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The Cryosphere
Discussions

Interactive comment on "The tipping points and early-warning indicators for Pine Island Glacier, West Antarctica" *by* Sebastian H. R. et al.

Anonymous Referee #2

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In this manuscript the authors seek to detect the onset of marine ice sheet instability (MISI) in model simulations of Pine Island Glacier, using techniques that have previously been applied to other complex systems. The novelty of this study lies in the application of critical slowing indicators to confirm MISI events. It provides an interesting framework for evaluating vulnerabilities in ice sheets that will be of interest to the TC scientific community. However, particularly due to its novelty within glaciology, some aspects of the paper need improving to aid the clarity, and it would benefit from further exploration/discussion of the usefulness of the techniques beyond the modelling example provided here. I have outlined these below, followed by line-by-line comments.

The paper includes a nice explanation and accompanying schematics of hysteresis; however, the critical slowing description and explanation of the indicators is less intu-

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itive. This may partly be due to the structure – Appendix A offers a useful demonstration of how critical slowing manifests in a carefully controlled simple experiment. I think it is safe to assume most TC readers will not be familiar with these concepts, and therefore I do not think this example should necessarily be tucked away in an appendix. A diagram of critical slowing in a similar vein to Figure 1 would be helpful, or some additional annotation to Figure A1. There is a disconnect between the flowline example in Appendix A, and the methods used for determining the onset of a tipping point in the main set of experiments. Could you show how critical slowing in the flowline experiment can be demonstrated with the various indicators you use in your main experiments? This would help show how these indicators are related to the the increased recovery time from a stepwise perturbation as the tipping point is approached.

My other main comment is about the usefulness of this method in detecting early warning signals in reality. Would the 300-year optimal window size apply to other catchments? What kind of observational datasets are required to implement this analysis, in a way that would act as a useful early warning system for MISI? The measurement used in this study (grounding line flux) does not exist (at least not at the quality/resolution required here) prior to the satellite era, so what is the alternative, given the 300-year window size? In your model simulations the forcing is applied gradually in order to avoid "one tipping point cascading into the next and result in three individual tipping points being misinterpreted as only one event" (L168). What are the implications of this for detecting tipping points in observations, where the system is not necessarily able to return to a quasi-steady-state with changing forcings? Do you have a sense of whether the indicators would hold up if the forcing is more rapid? Further discussion of these issues would strengthen the paper.

Other comments:

L13: "Self-amplifying retreat" this could be considered an overstatement. Self-sustaining retreat would be more accurate (and more in keeping with language further on in the manuscript).

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L18: “early warning indicators robustly detect critical slowing for the marine ice sheet instability”. It might be worth removing the term “critical slowing” from the abstract, and instead using a less jargon-y alternative, e.g. “robustly detect the onset of MISI”?

L31-32: “a complex range of factors can either cause or suppress the MISI” – such as? The two papers cited refer to buttressing, what about local sea level, GIA etc? Haseloff, 2018, should be Haseloff and Sergienko, 2018.

L68-70: “Our results reveal the existence of multiple smaller tipping points that when crossed could easily be mis-identified as simply periods of rapid retreat, with the irreversible and the self-sustained aspect of 70 the retreat being missed”: this seems to contradict your results and conclusions. The two smaller tipping points are not irreversible, as the system can return to previous state through stronger perturbations in the opposite direction – shown by the hysteresis loops in Figure 3.

L106: Basal melt rates: it is not clear from this paragraph whether basal melt occurs under grounded ice. How do you treat partially grounded elements? This has been shown to be important in modelling grounding line retreat (e.g. Seroussi and Morlighem, 2018, doi: 10.5194/tc-12-3085-2018).

L153-159: Unlike the other paragraphs in this section, this paragraph does not contain an outcome of your decision-making process – which of the criteria will you use?

L180-181: “Furthermore, the indicator reaches a critical value relatively close in time to when the MISI event gets underway”. Clarify that the critical value is 1.

L183-185: “For this early warning indicator…”. I don’t understand this sentence and it seems like it would be better suited (with added detail) to the methods. I thought both indicators have a critical value of 1 (section 2.2), so why does scaling the DFA help with comparison to ACF?

L188-189: “although variance cannot be used directly to predict when that threshold will be crossed” – perhaps this is obvious, but why not? Because there is no critical value? But crossing the critical value doesn't seem like a robust way of detecting the exact onset of MISI either, considering some of the trend lines in Fig. 4 cross x=0 before they reach the critical value?

L275: What do you mean by "i.e. a record length of 600 years" – how does that relate to the window size? Is that the minimum record length required?

L258: Basin of attraction has not been defined/explained.

Figure A1: Panel A, grounding line position in km: clarify the direction of retreat.

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