Response to comments on "Adjoint-Based Simultaneous State and Parameter Estimation in an Arctic Sea Ice-Ocean Model using MITgcm (c63m)" by François Massonnet (UCLouvain)

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The only point where I remain skeptical is on the justification of the use of one year only (2012) in the experimental setup. This point was also raised by the other reviewer, and I do not find a convincing reason why the experiment has not been replicated on another year. Is it because of a lack of computational resources? A lack of verifying observational data? To me, it is key to show the readers that the results obtained from one year are portable on other years; and if that hypothesis cannot be tested, then the authors must state the reasons.

On the statement in their response "In theory, when applying the data assimilation system to another year, data assimilation will adjust the control variables to bring the model simulations close to the observations for that specific year", I agree that it is how it *should* work, but can we have the proof? Can one simulation be done with the parameters of 2012 on another year? Again, this is to ensure the transferrability of the results to other years that the setup was tuned for. And if it is not possible, then the authors should acknowledge it.

Response:

We thank the reviewer for his thorough comments.

The use of a one-year assimilation window is primarily due to constraints on computational resources and time.

In this study, we demonstrate that the joint optimization of spatiotemporally varying parameters, initial conditions, and atmospheric forcing is technically feasible—and that this approach further improves sea ice simulations. This finding is particularly relevant for Arctic ocean and sea ice reanalysis, given that the optimal set of sea ice parameters may evolve alongside the thinning of Arctic sea ice. Additionally, optimizing the parameters of coupled ocean-sea ice models also merits testing with other assimilation methods (e.g., the Ensemble Kalman Filter, EnKF).

As we anticipate, the optimized parameters may not necessarily improve simulations for other years, given that the optimal set of sea ice parameters is likely to evolve alongside the thinning of Arctic sea ice. To address this, we plan to assimilate observations spanning the satellite era (1978–2025) and jointly optimize model parameters and state variables. This approach will enable the accurate reconstruction of historical Arctic ocean and sea ice changes, thereby supporting research on Arctic ocean and sea ice variability and trends

To avoid over-interpretation of this study and clarify our purpose, we have added the following text:

(1) in the Abstract (L26-29): "Given that the optimal set of sea ice parameters may evolve alongside the thinning of Arctic sea ice, the adjoint-based SPE scheme has the potential to more accurately reconstruct the histical Arctic ocean and sea ice changes

covering the satellite era, supporting research on Arctic sea ice and ocean variability."

(2) in the Conclusion and Discussion (L455-461): "This study demonstrates that the simultaneous optimization of model parameters and state variables is promising and merits testing with the other assimilation methods (e.g., ensemble Kalman Filters). However, given that the optimal set of sea ice parameters may evolve alongside the thinning of Arctic sea ice, the parameters optimized using 2012 observations may not necessarily improve model simulation for the other years. To address this, we plan to assimilate observations spanning the satellite era (1978–2025) and jointly optimize model parameters and state variables. This approach will enable the accurate reconstruction of historical Arctic ocean and sea ice changes, thereby supporting research on Arctic ocean and sea ice variability and trends."