text.

Section 2.5 It is not clear what the authors call "uncertainty". It has been defined in the beginning of section 2.5. Whenever referring to uncertainty it is the sea ice concentration uncertainty.

Is it a quantity representing statistical variabilities or derived quantity deviation from an accepted value? Yes, the sea ice concentration uncertainty is computed using our model for uncertainty which is described in section 2.5.

"ice concentration uncertainty of 1.4 % for the Bristol algorithm, and 1.7 % for the Bootstrap algorithm in frequency mode" compared to what? At what spatial and temporal resolutions? The instrument noise is an absolute error given in the same units as the ice concentration [percent]. The temporal resolution is given by the integration time of the instrument. Is this quantity relevant when discussing temporal and spatial variability and trends? The instrument noise is an independent error included in the tie-point uncertainty component (one of the two uncertainty components). The magnitude of this uncertainty is nice to know because it sets a lower level for the sea ice concentration uncertainty.

2.14 Level 4: Gap filling by spatial and temporal interpolation This section contains interesting description of filling in missing data. The gap filling is required if the proposed data set to contain high temporal resolution sea ice information. If the goal is to have data sets for climatology analysis, is it necessary to go through these additional computations? The step from level 3 (where no interpolation is done) to level 4 with temporal and spatial interpolation is not necessary but it increases the number of users of the data. The interpolated values are flagged so that it is possible to identify these as originating from interpolation.

In sections below, the authors discuss the hemispheric comparisons. Dis they actually filled temporal and spatial gaps in their data sets to carry out this analysis? Yes, the analysis is done on L4 data to avoid latitude-biases from coverage frequency (mostly relevant for SMMR).

Section 3.1 Where did the sea ice climate data records came from? The authors claim that the discrepancy between the ice cover values they derived and NIC ice charts are due to the "atmospheric noise". They could have taken a look at historical weather or AVHHR/MODIS cloud imagery to confirm or deny that is the main cause for the differences. This is "atmospheric noise" which is causing the discrepancies. AVHRR/MODIS data does not quantify water vapor, cloud liquid water, wind speed which are the major error sources over open water together with surface temperature. Sea surface temperature can of course be quantified using the infrared channels on

these two sensors but it is not the primary error source.

The increase in the discrepancy for the spring/summer seasons are very likely due to the algorithms do not accommodate seasonal variability in the emitting layer, e.g., melting snow, melt pond, change in the ice salinity. Statistics does not compensate for the physics of microwave radiation from different surfaces and propagation through the atmosphere. The dynamical tie-points that we use do compensate for seasonal and interannual changes in the sea ice brightness temperature signature globally. The local and regional variability in the signatures can, however, not be accounted for and does increase the sea ice concentration uncertainty. However, this increased uncertainty level during melt is quantified in the uncertainty estimate given for every pixel.

Part of the section 3.1 is dedicated to discussion of differences between NIC ice charts and ESICR data sets. Why than there is a separate section "3.3 Ice chart and ESICR comparison discussion"? The last paragraph in section 3.3 should be placed into the conclusion and summary section

Section 3.4 Do the hemispheric sea ice cover and open trends described using ESIGR generated data sets differ significantly from those observed by using Bootstrap or Bristol algorithms? We have moved the end of 3.3 to the conclusions according to your suggestion. It is clear that the Bootstrap, the Bristol and the ESICR is producing different trends given the same data. In the ESICR dataset the Bristol is used over ice (because it performed best over ice among all algorithms (Andersen et al. 2007)) and the Bootstrap is used over open water (because it performed best over water among all algorithms (Andersen et al. 2006)). This combination minimizes the sensitivity to noise overall.

Please also note the supplement to this comment:
http://www.the-cryosphere-discuss.net/tc-2016-34/tc-2016-34-AC1-supplement.pdf

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