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Interactive comment on "Better constraints on the sea-ice state using global sea-ice data assimilation" *by* P. Mathiot et al.

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Better constraints on the sea-ice state using global sea-ice data assimilation

by P. Mathiot, C. König Beatty, T. Fichefet, H. Goosse, F. Massonnet, and M. Vancoppenolle

I am an expert neither in glaciology nor climate modelling. I will comment on the data assimilation aspect and the related methodology which represent a significant part of this study.

I enjoyed reading the manuscript which has a clear and straightforward structure. To my

superficial knowledge on glaciology, this study is state-of-the art and quite demanding since the authors used a 25-member EnKF on a wind-forced global coupled sea-ice 3D model, for over 2 years of simulation. This seems to represent a very significant work.

I have several comments and criticisms on the methodological part, which I believe could significantly be improved. I see there four main problems:

(1) The description of Eq.(1) is just wrong. This equation applies to the forecast and analysis state, not each member of the ensemble. There is no such equation for the Ensemble Transform Kalman filter that you claim you use. There is a similar update equation for the stochastic EnKF but the observations in $\mathbf{d}$ are independently perturbed for each member.

(2) Some essential parameters (of indirect physical relevance) are missing in the data assimilation setup. What are the localisation lengths used here? What are the error priors chosen for each variable type? Do you resort to inflation?

(3) To run a consistent synthetic experiment, you should perturb the observations, which you do not seem to implement.

(4) By only describing the *analysis* experiments, your experiments just prove that your data assimilation system is consistent. In general, on average, the data assimilation run should be closer to the observation. But this is not enough to prove that it is useful. To truly validate a data assimilation system, there are several approaches. In your case, since sea-ice forecasting is of major geophysical, societal and industrial interest, I would suggest that you perform forecast experiments. For instance, each month of the 2-year experiment, perform a one-month (or longer) forecast and compare with the observation. Compare the performance of the free and data assimilation forecast run.

Assuming I correctly understood the authors' methodology, my main criticism is on point (4) which may require additional work.

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Minor remarks or related to the main points:

(5) p.1628, l.6 : Change "sea ice" to "sea-ice", for the sake of consistency.

(6) p.1628, l.9 : Change "through the use of satellite data" to "though the use of real satellite data". Otherwise the non-opposition to "synthetic" in the same sentence creates a confusion.

(7) p.1628, l.25 : Please define "Ice concentration". That is obvious to most of us but could help a broader readership.

(8) p.1632, l.20-21: What is "qualitatively close"?

(9) p.1634, l.16: "The EnKF is a sequential data assimilation technique that approximates model error statistics by using an ensemble of model runs". No: although it is clear you understand the point, the statement is misleading. Prefer "The EnKF is a sequential data assimilation technique that approximates state estimation error statistics by using an ensemble of model runs"

(10) p.1635, l.3-15: Please, clearly state that you are using an ensemble transform ensemble kalman filter.

(11) p.1635, l.16: See comment (1)

(12) p.1635, l.25: "Therefore, we decided to exclude these variables from the state vector.": do you mean "from the control vector"?

(13) p.1635, l.25-26: contradicts line 16.

(14) p.1637, l.21. Eq.(5) isolated in between two sentences.

(15) p.1638: I believe that Section 4 could be split and merged into Section 5 and Section 6.

(16) p. 1640, l.16: "the data are compatible with the model physics": when the data are perturbed as they should be, they are not per se compatible with the model physics.

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But the EnKF handles them by projecting the innovation onto the ensemble space. I suggest rephrasing: "the unperturbed synthetic observations are consistent with the model physics".

(17) p.1640-1641, Section 5.1: Please detail the chosen error magnitude such as the prior errors. What are the localisation lengths? (There must be one length together with a support radius to report.)

(18) p.1642, Section 6.1: Please, detail the chosen error magnitude such as the prior errors. What are the localisation lengths?

(19) p.1644-1646: Validate with a forecast (for instance). See main point (4).

(20) Throughout the text, there should not be any capital E in the "ensemble Kalman filter", only in the acronym.

(21) Throughout the manuscript: punctuation marks in the equations are missing.

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