

Anonymous Referee #2

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Please note that the comments from referee are given in black font “Times new roman”. Comments from the authors are given in blue font “Calibri”. The changes in the manuscript are given in green font “Calibri”.

General Comments

In this paper, the authors assimilate ice concentration and AVHRR-derived SST into a 10 km CICE model for Baffin Bay and the Labrador Sea for the period spanning from 2010-2015. A series of 3 experiments are performed to assess the model’s performance against ice thickness from SMOS, ice draft and keel depth from a ULS, and freeboard estimates versus CryoSat-2. A control run does not have any data assimilation, while the other two assimilate SST and SST and ice concentration. A nudging and optimal interpolation technique based on Lindsay and Zhang (2006) is used. Model mean ice thickness is compared against the SMOS ice thickness for the periods of Oct – March for the years 2010-2015. Overall, the “M2” test case which assimilates SST and ice concentration performs best, and is generally within the uncertainty bounds of the SMOS data; however there is a significant positive bias shown for all years. An impressive comparison of the model’s (M2) keel depth versus a ULS for 2005, 2007

and 2009 show very good agreement with data. However, model freeboard differences with CryoSat-2 data for Jan, Feb, and Mar 2011 show very little difference amongst the three test cases. Overall, while not “state-of-the-art”, this paper shows some improvement with the assimilation of SST and ice concentration in a regional ice modeling system. I recommend publication with minor revisions.

[We would like to acknowledge the reviewer for the comments and suggestions.](#)

Specific Comments

How are ice boundary conditions addressed in the model? Same technique as discussed in Prasad et al. 2015 paper? If yes, state this in the paper.

[The following text has been included for clarification](#)

“The net heat flux from the atmosphere is the upper boundary condition for ice thermodynamics. The heat flux from the ocean to the ice is the lower boundary condition. Based on temperature profile and boundary conditions the melt and growth of ice is computed. The open boundaries are configured in the same way as in (Hunke et al., 2010, Prasad et al., 2015)”

You use a 35-50 km SMOS ice thickness product for your thickness comparisons. You state that the SMOS data should not be used for thickness greater than 1 m; Figure 8 (middle column) shows a significant area of ice thicker than 1 m by March 15, 2011.

Why didn't you consider using a merged CryoSat-2/SMOS ice thickness product such as is available from AWI? Do you have plans to assimilate ice thickness or freeboard into your model?

Figure 8 has been described in the following sentence

“The Model M2 thickness, SMOS derived ice thickness, and the uncertainty of the SMOS derived measurement for 15 December 2010, 15 January 2011 and 15 March 2011 are shown in Figure 8, and include regions where observed uncertainties are larger than one meter”

During the time the merged product was not available. We will use the merged product in the future study. Yes, we do have plans to combine other products for assimilation.

Page 1 line 19: why limit discussion to “climate forecast researchers”? This is important for operational sea ice modeling as well.

The following text has been modified

“The climate forecast researchers and operational ice modeling communities depend on numerical modeling techniques implementing the physical process of atmosphere and ocean on large scale computational platforms along with data assimilation methods to retrieve the information on sea ice parameters.”

Page 3 lines 7-8: Why does the assimilation begin in January 2005? If the model is started from a no-ice state in September 2004, why doesn't assimilation begin in October 2004, when you should have data?

Please note that the AMSRE ice concentration product was available from January 2005 and hence assimilation started from the same period. Also, the model was given a 4 months spin-up.

Page 3 line 11: Explain how you use AMSRE for validation of the model if you are assimilating that same data?

This was corrected AMSRE was used for assimilation and the product was compared with OSI SAF data.

“ Ice concentration derived from AMSRE of resolution 6 X 4 km (Spren et al, 2008) were used for the assimilation of ice concentration.”

Page 4 line 1: What do you mean by “erroneous data”?

The following text has been modified for clarification.

The erroneous data, where the ice concentration error was 100% or retrieval algorithm has failed were filtered out before the comparison.

Page 7 lines 1-2: Why does M2 only assimilate SST when there are gaps in AMSR-E (and I assume AMSR2)? Why not assimilate all the time?

M2 assimilated SST only when ice concentration is not available for assimilation, otherwise the model assimilated both SST and ice concentration.

Page 8: Why is there no discussion on error reduction for the period from Nov 2012 – Dec 2015? A table of error stats would be helpful here.

Only an example has been provided here. The rest of the results are shown as Figure 4.

Page 9: Have you tested different values of α ?

Yes, different values of alpha were tested. A sensitivity of the parameter alpha has been shown in Lidsay et al. The value has to be further optimized considering the variable drag formulation variables for the model, which would be a future work.

Page 15: How is snow measured or estimated in the ULS data? I assume the model results shown in Fig. 13 are for M2? If yes, state in figure caption. How do M0 and M1 compare here?

Upward looking sonar measures the draft from below and the measurement of snow is not available. Since we were interested in the results of assimilated model only M2 results are given.

Page 17: I see little difference in Fig. 15 between column 2 and 3 in the plots. The paper states “M2 freeboard measurements are close to observed freeboard”. I disagree. Perhaps the Jan 2011 looks best, but overall, the differences seem small for all 3 test cases.

Yes, these differences are very small. But M2 is found to be the best match with the observation.

Page 1 line 18: add “it” after “makes” and before “practically”

Included

Page 2 line 7: rephrase to “into CDOM using a 3D”

Rephrased

Page 2 line 9: replace with “Lindsay and Zhang (2016)”

Replaced

Page 2 line 16: “extent were overestimated”

Changed

Page 2 line 19: “of the CICE model”; which version of CICE is used? Specify in text

Rephrased as

“CICE version 5.1.2”

Page 2 line 20: “, and the combination”

Rephrased

Page 2 line 21: “(Lindsay and Zhang, 2006; Wang et al., 2013)”

Changed

Page 2 line 22: replace “cheap” with “inexpensive”

Replaced

Page 2 line 24: “Baffin Bay and the Labrador Sea”. resolution. . .” “This work uses a high-resolution...”

Changed

Page 2 line 33: replace with “Density-based criteria (Prasad et al., 2015) to compute. . .”

Rephrased as

“ Density-based criteria were used as in (Prasad et al., 2015) to compute the mixed-layer depth and thereby compute the SST and the potential to grow or melt sea ice.”

Page 2 line 34: replace “fo” with “of”

Replaced

Page 3 line 3: give reference for and spell out NARR

References provided and NARR is replaced with North American Regional Reanalysis

Page 3 lines 7-8: reword last sentence as it is confusing. Page 3 line 10: “remote sensing data sets”

Rephrased as

“The data assimilation starts from January 2005 and continually assimilated whenever data was available.”

Page 3 Table 1: add a column with dates for AMSR2

Added

Page 3 last line: “The OSI SAF product”

Added

Page 4 line 2-3: reword sentence to “Measurements derived from AVHRR (Reynolds et al., 2007; Smith, 2016) were used for SST assimilation.”

Reworded

Page 4 line 18: “ice thickness (observations) shown in Table 2 include. . .”

Rephrased

Page 4 line 19: “knowledge of the”

Corrected

Page 4 line 22: “cover and the onset”

Corrected

Page 4 line 25: “from an ULS”

Corrected

Page 6: Reword first 2 sentences as they are poorly written

Rephrased as

“The assimilation module uses a combined optimal interpolation and nudging technique for ice concentration (Lindsay et al., 2006, Wang et al., 2013). The method can be represented generally as equation (1) (Deutch, 1965, lindsay et al., 2006).”

Page 5 line 12: here and in numerous places in the text, use “Lindsay and Zhang (2006) ” as the reference, not the way it is written in the paper.

Corrected

Page 7 lines 1-2: add parentheses to “AMSR-E (e.g., from 24 March 2005 to 31 March 2005), AMSR-E. . .”

Included parenthesis

Page 7 line 7: reword to “little improvement between M1 and M2 is shown for May 2010.

Rephrased as

“ Model M2 shows improvement in the ice concentration for January and March, but little improvement between M1 and M2 for May 2010. “

Figure 2: Makes dates Jan 2010, Mar 2010 and May 2010 BOLD black so they are easier to see. Caption is labeled wrong as it should be for Jan 2010, March 2010, and May 2010.

Corrected

Page 3 Figure 3 legend: reword to “The absolute error for models M0, M1, and M2 from a) January 2010 to September 2011, and b) August 2012 to December 2015.

The caption has been reworded to “the absolute difference for models ... “

Figures 5-7: Make the uncertainty shading a lighter gray as it is difficult to see the otherlines. What is the bias and RMSE for these comparisons?

Here we consider whether the model values are within the uncertainty limits of the observation.

Figure 8: same comment about making dates on plots readable. Can you add another column showing the difference between M2 and SMOS-MIRAS?

The figures has to be read with the uncertainty limits of the observation. Moreover, from Figure 5, 7 the uncertainty goes higher during late winter.

Figures 9-11: Make grey uncertainty lighter for readability. Captions not correct as M0 and M1 are shown (not just M2) as stated in Figure captions.

Captions are corrected.

Page 14: Explain the difference in uncertainty shown in Fig 11 from Dec 31 to Jan 1.

The following line has been added for clarification

“ the shaded region shows the uncertainty of the thin ice from SMOS data”

Page 14 line 7: reword to “blow-ups” or something similar

Reworded

Page 19: Make dates legible on all 9 plots.

Made clear

Page 20 line 13: sentence with “November end but lies” does not make sense.

Changed to

“The thin ice category thicknesses are overestimated from October to November end but the values are within the uncertainty limits of SMOS from December to March.”

Page 22: provide a more complete reference for Deutch 1965

Provided

Page 23 line 21: Provide a date for first Tietsche reference

Date provided