Reviewer 2:

Summary

The authors investigate the fully multivariate state and parameter estimation though idealized simulations of a dynamics-only model using the MEB sea ice rheology. They employ an iterative ensemble Kalman Filter (iEnKF) DA approach with a stopping criteria set to 40 iterations. The model runs are performed with a spatial resolution of 15 km and a 30 sec timestep to ensure numerical stability while resolving propagation of damage.

Four scenarios are evaluated inferring the model physical variables 1) under a perfect model setup (truth), 2) and the drag coefficient C_a, 3) and its erroneous damage parameters α, and 4) and its erroneous C_a and α. Different inflation strategies are used for all 4 scenarios. In scenario 1, a 42-day run free ensemble without DA, is followed by a series of 30-day assimilation experiments in which 3 of the 9 fields are bounded quantities (SIC, SIT, level of damage). When only 1 field is assimilated, that field gets most of the improvement. The cross-correlation between differing quantities is examined. In scenario 2, only one observation type (SIC or SIT) is assimilated, the analysis underestimates C_a at the end of the analysis time. However, assimilating SIC was closer to truth. They found the best skill in estimating C_a when assimilating SIV alone due to its close relationship with wind forcing and C_a. In scenario 3, the assimilation of SIC or SIT alone led to and under- and over-estimation of α after 30 days. The simultaneous assimilation of SIC and SIT led to almost a full recovery of the true α value of 4. Results showed that observations of SIV can not be used to retrieve α effectively. When all types of observations were assimilated in Scenario 4, the estimate of C_a was furthest from the truth. They found that the forecast of SIV can not be improved because it is strictly constrained by the wind field while other model fields with longer timescales showed improved forecasts. They suggest that coupled DA that estimates external forcing could improve SIV.

This a well written and well referenced paper with clear thought put into designing and executing the experiments. The tables and figures are concise and easy for the reader to understand. I recommend publication with minor edits as outlined below.

General Comments:

1. Line 395-396: Please comment on the statement "when SIT is assimilated with SIC, the adverse effect is subdued". This is partially true for $D < 0$, but for $d > 1$, damage is at 20.93%. Please explain.

    Answer: Thanks for the comment. This is a valid point. We add the following discussion on this in line 396 (revised manuscript):
    Interestingly, however, when SIT is assimilated together with SIC, the boundedness of the level of damage is improved for undamaged sea ice ($d < 0$ for analysis before post-processing) but is not so for completely damaged sea ice ($d > 1$ for analysis before post-processing). Yet, it is sufficient to improve the overall RMSE of the level of damage (see Fig. 5). One possible reason is that, without the thermodynamics, the forecast error mainly comes from the damaged sea ice and the overestimation of undamaged sea ice has little contribution to the RMSE after the post-processing .

Specific Comments:

1. Line 45: Add the following references: (Xie et al., 2018, Blockley and Peterson (2018), Fiedler et al., 2022)

    Blockley, E. W. and Peterson, K. A.: Improving Met Office seasonal predictions of Arctic sea ice using assimilation of CryoSat-2 thickness, The Cryosphere, 12, 3419–3438, https://doi.org/10.5194/tc-12-3419-2018, 2018.

    Fiedler, E. K., Martin, M. J., Blockley, E., Mignac, D., Fournier, N., Ridout, A., Shepherd, A., and Tilling, R.: 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, 61–85, https://doi.org/10.5194/tc-16-61-2022, 2022.

    Answer: They are added, thanks for the suggestions.

2. Line 54: with "the" changing number. . .

    Answer: Added, thanks.

3. Line 64: such "a" model

    Answer: Added, thanks.

4. Line 70: . . . has not yet "been" studied extensively. . .

    Answer: Added, thanks.

5. Line 87: . . . DA system "consisting" of

    Answer: Changed, thanks.

6. Line 96: rephrase to "methods can be found in chapter 7"

    Answer: Changed, thanks.

7. Line 105: remove "we"

   Answer: Removed, thanks.

8. Line 153: ..."the" DA's ability...

   Answer: Added, thanks.

9. Line 164: ...with "a" uniform...

   Answer: Added, thanks.

10. Line 396: effect is subdued check...

    Answer: This sentence is removed due to the major comment.

11. Figure 8: "true" and "forecast" blue lines are a bit difficult to differentiate. Can one of the colors be changed?

    Answer: Thanks for raising the point. We changed the colour of the forecast line from light blue to black, the truth uses a red line and the freerun still uses a blue line. We hope it reads better visually.

12. Line 593: use of "the" ensemble OR use of "an" ensemble

    Answer: Added, thanks.

13. Line 617: ...shed "light" (not plural)

    Answer: Changed, thanks.

14. Line 642: Is there another reference to add after "Bertino, 2009"? If not, remove the "," before the ")"

    Answer: Removed, thanks.

References