

# ***Interactive comment on “The GRISLI-LSCE contribution to ISMIP6, Part 2: projections of the Antarctic ice sheet evolution by the end of the 21<sup>st</sup> century” by Aurélien Quiquet and Christophe Dumas***

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Quiquet and Dumas present the results of the GRISLI-LSCE contribution to ISMIP6, which is an extensive model intercomparison showing the 21st century evolution of the Antarctic Ice Sheet (AIS) under a variety of climate scenarios (Seroussi et al. 2020). I think it is a worthwhile exercise to present individual model contributions of ISMIP6 in depth, as due to page limitations and readability the main ISMIP6-paper can only illustrate the general findings of the model intercomparison in broad strokes. Therefore, in my opinion this manuscript is well suited for the scope of The Cryosphere.

An in-depth analysis as the authors attempt here should identify the key features as well as strengths and weaknesses of the individual model contribution so the reader can appreciate the respective models skills and peculiarities when it comes to projecting the future evolution of the AIS.

The authors present interesting details regarding their model projections and how they differ from or agree with the ISMIP6 ensemble. The paper generally reads well and the figures are of good quality. To make this a valuable addition to the "TC-ISMIP6-canon" I would suggest a number of modifications and extensions mainly with regard to the Results-section as well as some stilistic overhaul to improve the general readability.

I will first list general comments pointing out where certain sections need more substance to elevate this manuscript above a mere documentation of GRISLI ISMIP6-results, followed by specific point by point edits/comments to the text.

#### 1. (section 3.1 Present-day simulated ice sheet)

The authors discuss the modelled present day state of the AIS in detail covering mostly thickness and velocity changes in the different regions of the ice sheet. This gives a nice first impression as to how well GRISLI is capable to reflect the current available observations. If I understand correctly the underlying assumption of the initialisation procedure was to create an ice sheet in equilibrium with the late-20th century mean climate state as opposed to one with ongoing mass loss. If this is correct it could be stressed more, and the consequences of the initialisation for the projection runs (potentially to stable) should be discussed. Furthermore, it would be really interesting to hear the authors opinion on inverting for ice thickness versus inverting for surface velocity. How are the ice sheet's future regional dynamics primed in the projections as a result of the inversion approach? What is the advantage/disadvantage of thickness inversion (e.g. realistic inital geometry/unrealistic flow patterns) in comparison to velocity inversion (e.g. realistic initial ice dynamics/unrealistic surface elevation)? Also, the authors focus a lot on ice shelf thickness and area changes which is important for buttressing

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and thus marine ice sheet stability. However, the ice thickness close to the grounding line is probably also an important indicator whether the initial ice sheet configuration is resistant to grounding line retreat or facilitates the latter. In general, it would be nice to have a more explicit discussion as to how the initial state of the ice sheet impacts the projections.

#### 2. (section 3.2.4)

The modelled grounding line response in the Ross and Filchner Ronne sectors seems to be very large for higher sensitivity runs if forced by e.g. NorESM1-M as discussed by the authors and shown in Figure 5 d. I suggest to expand the discussion of this response a little shedding light on the mechanisms and whether this response differs from the ISMIP6 ensemble substantially. Is this solely due to the strong forcing of NorESM1-M in these sectors or is there a model dependence if comparing the different ISMIP6 ensemble members?

3. (section 3.2.5) I think it is an important finding that ice shelf collapse does not seem to have a considerable effect until the year 2100 at least for GRISLI. Section 3.2.5 should be expanded by a discussion as to why this is the case. Did the authors carry out longer projections under ice shelf collapse (e.g. until the year 2300/3000)? Is MISI initialised in certain regions for longer simulation times? Or is the model setup so stable as to not allow MISI (doesn't seem to be the case if looking at Ross Sea grounding line retreat under NorESM RCP8.5 forcing). Is this result similar to the ISMIP6 model ensemble (i.e. do all models show negligible grounding line response to ice shelf collapse until 2100 CE?), or how does GRISLI differ here? As of now this section is very short and does not really allow for an assessment how sensitive this GRISLI setup is with regard to removal of buttressing force.

#### 4. (Discussion)

Here, the authors discuss a parameter sensitivity study not shown in the results section. Is this on purpose? I would suggest to include a section in the Results and present

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the main findings of these experiments there. As for Figure 12 I suggest to include a graphical aid for the reader which delineates what the authors think is a realistic parameter range (e.g. good fit to present day observables). I assume the fringes of the parameter range would generate an ice sheet configuration which are not in agreement with the general present day features of the AIS.

Point by point edits/comments:

general points:

-review your use of "important" (e.g. important acceleration, p1, l18) throughout the manuscript. Important for what? This is very implicit. I know what you mean but the word "important" should be replaced by an explanation of why the change is relevant throughout the manuscript.

-check throughout manuscript "consists in" and change to "consists of" where applicable.

-check your use of "pessimistic" and "optimistic" scenario and replace with e.g. "unmitigated" and "strong mitigation scenario" or alternatively just with the official CMIP abbrev.

-check use of "All together" and replace by e.g. "Overall"

-check use of word "systematic" throughout the manuscript.

-you use the form "on the one hand ... on the other hand" exhaustively, especially in the second half of the manuscript. This is not technically wrong, but it would improve the reading experience if you use other forms to express contrasting things from time to time.

-for sake of readability I suggest to modify occurrences of ice volume changes and write in exponential form (e.g.  $3e5$  km<sup>3</sup> instead of 300000 km<sup>3</sup>) and provide the sea level equivalent volume change in brackets right after.

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## Abstract:

p1, l2 this sentence could be changed to: The Antarctic ice sheet's contribution to global sea level rise over the 21st century is of primary societal importance and remains largely uncertain as of yet.

p1, l2-3: ISMIP6 itself suggests a range from negative to positive sea level contribution, while you write "from a few millimetres to more than one metre". This seems inconsistent to me.

p1, l5-6 I suggest to omit: "While in a companion paper we present ..." and shorten the sentence to "Here, we present the GRISLI-LSCE contribution ...".

p1, l8 omit "of sea level equivalent".

p1, l9: suggest to rephrase to "... of the ice shelves resulting in grounding line retreat while increased precipitation partially mitigates or even overcompensates the dynamic ice sheet contribution to global sea level rise."

p1, l12: change "retreats" to "retreat" and check use of retreats throughout the manuscript. p1 l12-13: change to "... in ice sheet models for projections of the Antarctic ice sheet's evolution."

p1, l17 include reference of potential total sea level equivalent ice volume (e.g.  $\sim 58.3$  m BEDMAP2 or  $\sim 57.9$  m BEDMACHINE).

p1, l18 rephrase this sentence and include reference, suggestion: "While the ice sheet was probably in a quasi mass-equilibrium in the eighties (citation?), it has since then lost ice at an accelerated pace, reaching a yearly sea level contribution of up to 0.7 mm yr<sup>-1</sup> during the last decade (...)"

p1, l21: replace "inexorably" with "irreversible".

p1, l22: change to "While the increase in mass loss is mostly associated with ocean warming, the increased precipitation ..."

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p2, l3: "the projected sea level contribution"

p2, l4. please rephrase model formulation, unclear what you mean here. "Overall, the uncertainties related to XY"

p2, l9: "... contribution to ISMIP6-Antarctica in detail, while its ..."

p2, l34: what about shorter timescales such as the one you are looking at here? Has GRISLI taken part in e.g. MISMIP? please elaborate.

p3, l10: "... and the total velocity results from the addition of the ..."

p3, l20: "initialisation procedure consists of ... which aims at determining the geographical ..."

p3, l23: "... under a constant present day ..."

p3, l31-32: please rephrase this sentence, unclear and poor style.

p4, l9 "is derived from" ?

p4, l10. "The geothermal heat flux is taken from ..."

p4, l19 "is derived from"

p4, l30: "GCMs". p5, l12: "... as the initial ..."

p5, l15: unclear what you mean by " ... even though the time evolution has no incidence on the forcings."

p5, l15: if I understand correctly you are using annual forcing, so I guess you can omit the specification of the month.

p5, l21: unclear: are they branched off from the historical experiment at 2014?

p5, l27: using different sub-shelf melt rate sensitivities ..

p5, l28 : ...of the sub-shelf melt model calibrated ..."

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p6, l1: rephrase " In order to allow for the interpretation of the model response to the forcings, a control experiment, ctrl\_proj , has been performed in addition to the ctrl experiment. As in the ctrl experiment ..."

suggest to omit the month as it is not relevant for the simulations

p6,l 19: check your use of "important" and rephrase with an explicit description of what the relevancy is.

p6,l21: the extend

p6,l26: rephrase "location and magnitude" and check use of "important"

p6,l28: rephrase to "Surface velocities of the major tributaries of the Ross ice shelf (Mercer- and Williams Glacier) and the Filchner-Ronne ice shelves (Foundation Glacier) are largely overestimated (include range here, e.g. up to factor 2 or whatever it is)"

p6, l31. explicitly explain why ross ice shelf is largely over- and Ronne ice shelf under estimated.

p7,l2: which other regions could be affected by the 16 km resolution, i.e. where do you think the grid size plays a dominating role on projections?

p7,9-10: suggest to provide names of ice sheet models which use velocity inversion in ISMIP6 so the reader can compare in Seroussi et al. 2020.

p7,l21 "mass balance uncertainties" - please specify regions with large mass balance uncertainties so the reader can grasp where these are relevant.

p7,l33 "... acceleration of ice volume loss over the course of the century."

p8,l1 as suggested in the general points please write volume changes in exponential form and provide sea level equivalent changes right after in brackets.

p8,l6 "(i.e. above floatation)"

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p8,l9 This is not necessarily the whole story as mass gains in grounded ice above sea level could overcompensate mass change in marine ice sheet regions. please elaborate.

p8,l9 : rephrase to "ice shelve volume is shrinking over the course of the century"

p8,l10 : please elaborate "ambivalent"

p8,l11 replace "perpetual" with "constant"

p8,l18 what is the reason for the decreased surface mass balance in HadGEM2-ES? If I plot precip alone over the AIS I get an  $\sim 30\%$  increase. From Seroussi et al. 2020 I gather that surface mass balance anomalies are computed from "changes in precipitation, evaporation, sublimation, and runoff". p8,l18 I assume you mean: basal melting underneath ice shelves is increasing? p8,30: "... wide spread thickening of the grounded ice sheet" p8,31: rephrase to "When using NorESM1-M this thickening is present to a lesser extent and compensated by the thinning that results from the grounding line retreat in some areas (Ross or Totten ice shelves for example)."

p9,l7: "Similar to CMIP5 climate models, the CMIP6 ..."

p9,l10 is this also the case for the ISMIP6 ensemble or a specific feature of your model?

p9,l16 "largest" instead of "greater"??

p9,l19: "maintain" what? p9,l24-25: please rephrase these sentences, I know what you mean, but the formulation as it stands is unclear. p9,l29: again, "maintain" what?? p10,l2: "The computation of the sub-shelf melt rate ..." p10,l2 unclear what you mean by "largely derived". I guess the basal melt rate is tuned to observational data. p10,l13: "the NorESM1-M forcing under RCP8.5 ..." p10,l26-28: please completely rephrase this sentence. p10,l30: suggest to omit "Respective" in section header p11,l12-14. please rephrase. p11,l19: suggest to rephrase to : "Modelled grounded ice surface velocity changes are limited with the notable ..." p11,l26: "Another way ... this century ..." p11,l27: replace "different natures" with "different causes" p12,l1: replace "somehow"

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with a quantification. p12, l4: unclear what you mean by "in line". Close to ensemble mean? p12, l8 : "(e.g. Bamber et al. ...)" p12, l28: "Such an approach ..." please quantify "much more computationally expensive" p13, l1: "While the atmospheric forcing ... p13, l13: "providing the means to investigate" p13, l20: "partly mitigating or over-compensating the effect of loss of buttressing due to ice shelf melt." p13, l23: "do not drastically change the simulated ice sheet volume ..." p13, l24: "...emission scenarios ..." p13, l24: replace "present" with "exhibits"

General point for the volume figure captions:

you often use the sentence " Simulated ice volume change for the historical experiment hist (1995-2015), the control experiments ctrl (solid grey lines) and ctrl\_proj (dashed grey lines) and for the projections using climate models run"

which is a bit bulky and only after that the description of what the panels show follows. For sake of readability I suggest to modify the respective captions so it reads: "Simulated ice volume change and sea level contribution for projections XYZ ..." and in the end include a sentence stating that the plots begin with the historical run and that ctrl and ctrl\_proj are depicted in gray (dashed and solid).

Figure 9: How come that for some experiments the AIS sea level contribution is negative for ice shelf collapse in comparison to standard approach? This should be discussed in the results! It seems only those runs which show AIS growth in standard approach show a relative AIS mass loss in the shelf collapse scenarios.

Figure 12: it would help if you indicate the parameter range which produces a "realistic" present day ice sheet with respect to observations for present day forcing, so the reader can identify which parameters are still "OK" to use. Also please remove double brackets e.g. ((a) and (b)) -> (a and b).

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