Review report of Ziegler & Rehfeld, "TransEBM v 1.0: Description, tuning and validation of a transient model of the Earth's energy balance in two dimensions"

By anonymous reviewer

Manuscript summary

Ziegler & Rehfeld present a two-dimensional energy balance model (EBM) in this manuscript, originating from Zhuang et al. (2017) but modified and improved in a number of aspects. The authors introduce EBMs as part of the larger modeling hierarchy and argue their special importance for understanding the climate system on long timescales. The model description is thorough and detailed enough to be read independently from Zhuang et al. (2017).

The model is tuned to ERA20CM reanalysis data, runs are compared with this data set and the original EBM by Zhuang et al. (2017). The model sensitivity to forcing is tested, and the extended EBM is also tested by running a millennium-long experiment run. A tutorial is included, and the manuscript is complete with discussion, conclusions and three appendices.

Overall impression and recommendation

The manuscript is well-written with an overall good structure. Most sections are clear and concise but see my suggestion in the minor comments below on sections 2.2 and 2.3.

The presentation of figures and tables needs some improvements.

I am happy to recommend the manuscript for publication after minor revision.

Relevant scope and novelty of the manuscript

It is pleasing to see that the authors present a state-of-the-art EBM in this study, making solid arguments to the applicability of such models as complementary to high-complexity general circulation models (GCM). The authors make the TransEBM v.1.0 easily accessible and improved compared with the EBM by Zhuang et al. (2017).

The contributions of the authors are clearly communicated in the manuscript. Ziegler & Rehfeld tune their model version to reanalysis data, providing means to test the model simulation skill in terms of root-mean squared errors (RMSEs). Furthermore, model extensions compared with the TransEBM by Zhuang et al. 2017 are summarized in Table 6. I take the liberty to categorize these modifications into two groups, where the first are of purely technical form. These include separate files for the individual surface maps, gathering the configuration in one external configuration file, providing complete output time series of T, C and S, and allowing parallelization of runs.

The other category can be perceived as extensions to the EBM modeling scheme: restarting, allowing transient, user-defined forcings and transient runs instead of constant forcings and equilibrium runs only. These latter modifications are validated in Sect. 3.2 and 3.3.

Minor comments, general:
I find the flow of the text disrupted in Sect. 2.2, due to the many small tables and long table captions. I ask the authors to make the row/column structure consistent for every parameter and shorten the captions if possible.
I suggest rewriting paragraph 2-4 of Sect. 2.3, preferably placing the details related to software, computer type, compilers and processor in the same paragraph.

Minor comments, specific
L. 10, 210,364: when referring to the climatological period, I would prefer to write the complete year 1989 (1960-**1989**, instead of 1960-89). You switch between both writings throughout the text.
L. 18: "…fill gaps left by proxy and observational records,» -> isn't a proxy record also an observational record? Consider reformulation.
L. 233: "… were only discarded if they produced a change in GMT by several degrees". Please specify to greater detail the cut-off. "Several degrees" is not informative enough.
L. 127: "…timescales of order 10^2 years and higher", consider replacing "higher" with "longer".
L. 251-252: "TransEBM agrees well with the reanalysis. In particular, it is able to simulate the dip in temperatures around the equator as well as the temperatures in the polar regions. « This appears to be contradicting the sentence on Discussion lines 371-372, or you need to elaborate:
"In the latitudinal temperature distribution, the dip in temperatures near the equator related to the Intertropical Convergence Zone (ITCZ) is not reproduced."
L.269-285: consider specifying that the validation in this subsection relies of the implemented restarting extension.
L. 286-306: Similarly, this validation is associated with the extension to transient forcings and transient simulations. Consider highlighting these features.
L. 288: "…follows Neukom et al. 2019, as does CO_2.» Not clear what you mean by "follows", please reformulate.

Comments on figures, including color choices
The following comments on color choices and contrasts for the figures are given because printed colors appear slightly different than they do on the screen. A high-quality printer was used for printing this manuscript, so the following comments should be generally applicable.

Page 5, Figure 2: the black font on blue background color is difficult to read in printout. You use italic fonts for CO_2 for the first time in the caption. Italics are also used later in the main text, but inconsistently. Normal fonts are used e.g. in the abstract. I prefer normal fonts for CO_2, please check throughout the text and make the use consistent.

Page 12-13, Figures 6-7: the individual colors used to distinguish "changed" and "unchanged" features are too similar for the printout.

Page 14, Figure 8: Yellow-ish colors are difficult to discern for the printout.

Page 20, Figure 13: Please add legends to this figure as well.

Page 21, Figure 14: colors of PAGES2k and CESM time series are too similar to discern for the printout.

Page 29, Figure C1: both panels labeled as (b). Numbers superposed on the maps are difficult to discern for printout.

Comments on tables:
Consider shortening captions for tables 1-4 in sect. 2.2.

Page 19, table 9: consider specifying the context of the zero-sea level of Grant et al. (2012).

Suggested addition and references:
Introduction pages 2-3, lines 58-73:
Studies show that EBMs are able to simulate hysteresis and tipping points, but CMIP5 GCMs cannot simulate such strong transitions, exemplified for the Arctic sea ice and the Atlantic meridional overturning circulation (Wagner & Eisenman (2015), Bathinay et al. (2016)). It could be relevant to highlight this capacity of the EBMs compared with more complex models.

Comments related to the GitHub code repository
Include readme file in repository:
The code is well-documented in the GMDD manuscript and in the GitHub repository. Please ensure that the manuscript and associated documentation can be easily traced from the repository. A readme file visible on the front page of the repository is recommended, referring to the Zhuang et al. (2017) and Ziegler & Rehfeld manuscripts. The readme file could for instance also list the necessary software needed to run the code and repeat the statement of the software license which is included in the manuscript.

Suggestion of test code visible on the front page of the repository:
The authors describe the default configuration file on manuscript lines 325-329. This information together with other defaults could be summarized and highlighted in a separate "Test run" file of the repository, instructing the user to an example testable code to help validate their installation.

References
Bathinay et al. (2016), "Beyond bifurcation: using complex models to understand and predict abrupt climate change», *Dynamics and Statistics of the Climate System*, 1, 1-31 (1), https://doi.org/10.1093/climsys/dzw004
Wagner & Eisenman (2015), «How Climate Model Complexity Influences Sea Ice Stability", *Journal of Climate*, 28 (10), 3998-4014
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