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Interactive comment on "A 20-yr reanalysis Experiment in the Baltic Sea Using three Dimensional Variational (3DVAR) method" *by* W. Fu et al.

W. Fu et al.

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Anonymous Referee #1 Received and published: 28 June 2012 General comments In their manuscript the authors present a multi-decadal Baltic Sea reanalysis experiment for the physical state of the Baltic Sea. For this experiment they employ a data assimilation system presented by Zhuang et al. (2011), based on the well known 3DVAR scheme. The reanalysis is then compared to independent observations to show that the results of the reanalysis improve when the data assimilation scheme is used. The reanalysis described in the article is an interesting contribution to the field that will allow new worthwhile studies. It would, for instance, be useful to construct several Baltic

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Sea reanalyses with different data assimilation systems and models. This would allow for inter-comparisons between e.g. different data assimilation systems and Baltic Sea models, which might deepen understanding about their performance. According to the paper one its goals is to assess the performance of the 3DVAR scheme in a long integration. While the comparison to nonassimilated runs is a good first step in this task, it would be beneficial in the future to also compare 3DVAR against other assimilation schemes for these kinds of applications. However, this task can be left to later studies, and I hope the authors return to these questions then. In general the methodology in the paper seems sound, although using 3DVAR for reanalysis is harder to justify than for operational purposes. Zhuang et al. (2011) motivate the use of 3DVAR in this system among other things with its low cost of computation, but this argument should be less relevant for this paper, since for operational purposes timely delivery and resource concerns are of greater importance than for reanalysis runs. The material is presented in a sufficiently clear manner, although both figures and language leave room for improvement. I recommend publication after minor revisions.

Reply to general comments: We'd like to thank the reviewer for the positive comments. This paper focuses on a long term reanalysis on the basis of an operational forecasting model, which, we think, is one of the best forecasting models in the Baltic Sea. Coverage and quality of the reanalysis may benefit a variety of other studies such as model-data comparison, case study, climate detection, etc. We agree on that data quality and timely dlivery are the kernel of a forecasting system for operational purposes. In this study, the 3DVAR is chosen as the assimilation scheme for its low computational cost and easy management (no adjoint model is required as in the 4DAR. Since the forecast model is now under continuous development, handling the ajoint model requires much more efforts and man power than the 3DVAR). Implementation of the 3DVAR is only a starting point of the assimilation system. In this paper, we aim at validating the method and acquaring experience for futher development. In the mean time, we attempted other assimilation methods such as the ensemble-based Optimal Interpolation for the same model and some results are compared with the results using current method.

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Some more results will be reported in the near future.

Specific comments 1. The language of the article needs to be polished thoroughly. There are for example several typographical errors which could have been caught with a common spell checker. The authors might want to consider a professional proofreading.

Thanks. A typo checking is performed through the paper to correct some spelling errors. Some sentences are reformulated and we also correct some grammatical mistakes.

2. I couldn't find a clear description of how 3DVAR is applied to the model. Since 3DVAR does not take the time dimension into account like 4DVAR, this means that the authors must have either assimilated each observation individually, or chosen some time window for which observations are gathered and then assimilated into the model at once. Since the first option is unlikely, I would appreciate a clearer description of this process in the article. How often is the data assimilation run? How is the choice of the time window motivated? Zhuang (2011) dealt with short operational forecasts, so one can reasonably assume that there the assimilation was applied before each run, but in this article the run is 20 years long.

Thanks for the comment. We add some more details on the implementation of the 3DVAR. As the reviewer said, the observations are combined into a time window and assimilated. Unlike 4DVAR, temporal impact of observations is not accounted for the 3DVAR. The T/S profiles are assimilated daily into an operational model if observations available. Assimilation time window is an important issue but is not much investigated in this paper. Since there is no adjoint model involved, observations witin a time window are usually assigned with different 'influence factor' according to the time lag in an empirical way. According to Zhuang et al (2011) and Fu et al (2011), the observations assimilated at one time show impact on the following forecast for 2-3 weeks However, as we know, the time window can be variable in different areas of the Baltic, for in-

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stance, the bottom Baltic proper water could be stagnant for years while the Danish strait water experiences quick changes. By assimilating the observations once a day, we assume that the continuous injection of observed information can gradually draw the model state towards the observations in an optimal manner. 3. Is this the first published multi-decadal physical state reanalysis for the Baltic Sea? If so, please state this more explicitly in the introduction, or alternatively cite previous reanalyses. Are you aware of any similar datasets?

Thanks for the suggestion. As far as we know, there is no published multi-decaldal reanalysis for the Baltic Sea and this is stated in the introduction.

4. The model domain apparently includes the North Sea, but results for it seem to be discarded as only Baltic Sea is presented. Why is that? Should this be discussed in the manuscript? Thanks. Figure 1 is modified to show our main focus . The North Sea has features different from the semi-enclosed Baltic Sea.For the purpose of presentation, the results in the North Sea will be analyzed in another paper.

5. Does the model include an ice submodel? If not, then that might limit the usability of this reanalysis in further studies. If it does, then please add at least a brief discussion of it, including the effect of SST assimilation to ice results. It would be quite simple, for example, to plot total ice extent and compare whether SST assimilation affects this at all.

Unfortunately, the ice submodel is not addressed in this study. The model used in this study includes the thermodynamics of ice built on Semtner's layer model (Semtner, 1976) but not the dynamics. A new full ice model is being developed in the DMI and will be included in the forecasting/assimilation model system.

6. Zhuang et al. (2011) tested the validity of 3DVAR implementation with a test case with an isolated observation. Have you either then or since then for this article done other test to assure yourself that your implementation of 3DVAR is valid? Do you feel confident in the correctness of your implementation also for long integrations like this?

Thanks. Zhuang et al (2011) described the implementation of the 3DVAR and re-sults from 1-year experiment. Since then, we have tested both the anisotropic and isotropic Recursive filter, the effect of de-correlation scales, the impact of observations in delayed-mode, etc. Some technical issues are also examined to ensure the stable integration for multi-decadel run, for instance, the dynamical quality-control procedure.

7. p. 1935 l. 12. eco-system -> ecosystem Thanks. It is corrected.

8. p. 1940 l. 9. Have you tested larger magnitudes than 3 deg C and 2.5 psu? If so, what happened? Thanks. If the innovations exceed 3 deg c or 2.5 PSU, in the Bornholm region, the model produces spikes in the vertical stratification and gets crashed sometimes.

9. p. 1940 l. 15. nexe -> next Thanks. It is corrected.

10. p. 1945 l. 16 Recommend changing mon -> month. Using the nonstandard abbreviation saves only two letters but introduces the risk of misunderstanding. You might also consider changing yr->year elsewhere in the text, where appropriate Thanks . the abbrevations are changed accordingly in the paper..

11. p. 1958 l. 10 The Zhuang et al. (2011) reference should be updated to the OS article instead of the discussion paper. Thanks. It is updated.

12. Figure captions should be improved. Many captions are short and it takes time to find the information related to the figures from the text. Clearer captions would make the paper more accessible. Thanks a lot. We update the figure captions with clearer description.

13. Figure 1: This figure seems to represent the domain of the model. However, the caption references a model called "DMI-BSHCmod", while the text references a model called "HIROBM-BOOS" (p. 1931, l. 4). Which one is used? This figure also does not clearly indicate the actual domain. I recommend adding coordinates of the domain boundaries to the caption and a line indicating what seems to be the boundary of the

model between the North Sea and the North Atlantic at approx. 59N. Consider either adding or changing this figure to a picture of the actual model bathymetry, which is not currently depicted. Also, the nested grid described in the text is not shown anywhere. There are many things that could be improved in this figure and it would benefit from a total redrawing.

Thanks a lot. Figure 1 is redrawn and updated. The Baltic Sea is presented where the nested grid is demarcated. Since the main focus lies in the Baltic Sea, the open boundary in the North Sea is described in the text and referred to a technical report for detailed description.

14. Figure 6: rmse->RMSE, bais->bias Corrected.

15. Figure 9: rmse->RMSE, bais->bias Corrected.

16. Figure 10: Caption has extra parenthesis. Thanks. It is corrected.

17. Figure 11: Stamp maps are tiny and hard to decipher. Please consider if they could be made more readable. Thanks. The maps are updated.

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