Nonlinear Processes in Geophysics Discussions

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Comment on npg-2021-5

Anonymous Referee #1

Referee comment on "A study of capturing Atlantic meridional overturning circulation (AMOC) regime transition through observation-constrained model parameters" by Zhao Liu et al., Nonlin. Processes Geophys. Discuss., https://doi.org/10.5194/npg-2021-5-RC1, 2021

Review of "A Study of Capturing AMOC Regime Transition …" by Z. Liu, S. Zhang, Y. Shen, Y. Guan and X. Deng.

In this manuscript the authors describe a series of twin experiments in which the Ensemble Adjustment Kalman Filter (EAKF) is used for state and parameter estimation in models of the Atlantic Meridional Overturning Circulation (AMOC). The models in question are box models, driven by atmospheric input taken from the output of chaotic, rather than stochastic systems. The authors demonstrate that their methods allow reliable estimation of unknown parameters in the model AMOCs, which exhibit multiple stable equilibria. The results described here will be of interest to a broad segment of NPG readers, but the manuscript as it stands needs a great deal of work to make it acceptable.

Application of data assimilation methods to use observations to track the evolution of solutions of systems that exhibit multiple stable modes has been described by many authors since the 1990s; see, e.g., Weir et al., Nonlin Proc Geophys 2013 and references therein. A look through the literature since the 1990s will also turn up examples of simultaneous state and parameter estimation in simple systems. The novelty of the present work lies in the specific application to regime transitions in the AMOC. I don't know of other examples of application of optimized methods such as the EAKF to joint state and parameter estimation of box models of the AMOC, which have been around since Stommel (1961).

The authors need to be more specific about exactly how their results differ from existing results, and why they are interesting. The closest thing that I can find to a statement of purpose appears at the end of the introduction, p4, beginning on line 111: "Here we

present a method for improving the modeling of AMOC multi-equilibria. The new method is shown to simulate the AMOC transition between different equilibrium states accurately in two simple coupled models …" As noted above, others have shown the ability to simulate transition between different equilibrium states in other systems. If the authors' methods are novel, they should point out their differences from other methods that have been applied to similar systems.

Their presentation of their three box model, equations (5)-(10) is confusing. Why different systems of equations for the thermal and saline modes? For details of the model they refer the reader to Shen et al. (2011) and the model described there is a single system that exhibits both saline and thermal modes. The model they finally use, defined in equation (12), is a complex system with many switches. I don't understand why this is necessary. Why not just use some form of (5) from Shen et al. (2011)?

The results they get from this model, driven by a chaotic atmosphere, are encouraging. Figures 5-7 show that the data assimilation/parameter estimation system works well, reproducing the "true" trajectory quite accurately and producing a good estimate of the unknown parameter, while leaving out the parameter estimation steps, and using EAKF for state estimation without adjusting the parameter to its true value does not do nearly so well.

At the end of this section the authors state: "The MOC3B-5V model is just a simple conceptual model, and the model states x2, w, and η simply conceptually simulate the variation characteristics of the atmosphere and the ocean. Although the transitions of AMOC are simulated by the MOC3B-5V model, the specific physical meaning of the model is not explicit enough. The method of capturing regime transitions in Sect. 2 is proved to be feasible in the simple model, and the next step is to apply the method to a physics-based MOC box model." The next section describes experiments with a "physics-based MOC box model," which is no more complicated than the MOC3B-5V model in the previous section, and the authors do not make clear what conceptual points are made with the MOC3B-5V model that are any less clear in the "MOCBM." It seems to me that the sections dealing with the MOC3B-5V model, i.e., much of section 2 and all of section 3 could be left out entirely without any loss of understanding on the part of the reader, however convincing figures 5-7 may be. It shouldn't be too hard for the authors to include additional figures corresponding to figures 5b, 6 and 7 to illustrate the details of the MOCBM experiment

The two systems dealt with here are highly parameterized, but the parameter the authors chose to estimate, in both cases, was a parameter in the atmospheric model, equations (11) and (16). Why didn't they choose a parameter in the box models?