

This paper introduces new developments to the sea ice data assimilation in the ECMWF Ocean Reanalysis System. It particularly focuses on how to address the problem of implementing data assimilation increments into multicategory sea ice models. The experiments are well designed and thought out, and the results can be useful for sea ice data assimilation developments in the future. The article provides interesting and novel methods for improving the sea ice data assimilation method. However, the justification of some choices in the study as well as discussion of the results should be enhanced before publication. In addition, some of the figures need refining.

Major Comments

Why is OSISAF sea ice concentration chosen over other available observations? The choice of OSISAF data over other datasets needs to be justified in the text. It should also be considered how the observational uncertainty of the sea ice concentration observations effects the results particularly at the ice edge.

In figure 4 the authors only show the difference between the Gamma splitting and background splitting, but I think it would also be informative and useful for the discussion to show Peterson splitting against background splitting or Gamma splitting against Peterson splitting. This would be useful to see if there are further differences at the ice edge.

The ice induced temperature increment approach for the assimilation is interesting. I am wondering why the authors only chose smaller values of α than the control for their experiments in Section 6.3, and none larger? From the current analysis it looks like an α larger than five may lead to lower RMSE.

Minor Comments

Sometimes used sea-ice with hyphen and sometimes sea ice without hyphen, need to be consistent.

Line 24: NEMOVAR not defined

Line 28: Many others have applied Ensemble Kalman filter approaches which are relevant to this study:

Fritzner et al., 2019 assimilates SIC, SIT and snow depth in this approach

Williams et al., 2023 Assimilation of thickness distribution

Fiedler et al., 2023 Assimilation of Freeboard

As another method: Yang et al., 2014 assimilates sea ice using SEIK filter

Line 34: “Other developments on sea-ice assimilation including attempt to constrain” should be “include attempts to”

Line 50: remove “the” before SI3

Line 70: Are these the default bounds for the categories in the SI3 sea ice model or do the authors choose unique ones? Why are they chosen?

Line 106: “We have seen that” can be removed.

Line 126: Sea ice concentration and thickness are often treated as independent variables, but they can be correlated. For example during the melt season thinner ice will melt more quickly than thicker ice from the ocean and atmospheric forcings.

Line 201: should be “first appeared”

Line 216: “Is used” is repeated

Line 230: The sentence is unclear and quite long. It should be reworded or broken down for readability.

Line 274: The sentence “Ice induced temperature increments give the largest impacts of all developments.” should be expanded upon/explained further to conclude clearly.

Lines 282-292: The work of Bocquet et al., 2024 which produced a longer time series of freeboard and ice thickness from 1994 for both Arctic (winter only) and Antarctic (year-round) should be mentioned also. Numerous other studies which have also assimilated ice thickness/freeboard alongside Mignac et al., 2022 could also be mentioned.

Figures

Generally, in many figures the colour bar is not labelled and units are not provided.

Figure 1: The authors used “melt pond” in the caption, but “meltpond” without space in the figure, need to be consistent.

Figure 5: It’s difficult to see the differences with the current chosen colour scale.

Figure 7: “sea” is repeated in the caption.

References

Bocquet, M., Fleury, S., Rémy, F. and Piras, F., 2024. Arctic and Antarctic sea ice thickness and volume changes from observations between 1994 and 2023. *Journal of Geophysical Research: Oceans*, 129(11), p.e2023JC020848

Fiedler, E.K., Martin, M.J., Blockley, E., Mignac, D., Fournier, N., Ridout, A., Shepherd, A. and Tilling, R., 2022. Assimilation of sea ice thickness derived from CryoSat-2 along-track freeboard measurements into the Met Office's Forecast Ocean Assimilation Model (FOAM). *The Cryosphere*, 16(1), pp.61-85.

Fritzner, S., Graversen, R., Christensen, K.H., Rostosky, P. and Wang, K., 2019. Impact of assimilating sea ice concentration, sea ice thickness and snow depth in a coupled ocean–sea ice modelling system. *The Cryosphere*, 13(2), pp.491-509.

Williams, N., Byrne, N., Feltham, D., Van Leeuwen, P.J., Bannister, R., Schroeder, D., Ridout, A. and Nerger, L., 2023. The effects of assimilating a sub-grid-scale sea ice thickness distribution in a new Arctic sea ice data assimilation system. *The Cryosphere*, 17(6), pp.2509-2532.

Yang, Q., Losa, S.N., Losch, M., Tian-Kunze, X., Nerger, L., Liu, J., Kaleschke, L. and Zhang, Z., 2014. Assimilating SMOS sea ice thickness into a coupled ice-ocean model using a local SEIK filter. *Journal of Geophysical Research: Oceans*, 119(10), pp.6680-6692.