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Nonlinear Processes in Geophysics
Discussions

Interactive comment on "Anthropocene Climate Bifurcation" *by* Kolja Leon Kypke et al.

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In this paper an energy balance model (EBM), presented in (Dortmans, 2019), containing a surface (represented by a surface temperature) and a single layer atmosphere (represented by the atmospheric radiation) is forced with increasing greenhouse gas concentrations following the four IPCC RCP scenarios. The EBM can represent different zonal bands, or the polar regions with oceanic and atmospheric heat fluxes across the zonal boundary. The model includes ice albedo – and water vapor feedbacks and an implicit ocean and atmosphere heat transport feedback.

The model has a bimodal regime with a saddle node bifurcation to a warm polar region state, which will be reached after the next century if the CO2 level reaches 2000 ppm. The mechanism responsible for the bifurcation structure is via the sigmoidal dependence of ice albedo on temperature, essentially similar to Budyko-Sellers EBM. In

the parameter space spanned by the atmospheric CO2 concentration, the water vapor relative humidity, the oceanic heat transport and the steepness of the albedo switch, there is a cusp separating the fold and a mono-stable state.

The paper is well written, and I recommend publication. The authors might, however, consider a few revisions, which in my view would make it even more readable:

First of all, it is always a delicate balance, how much material to repeat from previous papers, in this case the reference above introducing the model. In my view it is either or: Either the reader is required to also consult other papers, or the paper should be fully self-contained. In the latter case a few additions would be helpful:

Explain the asymmetry between eqs. 1 and 2: Why use I_A and not T_A as variable? As is now, both have dimensions of W/mˆ2, with the consequence of different dimensionalities for c_S and c_A. This confused me at first.

Eq 10 for vertical heat transport f_C seems overly complicated for such a simple EBM. It is stated that the formula is obtained (derived, I take it) in (Kypke 2019. This a PhD thesis, which is not easily accessible for the reader. Consider at least hinting at where it comes from. Perhaps even a graph, f_C as a function of T_S. Though hard to read, I think there's a ")" missing (same goes for eq 22).

Now the mathematical analysis begins with Eqs 15 and 16: It would be helpful to remind the reader that mu enters via eta (through eq. 9), since mu will be the "control parameter" in the following.

A few more remarks:

Figure 6 (a) shows the responses in the four cases before the bifurcation point. These responses are quite linearly related to the RCPs (Figure 4). The same goes for the GCM scenarios presented in IPCC AR5 (Fig AI.8). The statement (line 239) that the EBM results are in good agreement with the GCM projections is thus an overstatement, both are related to the RCPs.

The bifurcation for the Arctic and not the global EBM depends critically on the oceanic heat transport F_0. It would be useful with a comparison of this EBM with the classical 1-d EBMs where meridional heat transport is modelled as a diffusion.

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