

Sea ice in the Baltic Sea during 1993/94–2020/21 ice seasons from satellite observations and model reanalysis

Anonymous Referee #1,

https://editor.copernicus.org/index.php? mdl=msover_md& jrl=778& lcm=oc108lcm109w& acm=get_comm_sup_file& ms=120859&c=269726&salt=5798643141918097389

Thank you very much for taking the time to thoroughly review the manuscript and for providing your valuable feedback. We have carefully considered your comments and are pleased to provide our responses to your questions and remarks below.

General comments:

Rev1.1)

While methodology and results in the paper are properly presented and discussed, I have some questions and remarks on the used datasets and some other major comments below. Satellite data sea ice fraction was taken Copernicus SST product. According to product documentation this sea ice fraction comes from the ice chart in which it based on manual analysis. Thus, sea ice fraction does not come from any automatic algorithm, which must mentioned in the paper.

Response: Description “The sea ice fraction data in the product is taken from the sea ice charts from the national ice services at FMI and SMHI, which is based on manual interpretation by the operator” will be added in the manuscript.

Rev1.2)

Sea ice thickness seems to be taken from Copernicus Marine Baltic Sea–Sea Ice Concentration and Thickness Charts product dataset with product id SEAICE_BAL_SEAICE_L4_NRT_OBSERVATIONS_011_004. This dataset is the manual ice chart, and ice thickness is level ice thickness, and that is why you likely observed model overestimating ice thickness; more off-shore than near the coasts where there is level landfast ice. You refer ice thickness as the SAR & ice chart based product, but ice thickness in the ice chart is based on in-situ data from coastal stations and icebreakers. Or is there an error in the text and you in reality use Baltic Sea - SAR Sea Ice Thickness and Drift, Multisensor Sea Ice Concentration product which has sea ice thickness dataset where ice thickness from the ice chart is spatially enhanced using SAR imagery?

Response: There is no error regarding the sea ice thickness product. The product used in the study for sea ice thickness is indeed from Copernicus Marine Baltic Sea–Sea Ice Concentration and Thickness Charts product dataset with product id SEAICE_BAL_SEAICE_L4_NRT_OBSERVATIONS_011_004. The product has daily ice thickness data from the ice chart which is adjusted using SAR image, mentioned in the product user manual¹. It is validated against icebreaker ice thickness data in the QUID file of the product², and shows similar statistics to the Baltic Sea - SAR Sea Ice Thickness and Drift, Multisensor Sea Ice Concentration³.

References (for above text):

1. For Baltic Sea – Sea Ice Observations SEAICE_BAL_SEAICE_L4_NRT_OBSERVATIONS_011_004/011, Issue: 2.14, section III.1.1 Ice charts of the Finnish Ice Service
2. QUID for SEA ICE TAC Products 011_004, 011_011, 011_019, Ref. CMEMS-SEAICE-QUID-004_011_019, issue 1.1
3. Product id: SEAICE_BAL_SEAICE_L4_NRT_OBSERVATIONS_011_011, <https://doi.org/10.48670/moi-00133>

Rev1.3)

Section 4 should be under Section 5 'Results', and Section 5 could start with short introduction of the section contents.

Response: Suggested changes will be made in the manuscript.

Rev1.4)

The sea ice fraction threshold for calculating sea ice extent from the model data was tuned against the satellite data SIE. How do you know here that the satellite data SIE is more accurate than the model SIE? Possible that satellite data needs bias correction not model data?

Response: The sea ice data in the satellite product is based on Copernicus SI-TAC products (which includes Ice charts and SAR based sea ice data) and high resolution SMHI data [RD.5] (Product user manual: CMEMS-SST-PUM-010-016-040, <https://doi.org/10.48670/moi-00156>). Although SIE based on this data can certainly have uncertainties, these datasets have consistently been used in studies to validate other datasets (Karvonen 2021; Leppäranta 2023; Pärn et al. 2021; Mäkynen et al. 2020) and are available for a long term period.

Since there is not yet a better automatic tool for interpretation of sea ice in high resolution imagery, and due to the lack of field observations, ice charts are considered being the data sets that best describes the true state of the sea ice, and thus other sea ice data sets use these as reference.

(CMEMS-SI-QUID-011-001to007-009to014, QUALITY INFORMATION DOCUMENT

For SI TAC Sea Ice products 011-001, -002, -004, -006, -007, -009, -010, -011, -012, -013, -014, issue 2.10).

Required changes will be made in the manuscript to make it more clear.

Rev1.5)

In Section 4.2 explain how corrected ice thickness was calculated, diving by 1.814?

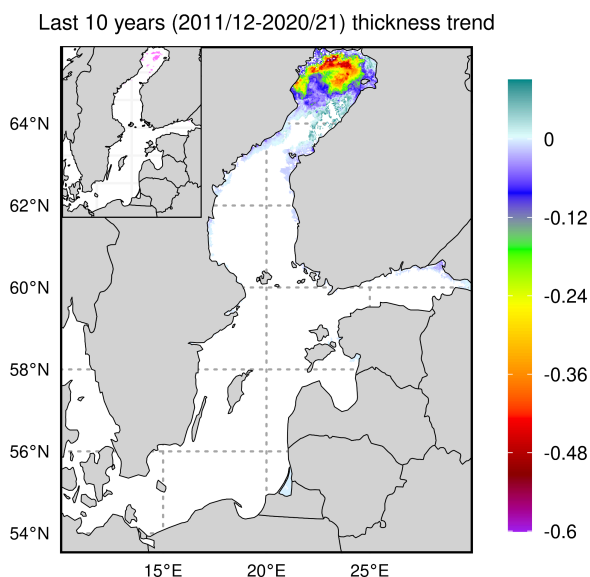
Response: Yes, that is correct.

It will be mentioned in the manuscript.

Rev1.6)

How results of the trend analysis would change if you use different time intervals, e.g. five or ten Years?

Response: In our study, the trends patterns for different time intervals are still somewhat similar with varying magnitude but due to smaller sample size, the trends are not significant at 95 percent confidence interval. Example figure for trend of last 10 years mean sea ice thickness (cm) attached below.



Specific Comments:

Rev1.7)

line 7: “recent period (2007–2021)”

Definition of this recent period here is vague without defining what is the preceding period. Figure 1 is not introduced and discussed in Section 1. Same color is used for Bothnian Sea and Danish Straits.

Response: Suggested changes will be made in the manuscript.

The relevant line in the abstract will be changed to “The sea ice characteristics during the recent period (2007/08–2020/21) show decreased sea ice fraction and thickness compared to the preceding period (1993/94–2006/2007) of the study.”

Figure 1 will be introduced and discussed. Color used for the Danish Straits sub-basin will be changed.

Rev1.8)

I. 28: BACC II Author Team, 2015

This reference is missing from reference list.

Response: Reference “Rasool, S. I., Menenti, M., and Bolle, H.-J.: Second assessment of climate change for the Baltic Sea basin, Springer, 2015” will be added in the manuscript.

Rev1.9)

*I. 42: “Remote sensing techniques have evolved to enhance the efficacy of ice information services”
Include here some newer references, e.g. papers by Karvonen et al.*

Response: Newer references “Karvonen 2017; Karvonen 2021” will be added in the manuscript.

Rev1.10)

*I. 55: ice state over previous model products (QUID_REAN).
Explain QUID_REAN, or give reference.*

Response: Reference “(Panteleit et al. 2019, CMEMS-BAL-QUID-003-011)” will be added in the manuscript.

Rev1.11)

I. 71: spell out SMHI and FMI when first time used.

Response: Suggested changes will be made in the manuscript.

Rev1.12)

*I. 80: “The system is forced by ECMWF ERA5 meteorology (ref).”
give reference*

Response: Reference “(Hersbach et al. 2020)” will be added in the manuscript.

Rev1.13)

*I. 123: “the dataset (the lm function from R)”
explain this lm function from R*

Response: Description “(the lm function from R, lm is used to fit linear models and can be used to carry out regression)” will be added in the manuscript.

Rev1.14)

*I. 131: “The quality information document (QUID) ...”
Give reference for the QUID document, it is not Karvonen et al. 2007.*

Response: Reference “(Panteleit et al. 2019, CMEMS-BAL-QUID-003-011)” will be added in the manuscript.

Rev1.15)

Figure 3 is introduced in the text after Figure 4.

Response: Required changes will be made in the manuscript.

Rev1.16)

Figure 8: very difficult to see black contour lines.

Response: Required changes will be made to improve visibility for the figure.

Rev1.17)

Table 3: maybe SIT data with 0.1 cm accuracy

Response: Suggested changes will be made in the manuscript.