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Earth System Dynamics
Discussions

Interactive comment on "Collapse of the Atlantic Meridional Overturning described by Langevin dynamics" *by* Jelle van den Berk et al.

Jelle van den Berk et al.

jelle.van.den.berk@knmi.nl

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The paper by van den Berk et al "Collapse of the Atlantic Meridional Overturning described by Langevin dynamics" is an interesting application of the classic analytical approach of Poston and Stewart with introduced stochasticity for modelling AMOC trajectories of the EMICs published in [Rahmstorf et al 2005]. I think the paper should be published after a minor revision.

R: We thank the reviewer for helpful comment and suggestions. Below our responses.

The title should be corrected: "Modelling collapse of the Atlantic Meridional Overturning using the Langevin dynamics".

R: Our suggestion would be "Characterisation of Atlantic Meridional Overturning hys-

teresis loop using Langevin dynamics" to emphasise the purpose of the paper better: using a reduced set of numbers to quantitatively describe the AMOC collapse under a freshwater forcing.

As the authors admit themselves, EMICs are not sufficiently,representative of the real climate. Also, given the number of parameters the authors use to fit their model (six) and their geometrical origin (see description of ν and λ), Iunderstandwhytheauthorsclaimthatonlythef reshwaterf orcingisthevariablethatdeterminesthedynamicalb

R: There seems to be a typesetting problem here that renders some of the comment unreadable. However, the other possible forcing effect is thermal, and in principle a sufficiently large warming could also halt deep water formation and collapse the AMOC. Since temperature changes are not a forcing variable in the climate models, we have not included this effect.

It would be interesting to see how the model can be used for forecast of bifurcations. The authors perform derivation of the model parameters using Bayesian framework, but once the model has been fully formed and the parameters are obtained for several EMICs, can the authors attempt forecast or hindcast of the bifurcating time series?

R: We thank the reviewer for this interesting comment which could be explored in further research. A forecast from a partial AMOC weakening series would require a continuation of the freshwater forcing timeseries, and maybe making use of the EMIC derived values as estimates. The value of te freshwater forcing is crucial, however, but this may be estimated from climate projections

[Rahmstorf et al 2005] paper used 11 models and only hysteresis loops were presented (not actual AMOC trajectories) https://agupubs.onlinelibrary.wiley.com/doi/pdfdirect/10.1029/2005GL023655?download=true

R: This is a link to Rahmstorf &a (2005) and another set of even simpler models (with a total of 11 models) are studied in that paper. Those models only have an energy

balance model as the atmospheric component. We ignored those because of their simplicity and argue that their characterisation is too far removed from the real world or CMIP class models.

Can a figure be added with plotted time series that could be derived from the obtained model? For example, for the set of parameters averaged over a set of the selected EMICs? I wonder how realistic could be the time series and at what time scale it could forecast an AMOC bifurcation?

R: This is a good suggestion, but unfortunately no timeseries were given in the published data. To derive those new runs have to be made. The hysteresis loops are obtained by changing the forcing with small steps and then obtaining a new (quasi) equilibrium state for the changed forcing.

I understand that the framework is quite heavy computationally. Can the authors add discussion on how applicable can be this approach in other areas of geosciences where similar potential models may be used?

R: In principle, any hysteresis curve that is produced under a forcing where the lambda and nu transformations suffice to normalise the curve could be used. Other geophysical processes might be icesheet mass loss (e.g. Robinson, Alexander & Calov, Reinhard & Ganopolski, Andrey. (2012). Multistability and critical thresholds of the Greenland Ice Sheet. Nature Climate Change. 2.), forest dieback (e.g. Staal, A., Dekker, S.C., Xu, C. et al. Bistability, Spatial Interaction, and the Distribution of Tropical Forests and Savannas. Ecosystems 19, 1080–1091 (2016)), or lake turbidity (Scheffer, M., van Nes, E.H. Shallow lakes theory revisited: various alternative regimes driven by climate, nutrients, depth and lake size. Hydrobiologia 584, 455–466 (2007). Any process which allows two stable states with rapid transitions between them and an asymmetric response to the forcing could be described by our method. We will add the above as an additional paragraph to the discussion (with the above references included not inline, but as usual).

The authors derived datasets from the published figures - is it allowed practice? Shouldn't they be obtained from the authors as datasets? Can the authors add information about the derived datasets in the table (number of points, etc)? Also, can more recent EMICs be used?

R: We strongly support the development of open science and making data findable and accessible. Unfortunately we have been unable to obtain the original datasets from the authors (we unfortunately received no reply to our request). The (individual points of the) measured values were retrieved from the plots by inverting the transformation matrices. This can be done for certain plots that are converted to pdf from plotting software such as Matlab. The dataset is then numerically the same as the set used to produce the plots in Rahmstorf &a (2005). The publisher allows for the use of individual graphics from their publications: we will note this in the text.

We will include a table with additional information about the dataset.

In principle any hysteresis curve can be used, but we have not expanded the data set beyond the Rahmstorf &a set.

Further comments

The abstract should be modified to say that model is fitted to the trajectories.

R: To be corrected.

In the first paragraph, AMOC acronym is introduced twice.

R: We will remove the 2nd mention.

Instead of "invigoration" it is better to say "re-activation".

R: To be corrected with “resurgence” as suggested by our other reviewer.

Line 90 – "diagrams"

R: To be corrected.

Figure 2 - labels in all panels should be of the same font size

R: We will replot with the same label size.

Line 124 - "the simplest"

R: To be corrected.

Line 152 - grey lines are mentioned in Figure 4, not clear which, maybe make them dashed? Similarly, dashed lines in Figs. 6,7 are impossible to see - enlarge these figures and all labels.

R: We will replot with a colour different from grey and enlarge the labels.

Table 1 should be expanded to include more information on the selected models - countries, resolution, etc.

R: We will include such a table.

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