Earth System Dynamics Discussions

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Comment on esd-2021-7

Anonymous Referee #1

Referee comment on "Abrupt climate change as a rate-dependent cascading tipping point" by Johannes Lohmann et al., Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2021-7-RC1, 2021

This well written work proposes a conceptual model coupling ocean dynamics with sea-ice cover dynamics. Their model exhibits rate-induced bifurcations in the ocean dynamics and their results suggest that cascading bifurcations may be a general mechanism in inducing abrupt transitions in climate systems. The authors nicely illustrate the influence of noise on the bifurcation behaviour with convincing numerical simulations. The authors further show that the critical slowing down experienced during rate-induced bifurcations may be difficult to detect using the standard variance indicator (but is readily detected in the sea-ice dynamics which experiences a "classical" bifurcation) and propose a simple indicator based on estimating the elements of the associated Jacobian.

I enjoyed reading the paper and believe that its results — both on the particular role of rate-induced bifurcations on cascading transitions and on warning indicators — are valuable for the community, and I recommend publication subject to some comments the authors may want to take on board.

The authors identify the importance of sea-ice for the occurrence of abrupt climate changes and couple its dynamics into a Stommel box model. The authors may want to put their model with its inherent dynamic mechanisms in context to other similar attempts highlighting the different implied dynamical mechanisms; for example the conceptual models considered by Boers et al, Proc Natl Acad Sci 115(47):E11005–E11014 and by Gottwald, Clim Dyn (2021) 56:227-243.

The authors tune the parameter h in (5) to allow for what they coin smooth bifurcations. Are there observations suggesting that transitions are smooth or non-smooth? Also, it might be helpful to show the two cases of non-smooth and smooth in Figure 3 (and also for the Stommel model). This would clarify what the authors mean by smooth and non-smooth bifurcations; depending on the background of the reader these terms may invoke different associations. Might also be worthwhile defining this in the manuscript.

It was not clear to me how their model allows for the succession of abrupt climate changes such as the DO events mentioned in the introduction. The model seems to

capture only single transitions. Can the authors comment on this?

Regarding the new proposed warning indicator J. Am I correct in thinking that the reason why looking at the individual elements of the Jacobian rather than at the eigenvalues of the Jacobian is that the estimation of each element is done via finite-differencing (which is a bad estimator for noisy data) and calculating the eigenvalues exacerbates this via multiplication?

Typos and minor comments:

Figure 1. What are the values of \eta_3 in (b) and of \eta_1 in (c)

Line 266: andBoers —> and Boers