Reviewer 1 (Steph Cornford)

Carr et al describe numerical simulations of three major Greenland glaciers from the present day to 2100. For each glacier an ensemble of simulations is constructed by varying (a) the climate (via the surface mass balance) according to published future projections, and (b) the physics approximation of sliding at the ice bed. All simulations begin with ice thickness and velocity in line with present day observations. They conclude that their variation in sliding physics has a far lower impact on future sea level rise than their variation in SMB. I would argue that this is model sensitivity rather than uncertainty, without observational calibration of the evolution, but the same language of uncertainty crops up elsewhere. We are happy to replace uncertainty with sensitivity if required.

The experiments make sense as modelling studies, and the conclusions are justified (although differing from one paper, which is discussed) but an important sliding law has been omitted. This is the regularized Coulomb law (e.g Joughin 2019), which is related to the Schoof and Tsai rules that are discussed, but produces Coulomb-like sliding over a wider region of a typical glacier. It might make little difference, but should be considered. It is particularly important because it agrees most with time-dependent satellite observations in some regions (which is also worth noting in the introduction). We thank the reviewer for highlighting this law, which was very recently implemented in Ùa and was therefore not used in the original study. It would take a considerable amount of time to re-run all of our experiments with this additional law, so we feel that its inclusion is beyond the scope of the current paper. As the reviewer notes, as it may well make little difference: one of the key messages of our paper is that sliding law choice generally makes very little difference to sea level rise and we already include the Tsai law, so we do not expect significantly different results with the Joughin law. However, we will add this sliding law to the introduction, so that the reader is aware of it and note it as an avenue for future work to explore.

(Hilmar: This remark by the reviewer is very interesting and this has led us to implement in Ua the sliding law suggested by Joughin. While we have not done new runs for Greenland, we did inversions for WAIS where we have a large library of existing inversion products obtained with a number of different sliding laws. We found, as noted by Joughin, that this sliding law does not automatically result in a reduction of the basal drag to zero as flotation is approached from upstream direction, even in areas of high sliding velocities. For this reason, it appears that Joughin introduced some further modifications to the sliding law parameter to taper the drag down to zero in those areas. While we are definitely interested in exploring the implications of this sliding law of Joughin further, we feel that some additional criterion is required for how the sliding law parameters are modified as the grounding line is approached. Without a clear description of how this is to be done generally, the sliding law of Joughin is arguably not fully defined. We note that in the 'Cornford' sliding law (see comment below) this reduction to zero drag in the vicinity of the grounding line automatically achieved")

I understood the paper in general although there are a small number of typos/grammar errors.

Specific comments

Fig 3 is a good figure, but the labels are small. We will increase the size of the labels.

Figures 5,6,7,8 repeat the same data shown in Fig 4. It is not obvious to me that they serve a purpose. At the same time, other useful figures, e.g plots of the model initial state vs observations are not included. We will review these figures and remove them and/or move to the supplementary info.

Please do not name a 'Cornford' sliding law (line 90, 130 and elsewhere). It appears in earlier work (which is cited in both the Cornford and Asay-Davies papers mentioned), and Cornford certainly makes no claim to it . It will also be useful to say something about the physical meaning of each law when they are introduced. We will add a couple of sentences to introduce the physical meaning of each law as suggested by the reviewer. The physical idea behind what we referred to as Cornford sliding law, is to combine Weertman and Columb behaviour in one sliding law. This is done by taking the reciprocal sum of basal drag as given by those two sliding laws and raising each term to the power of m. This can be referred to as “rpCW”, ie as the “reciprocal sum, raised to the power m, of Coulomb and Weertman sliding laws”. We understand the comment raised by the reviewer and will simply refer to the sliding law as “rpCW”. The equations defying the sliding law should make it clear why we use this abbreviation.

Eq 2: use the same conventions as eq 1 and eq 3 (\tau ^B_b to match \tau ^W -b) We will update this notation.

Eq 7 : looks incorrect, as though the second term inside the integral has been copy-pasted from the first and then not edited in some way. We will update this part of the equation.

L202: ‘fully converged’ : really? That is unusual, if not impossible. Was there a stopping criterion? We acknowledge that using the term ‘fully’ converged was inappropriate here and we will remove it. Instead, we mean that we stop the inversion when the amount that the misfit is changing with each step is very small. We will add in a statement about the stopping criteria for each inversion, in the form of the norm of the gradient.

References

Joughin I, Smith BE, Schoof CG. Regularized Coulomb Friction Laws for Ice Sheet Sliding: Application to Pine Island Glacier, Antarctica. Geophys Res Lett. 2019 May 16;46(9):4764-4771. doi: 10.1029/2019GL082526. Epub 2019 May 13. PMID: 31244498; PMCID: PMC6582595.