Answer to interactive comment on "Delaying future sea-level rise by storing water on Antarctica" by K. Frieler et al.

Please find the authors' answer below in red.

Anonymous Referee #1
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Review comments on the paper: Delaying future sea-level rise by storing water on Antarctica

By Authors: K. Frieler, M. Mengel, and A. Levermann

General comments: As a scientist in the field of climate change and as a practitioner in the field of mitigating its potential effects on our society, I am willing to entertain and in favor of all comprehensive, inclusive and well-studied innovative ideas that would help resolve the current and "potential" future effects of the climate change in a sustainable manner. The focus of my review of this paper is based on this point of view.

In this paper the authors are proposing the idea of pumping sea water on the Eastern Land mass of Antarctica for the purpose of, as it is stated in the title of the paper, "Delaying" future sea-level rise. This title in itself has raised red flags in my mind when it comes to sustainable mitigation efforts of the problem. The answer to that question was given by the authors in the conclusion of the paper where they state: "When the pumping is stopped the additional discharge from Antarctica will increase the rate of sea-level rise even beyond the warming-induced rate. In this sense the presented approach means raising a loan on Antarctica that future generations will have to pay back." Aside from all the other deficiencies that exist in the current paper, whether it is an admitted deficiency or an ignored (not considered) one, this conclusion in itself should have been good enough a reason for the authors not to pursue this idea further.

Yet, we have a technical study, which after an elaborate and detailed modeling exercise, tells us that ice flows slower than liquid water which may help delay the sea-level rise for a considerable period of time. In this reviewers opinion this is not a scientific finding which is worthy of publication.

Specific comments:
Page 4: The authors, after detailed analysis of the energy requirements of the proposed procedure, reach the following conclusion: "Although the approach may be the only way to protect entire coast lines it will not be feasible without major technical innovations solving the fundamental energy problem. In the following we explore the option from an ice dynamical point of view."
a. This reviewer does not agree with the premise of the above statement, that is the proposed approach is the only way to protect the entire coastline.
b. This reviewer is of the opinion that the proposed procedure does not address the concerns of vulnerable coastlines further away from Antarctica although the statement above refers to "entire coastline." As the authors probably well aware, due to sea water temperature differences, the sea-level rise is negative near Antarctic when compared to the

impact on low lying land masses for island regions near warmer regions. Has the authors analyzed the spatial variation in sea-level rise which is reported to be an important concern in IPCC (2013) studies, and how the proposed procedure will mitigate those concerns at warmer regions over the next 100 years while pumping is going on in the Antarctic region? Will there be any significant effect (if any) for those warmer regions over the next 100 years?
c. The author's conclusion in the above statement on pp. 4 (and also in the conclusion) is that the proposed procedure is not currently feasible from the energy requirements point of view. Given this observation the authors pursued this idea from an ice dynamics point of view to show the reader that the back flow to sea will be delayed. In the opinion of this reviewer, this is not a scientific finding but a good modeling exercise.

Page 4: The authors in their study estimate the following: "The water volume that is equivalent to one meter of global sea-level rise would elevate the Antarctic ice sheet by ~25m if distributed uniformly. The currently observed ~3mmyr-1 of global average sea-level rise due to thermal expansion, additional water added from glaciers and ice sheets, and changes in land water storage corresponds to about 1012 m3 yr-1 of ocean-water volume."
Given that we are to mitigate 2 to 5 m of sea-level rise, have the authors estimated the effect of the weight of this added sea water on the land mass, or on the propagation of the ice sheet in front of this newly added frozen sea water near to the coastline?

Page 9: The authors for the first time refer to the salinity issue in the statement, "In this context it has to be noted that the additional ice that is added to the ice sheet is made of sea water and thereby will have salinity."
And in the following statements they indicate that they have not looked into the rheological or the computational effects of this condition. Here the authors are completely discounting the current and potential future environmental effects of placing a layer of frozen salt water ice sheet over a land mass. How does potential salt water discharges that would occur in the future replacing the current rate of fresh water discharges affect the environmental balance of the salinity of sea water and sea water circulation and many other problems associated with that such as saltwater intrusion into coastal aquifers in the future?

Page 9: In the conclusions the authors state "This study has to be complemented by investigations on possible consequences of the procedure. . ..." and they go about listing many problem areas that need to be investigated. This reviewer agrees with this point which only renders the current paper an incomplete study.

Conclusion: In conclusion there are more unanswered questions related to the proposed procedure than the findings reported in the study. This is reported by the authors at various places of their paper. In light of these reasons the proposed process is not feasible (according to the authors) and would place a significant burden on future generations (as stated by the authors). Aside from these two observation, the technical findings of the paper is not significant for it to be considered for publication.

Answer:

We provide a joint answer to the different objections as they are commonly based on assumptions regarding the role of science we do not share.

First of all a scientific paper does not have to provide a full answer to a given problem. In fact, this is very rarely the case facing highly complex problems involving different disciplines. In contrast, knowledge generation is a stepwise process building a many different individual contributions.

Secondly, science does not have to judge whether a certain approach should be followed or not. Instead it can only provide the insights to enable societies or decision makers to evaluate certain options of responding to a given a problem.

Our paper introduces an option of delaying sea-level rise by storing ocean water on the Antarctic ice sheet. It provides an estimate of the distance from the coast that is required to allow for a millennium-scale storage. It offers a deeper understanding of the processes determining the critical distance. Whether a delay of sea level rise is helpful, worth the effort, or beneficial facing other negative side-effects is a societal decision.

Thus, given our conclusion that "…the presented approach means raising a loan on Antarctica that future generations will have to pay back." society has to judge whether the idea should be pursued further. It is neither a decision of the authors nor of the reviewer. We clearly state the limitations of the approach and the limitation of our assessment following best scientific practice.

Regarding specific objections going beyond what we consider a misinterpretation of the role of science by the reviewer:

1. Spatial patterns of sea level rise

The additional ice would increase the mass of Antarctica and thereby the attraction of the surrounding ocean water. This well-known gravitational effect is expected to increase the sea level in the vicinity of the Antarctic continent compared to the global mean in favor of higher populated regions further north where sea level will be reduced stronger than the global mean.

2. Salt water discharges

The salt water stored on the Antarctic continent would be taken from the surrounding ocean and slowly transported back. The process is not expected to significantly alter the salinity of the southern ocean.

3. Effect of the weight of this added sea water on the land mass

These effects are expected to be locally restricted to the Antarctic continent and negligible on the time scales considered. The Antarctic ice sheet is on average 3-4000 meters thick. The ice added will be of the order of a percent of that.

In a revised manuscript we are more than happy to take all comments of the reviewer into account and discuss them in the manuscript.

We do however strongly believe that the manuscript that we provide represents a valid scientific study and that the reviewer has not presented any scientific argument against its publication.

We hope that the editor agrees with us on this point.

Sincerely,
Katja Frieler, Matthias Mengel and Anders Levermann