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Geoscientific Model Development Discussions
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Interactive comment on "AMOC-emulator M-AMOC1.0 for uncertainty assessment of future projections" *by* Pepijn Bakker and Andreas Schmittner

Anonymous Referee #1

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The authors introduce a new box-model based emulator of the Atlantic meridional overturning circulation, M-AMOC1.0, to the community. I agree entirely with the motivation for doing so. Uncertainty in future climate projections and the responses of GCMs to them due to parameter uncertainty are key challenges in the field of climate science. The paper is well written, and easy to follow. Figures and tables are sufficient and clear (some typesetting issues aside).

I am rather underwhelmed by the performance of M-AMOC1.0 as presented here. It does not capture the response of the GCM sufficiently well that I would be confident in the results. As it currently stands neither the uncertainty in the emulator itself or its ability to assess uncertainty in AMOC projections are explored rigorously.

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Discussion paper

However, I find the idea interesting and I am sympathetic to the motivation. I would like to see the emulator published, but only subject to major revisions.

Major comments:-

I don't understand the reasoning for why you generate 100 reasonable fits and then select only the 10 best fits (P7 L15). Firstly, this emulator/box-model should be cheap to run, so why choose such small numbers? Surely ensembles of order 10,000 or 100,000 are more reasonable. Secondly, the choice of 10 best fits seems to narrow the ranges of several parameters (e.g. V4, F1, h1, Γ). By doing this you rule out large regions of parameter space that give perfectly reasonable fits, and could behave differently under different forcing scenarios. If the primary aim is to assess uncertainty in AMOC projections I would expect to see a rigorous analysis of the uncertainty. By discarding large areas of parameter space uncertainty will certainly be underestimated.

In the four scenarios not seen by the emulator (Fig. 8) the behavior of UVic is clearly not captured in two cases (lower left and upper right). There are no confidence intervals plotted (or computed as far as I can tell), but I believe the GCM would lie well outside 2 standard errors in those two cases. Therefore, the GCM would still need to be run for any untested scenario. I would not trust the emulator in its current form.

On multidecadal timescales the emulator is plagued by sensitivity to surface temperature oscillations. These seem to have arisen from the addition of the atmospheric boxes to the ocean box model published by Zickfeld et al., 2004. Can the authors confirm that this is the case, and if so can they control this sensitivity, e.g. by introducing a damping/mixing term?

If the authors have good reason to retain this behavior they need to test the sensitivity to the phase of the variability. For all of the scenarios, the chosen start date (2006) appears to be shortly after a peak in the strong multidecadal variability, so the AMOC is preconditioned to decline at this time. Under all scenarios the AMOC in the 'best' emulators appear to decline faster than the UVic model. Consequently, the SA tuning

and the cost function used may be adversely affected by this multidecadal variability.

On centennial timescales the emulator (as currently presented) does not capture crucial features of the AMOC response to the forcing (Fig. 7). In particular I would draw attention to the RCP4.5 scenarios, in which the GCM exhibits a strong reduction followed by a steady recovery. The emulator fails to identify either the timing or amplitude of the AMOC minimum and it fails to identify the recovery phase. In addition it appears to show signs of a recovery phase under RCP8.5 when UVic shows none. The authors state (P9 L28) that the fit can be improved, but that this would entail a higher overall cost function for the SA tuning method. Is this indicative of a poor choice of cost function? Does it mean that the box model should be tuned separately for each scenario?

A far more substantial summary is required. For example, the emulator's limitations need to be clearly stated (and whether/how the authors think these can be addressed). For what purposes are the emulator suitable in its current form, and for what purposes might it be useful subject to further work? With the current analysis, I disagree with the statement that ". . .the UVic-based AMOC-emulator captures well the overall characteristics of the multi-centennial response of the AMOC. . .".

Minor comments:-

Page 3 Line 12: Prescribed FW fluxes: F1 and F2 are tuned parameters. I would have expected these to vary as a function of the forcing/climate. What is the justification for fixing them?

Page 5 Line 10: What you also fail to consider are nonlinearities between these parameters. Co-varying the parameters in Tables 1 and 2 could yield very different behaviours.

Page 5 Line 30: algorith > algorithm

Page 6 Line 4: I find the arbitrary choice of +/- 200% rather strange. What is the

justification for this?

Page 6 Line 8: analogues > analogous

Check typesetting in Tables (e.g. Table 1 column 2)

Table 1: (typo) dependend > dependent

Check typesetting on Figure 8: it appears corrupted.

Figure 4 caption: (typo) relatvie > relative

Figure 8 caption: (typo) calculate > calculated

Figure 8 caption: (typo) rigth > right

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