Review of “Model-to-model data assimilation method for fine resolution ocean modelling” by Georgy I. Shapiro and Jose Maria Gonzalez-Ondina.

General comments

The manuscript presents a novel method for DA in a high-resolution ocean model (child) which is nested into a coarse-resolution data assimilated model (parent). The method consists of two steps: stochastic downscaling of the parent model to the grid of the child model, and an assimilation step using the downscaled field as observations and applying a simplified Kalman gain formula to obtain an analysis for each grid node independently. The method is demonstrated for 3 synthetic cases. The manuscript is well-written and nicely structured. The readability of the manuscript could however be improved by better visualization of the results.

My main concern with this manuscript is how well suited the three cases are to demonstrate the potential of the method for the proposed application, namely high-resolution ocean models. All three examples are two-dimensional fields of one state variable that can be described by smooth functions. I find the lack of small-scale variations that would mimic sub-mesoscale features in the true fields to be an unrealistic assumption in the presented experiments, as such variations will always be present in any realistic case. High-resolution models can be useful applications for dynamically active regions offshore. However, high-resolution models are more frequently applied for coastal regions. The examples in the manuscript do not address the suitability of the proposed method for regions where increased resolution is applied to better resolve complex topography and coastlines with mismatch in land mask between parent and child models, nor is this issue addressed in the discussion.

Another question that remains unanswered is whether the description of the ocean state is dynamically consistent after an assimilation procedure that is applied point-wise for each state variable. If this is not the case, it will most likely result in numerical instabilities when initializing the forecast from such an analysis and thus additional post-processing will be required for the method to be applicable.

While the motivation of the preprint is highly relevant and the suggested method has some appealing qualities, I am not convinced that the results presented here are sufficient to support the claim that the SDDA is an appropriate method for improving the accuracy of a fine resolution ocean model. Therefore, I recommend reconsidering publishing the manuscript after major revision.

Specific comments

Introduction:
Line 63-64: The synthetic cases are not introduced or otherwise mentioned in the main body of the manuscript before this point. I would suggest either rephrasing or including a sentence or two in the above paragraph.

Data and Methods:

Line 80: In the general equation for the cost function the observation operator *H* may include a conversion from model variable to the observed quantity in addition to interpolation, although this is not the case for the presented method.

Results:

$\mathbf{V}_B$ and $\mathbf{V}_R$ determine how much weight is given to the fluctuations of the background vs the fluctuations of the downscaled product. I cannot see that there's any mention of how the values of these key parameters are set, nor a discussion on how these choices affect the results. The aim should be to weight the two solutions in a way where the child model is prevented from drifting from the assimilated parent model, while at the same time retaining high-resolution dynamical features that arise from e.g. improved topography.

The proposed SDDA method consists of two steps, namely a stochastic downscaling of the parent model to the grid of the child model, and an assimilation step where the downscaled parent model values are treated as observations and combined with the first guess of the child model. I think an analysis of how these two steps contribute to the total improvement of the SDDA could provide valuable insights. Given the smooth nature of the chosen examples, I suspect the DA step might increase RMSE and bias compared to the intermediate solution given by the SD step.

Fig 7: It is nearly impossible to see any difference between figures 7c and 7d - perhaps zooming in on a smaller part of the grid or using a different colormap for the difference plot could be beneficial?

Discussion:
In the discussion, the SDDA method is compared with a "standard" DA method, and is demonstrated to be superior. Again, the choices for **B** and **R** will strongly affect the results and it would thus be relevant to report whether or not they differ significantly between the two methods, as well as how changing their values affect the results. Evaluating the cost function values in addition to RMSE and bias could perhaps also help to shed light on the differences.

As spectral nudging (see e.g. Katavouta and Thompson, 2016) addresses the very same issue as the proposed method, namely ensuring that a high-resolution model does not drift away from the large-scales that are well constrained by observations assimilated in coarser ocean models, I think a discussion on how the SDDA method compares with spectral nudging both in terms of quality of the results and computational efficiency would be of interest to the target audience for this manuscript.

Figures:
The authors might want to consider adopting scientific colormaps and avoid using red and green colored lines in the same plots. See e.g. Crameri et al. (2020).

Technical comments

Data and methods:
Equation 1: the observation vector **y** should be in bold font.
Line 84: A period is missing after the reference.
Line 96: a "b"-superscript seems to be missing from the left-hand side of the equation.

Line 200 - 201: Same resolution is stated for both parent and child.
Line 214: “A = 1”
Line 219: “eddies *can* exist nearly anywhere”

Results:
Line 241: “an analysis” or perhaps initial conditions?
Although the section indeed presents results for cases A-D, the statement at line 242 of “four examples” reads as a typo in the current context.

Discussion:
Line 424: observation***s.***
Line 468: mode***l***-to-model

References

Crameri, F., Shephard, G.E. & Heron, P.J. The misuse of colour in science communication. Nat Commun 11, 5444 (2020). https://doi.org/10.1038/s41467-020-19160-7

Katavouta, A., and Thompson, K. R. (2016). Downscaling ocean conditions with application to the gulf of maine, scotian shelf and adjacent deep ocean. Ocean Model. 104, 54–72. doi: 10.1016/j.ocemod.2016.05.007