Review of Kreuzer et al. by Caroline van Calcar

Kreuzer et al. quantify the significance of relative sea level change on the critical access depth of Antarctic ice shelfs, and therefore on the ocean temperature and basal melt rates. To study this relation, relative sea level changes are computed using a coupled 3D GIA – ice sheet model. The present day bedrock topography is adjusted accordingly, after which the critical access depth is computed using a flood fill algorithm. Finally, the changed ocean temperature for the adjusted topography is used to compute basal melt rates on the present day ice geometry using the PICO model. They find significant changes in basal melt rates when accounting for relative sea level changes for three different scenarios; one for last glacial maximum conditions, one hypothetical ice free scenario and one projection up to the year 2300.

The manuscript is well written and the results are presented in outstanding figures. The results are analyzed thoroughly and provide detailed insights on the effect of relative sea level changes on critical access depths, ocean temperatures and basal melt rates. The method provides an opportunity to study this effect without the need of a computationally expensive ocean model. Even though the method contains significant simplifications compared to using an ocean model, the manuscript has significant scientific value because the results provide a first order estimate of the range of basal melt rate changes when including relative sea level changes.

The scenarios are chosen to quantify the range and magnitude of the effect of relative sea level changes on basal melt rates. Concerning the ice free scenario, the total bedrock deformation over 86000 years of maximum 800 meters in the interior of Antarctica is extremely high compared to bedrock deformation rates of the interior of Antarctica over a glacial cycle, of which Figure 2a shows is in the order of 80 to 100 meters. Using the extreme uplift of the ice free scenario to compute basal melt rates on the present day ice sheet geometry show that the impact of relative sea level on basal melt rates is high, which is to be expected for such an extreme scenario. However, if this method were to be included in the coupled model where the relative sea level – critical access depth – ocean temperature feedback is taken into account, this scenario doesn't provide information on the expected changes in basal melt rates since there would be no ice shelf to compute the basal melt of. The relevancy of the ice free scenario for further research is not clear from the manuscript. The scientific value of this scenario and the implications of the results for future science should be discussed in the manuscript.

By simulating different scenario's, the method is tested for different climate forcings and ice sheet evolutions. However, the impact of significant modelling choices on the basal melt rates is not tested. For example, this study uses only one rheology of the Earth whereas relative sea level differs significantly between different rheologies. It would be useful to analyze the sensitivity to a different rheology used by Albrecht et al. (submitted). However, this manuscript doesn't state the computational cost of the flood fill algorithm so it is difficult to assess whether this is feasible. If it is not feasible, the effect of a different Earth rheology should be discussed in the manuscript qualitatively.

The introduction and method sections should be more clear on which simplifications are applied in the proposed method (compared to using an ocean model) and the effect of these simplifications should be described in the method section. The introduction lacks a discussion on the current knowledge on the effect of GIA on ocean dynamics and which studies exist on this topic. This is partly discussed in lines 395-400. However, elaborating on this in the introduction places the method section in context and improves the readability. The method section lacks an evaluation of the validity of the use of a simplified method to study the effect of relative sea level on ocean temperatures instead of using an ocean model. A thorough description should be included.

Detailed comments

Line 10-12: It would be easier to understand if this sentence were to split up in two parts. Include in the first part of the sentence why including relative sea level leads to a decrease of present-day sub shelf melt rates at last glacial maximum. Then explain how subsidence of bedrock can lead up to a doubling of basal melt rates. Also include which time period was simulated.

Line 65: Include the reference Gomez et al., journal of climate, 2018, among the references to coupled 3D GIA – ice sheet models.

Line 82: Figures S1-S3 have not been mentioned yet so Fig. S4 should be renumbered to Fig. S1.

Line 85: I miss information on what is already known about bedrock deformation in relation to ocean dynamics and the effect on ocean temperature. See general comment.

Line 98: Since the basin numbers are used to discuss the results it would be useful to include a figure showing the basins and the number of each basin.

Line 104: This line states that ice-shelf basal melt rates are estimated from relative sea-level changes, whereas that is not the case. I suggest to change “from” to “including”.

Line 120-122: The use of the present day ice geometry to compute basal melt rates is stated in line 120-122 but the implications of this simplification should be discussed. Discuss how this effect would be different if the method were to be applied with an evolving grounding line.

Line 129: The computed regional sea level is highly dependent on the Earth rheology used in the GIA model so these parameters should be described in more detail and the reference should state which rheology from Bagge et al. is used. A figure of the lithospheric thickness and the viscosity should be included in the supplementary materials.

Line 131: Is the coupling interval also 100 years to compute relative sea level for the yr2300 scenario? If so, include in the text how this time step choice effect the results (since GIA feedback could occur on much time scales than 100 years in regions with low mantle viscosity and thin lithosphere).

Line 131-133: I suggest to include in this sentence that the coupled simulations are conducted for Antarctica. The ice loading history of the northern hemisphere is mentioned later in section 2.5 about LGM15k. I would remove it from line 132-133 because it is confusing that northern hemisphere loading is only mentioned for the LGM15k scenario and not for the other two scenarios.

Line 134: The Earth’s rheology determines relative sea level and can differ significantly dependent on the rheology used. Please include a figure of the lithospheric thickness and the mantle viscosity that is used for this study. Also state the resolution of VILMA and PISM here.

Line 136-138: Please explain in more detail what is done in this step. It is unclear why present-day topography would need to be updated instead of 15ka, 2300 and the final ice free time step.

Line 149: Define “deepest grounding line fraction”.

Line 161-162: Please include how the present day control conditions exactly determined for each scenario?

Line 180: Please clarify how the initialization of PISM is related to the computation of basal melt rates. Also include over which time period PISM is run to compute basal melt rates. It is stated that the results are regridded to 4 km resolution but more interestingly would be to indicate at which resolution PISM is run.

Line 183: Please include in this section at which moment in time step 2, 3, and 4 of the method are computed for each scenario.

Line 185: This line states that the scenario is preceded by a spinup of two glacial cycles, but it is not discussed over which time period the coupled model is run to produce the final results used to compute the critical access depths. Also explain if the initial topography was inverted for differences with present day observed topography when conducting the glacial cycle runs. Furthermore explain which forcing has been used.

Line 195: Include over how much time the ice load is removed or if it was removed instantly.

Line 195-199: Please also mention the initial conditions for this scenario in terms of ice geometry and topography.

Line 199-200: Indicate the initial conditions of the coupled model at the year 1850. Indicate for how many years the historical run last. Also, please show the RSL change rates over the historical period in a figure.

Line 205-210: Is the GMSL contribution excluding the AIS component added linearly? Please state in the text how this contribution is applied.

Line 226-228: Clarify which additional ice load is meant.

Line 279: Is the change a decrease? Please specify.

Line 286-288: I suggest to include a detailed description in the method section.

Line 288: Please add a reference to figure S3. Does the horizontal adjustment change the shelf area over which basal melt takes place? If so, include whether increased basal melt rates could be caused by an increase in ice shelf area.

Line 293: Please define “overflow depth”.

Line 300: Is this signal an increase? Please specify.

Line 336-339: This line states that the cooling effect supports more refreezing but the effect of the change in salinity is not mentioned. Could you reflect on the importance of the temperature changes versus the salinity changes? Dominates a temperature change in the range of 0.5 degrees Celsius over a salinity change in the range of 0.21 psu or are both changes equally important on the basal melt rate changes?

Line 425-427: This is not necessarily the case, it depends on the forcing. A very weak rheology has a stable bedrock or shows even uplift during short periods of a warming climate during the glaciation phase. The bedrock therefore subsides less than using a stiffer rheology that does not respond to short periods of warming (van Calcar et al., gmd, 2023)

Line 431-436: This must be more clear from the beginning to be able to understand the method (see also comment on line 286-288). Also, I assume the grounding is evolving the RSL simulations. Please indicate precisely over which steps the grounding line does not evolve.

Figure 1: Please indicate the sill depth in the figure. Furthermore, different contour line representing salinity have the same number (34.65). Is this correct? If so, could you explain how to interpret this?