

Review of “CMIP5 model selection for ISMIP6 ice sheet model forcing: Greenland and Antarctica” submitted to TC by A. Barthel et al.

With the aim of selecting a set of global climate models that represent best the current and projected climate of the Greenland (GrIS) and Antarctic ice sheets (AIS) to force the ice sheet models of ISMIP6, the authors evaluate, compare and rank 33 CMIP5 AOGCMs using observational data (present-day) combined with various atmospheric and oceanic metrics (scenarios). As a result, an ensemble of six AOGCMs (i.e. three core and three targeted) is selected separately for the GrIS and AIS. These models show the best agreement with present-day observations while maximizing the diversity of future projections. The authors show that CMIP5 models performing the best differ in Greenland and Antarctica, and that they do not represent atmospheric and oceanic processes equally well.

This is a sound, very well written study that is highly relevant for the Cryosphere community. The AOGCMs selected here will be used to force ice sheet models participating in the ISMIP6 project. Using the outputs of the best performing AOGCMs as forcing will prove essential to better project the mass balance of the GrIS and AIS in a future warming climate, and to improve estimates of their relative contribution to global sea level rise. I deem that the manuscript should be accepted for publication in the Cryosphere after applying some **minor revisions**. The authors can find my comments hereunder.

General comments:

- 1) The conclusion section should be reformulated to stress the main results of the study, i.e. purpose of the inter-comparison exercise, which climate models have been selected to force the ice sheet models, some perspective and future work based on e.g. CMIP6 models. The current conclusion section should better be moved to the discussion section. In addition, reference to Tables 2 and 3 appear for the first time in the conclusion section, while they should better be discussed at the end of Section 3.3 (Table 2) and Section 4.3 (Table 3).
- 2) The authors refer multiple times to forthcoming papers that are currently in preparation. I would strongly advise to remove those references or better use a personal communication statement as at e.g. **L61, L87, L144, L254-255**.
- 3) The authors should define the acronyms (e.g. ta850, prw, ...) used for the evaluation metrics. These are currently not listed in the main manuscript making the interpretation of Figs. 2, 4, 5, 7 and A1 difficult. This should be done at **L107-111** (AIS) and **L113-114** (GrIS). For clarity, sea surface temperature in summer and sea ice extent in winter could be better defined as sst[s] (instead of tos[s]) and sie[w] (instead of mwsie). For consistency, I also suggest to replace $\partial prw[a]$ by $\Delta prw[a]$ in the main text and figures (e.g. L164-168). In addition, at L165-166, the authors refer to winter sea ice concentration (i.e. fraction of a pixel covered by sea ice) as opposed to sea ice extent (i.e. integrated area of pixels with a sea ice fraction > 0.15). Please clarify which quantity is used in both cases.

Point comments:

L19: The authors should also refer to more recent studies such as Mouginot et al. (2019; GrIS) and Shepherd et al. (2018; AIS). See also additional references.

L39: Remove “AOGCM” since it is first defined at **L41**.

L49: Could the authors provide a reference here (i.e. after ice shelves)?

L50: Could the authors provide a reference?

L53-54: The authors should add “e.g.” before “Noël et al., 2018” and “van Wessem et al., 2018”. For instance, Langen et al. (2017) and Niwano et al. (2018) also show good agreement between HIRHAM5 and NHM-SMAP RCMs and in situ measurements over the GrIS.

L107-109: I strongly suggest: “850 hPa (ta850; average of [...] precipitable water (prw), [...] pressure (psl), temperature (sst[s]) and winter sea ice extent (sie[w]) [...] jet strength (Jstr) and position (Jpos), [...] maximum in annual mean 850 hPa zonal wind [...]”.

L113-115: I strongly suggest: “[...] 700 hPa (ta700; average [...] at 500 hPa (zg500), inside the Modèle Atmosphérique Régional (MAR; Fettweis et al., 2017) [...]”.

L115: “do not significantly impact MAR results”.

L131: “ORCA025”. **L138:** Could the authors provide a reference here?

L141-142: “World Ocean Atlas (WOA; Locarnini and [...] 2018 WOA data (Locarnini [...])”
L166 and L169: Add “(ΔT)” after “ocean temperature”.
L173: At L156, the authors refer to 7 metrics for Greenland, while “6” is stated at L173. Do the authors discard Δz_{500} from the comparison between future climate projections? Please, clarify.
L182: Add “(Fig. 2a)” after 0.13 and “a” after “Figure 2”. **L183:** Add “(blue)”, “(brown)” and “(yellow)” after “sub-surface ocean”, “atmosphere” and “surface ocean”. Same at **L240:** “(pink)”, “(red)” and “(light blue)”; at **L249** “(yellow)”, **L254:** “(brown)” and “(dark blue)”.
L208: I suggest: “We highlight the 3 core (red) and 3 targeted (yellow) AOGCMs selected in [...]” and remove **L218-220:** “In Fig. 3b [...] Amundsen region”.
L236: Top 3 (core models). **L248:** Top 6 (targeted models) and same at **L314** and **L328**.
L242: Add “(dashed)” after “median”.
L250: Do the authors mean “showing similar median projections under RCP8.5”? Please, clarify.
L266: The authors certainly mean “(Sections 4.1 and 4.2) and ensemble selection (Section 4.3)”.
L303: “highlighted in Fig. 6b”.
L307: $R^2 = 0.31$ is a weak correlation. Please, clarify.
L312: “[...] show that RCMs outperform global climate models [...]”.
L315: What about EC-EARTH? No values are shown in e.g. Fig. 6. Could the authors elaborate?
L317: Add “Fig. 7a” after “median”.
Section 4.3.1: The authors should refer to Figs. C3 and C4 here.
L333: For consistency, ΔT BB (instead of Baffin Bay) and “ACCESS1-3”.
L347: Do the authors mean that a similar evaluation/model selection and ranking is not planned/possible using CMIP6 models? Or that the evaluation/selection of CMIP6 models was not performed in the current study? Please, clarify.
L408: “ACCESS1-3”.

Stylistic comments:

L12: Maybe “limitations” instead of “constraints”. **L17:** I suggest: “[...] most uncertain contributors to global sea-level rise over multidecadal to millennial timescales.”. **L35:** I suggest: “[...] and oceanic forcing contribution to the mass balance of both ice sheets vary greatly, and depend on [...]”.
L44: Maybe “converting” instead of “translating”. **L45-46:** I suggest: “[...] resolution that is too coarse [...] gradients impacting the surface climate of the ice sheets [...]”. **L55:** Maybe “unable” instead of “challenged”. **L73:** I suggest: “[...] some of the limitations of the selection procedure, and discuss [...]”.
L111: “[...] (in $m s^{-1}$), compared to time-slice [...]”. **L203:** Maybe add “(core)” after “top 3 models”.
L206: “multi-model”. **L225:** “but this region is projected to warm moderately [...]”.
L235: Remove “to choose from”. **L238:** I suggest: “The correction is robust and removes [...] a time and changes the weight [...]”. **L257:** Maybe “large number” instead of “high number”.
L299: Remove one of the double “an”. **L359:** I suggest: “key processes for projections may still be missing.”. **L366:** “models are assessed”. **L367:** “evidenced in our analysis.”. **L369:** “Concerning independence”. **L387:** “e.g. Agosta et al., 2015” and “Meijers et al., 2012” before “Sallée et al., 2013”.
L392: “their results differ from the current study [...] ocean-driven basal melt”.
L397: “the different model performance”. **L401:** “ice flux of the different ice sheets”. **L403:** Maybe “reasonable” instead of “feasible”. **L404:** “RCP scenarios, ..., parameters setting, ...”.
L415: I suggest: “better or project climate warming at different rates.”. **L423:** “We refer readers interested in the [...] simulations to Slater et al. (2019).”

Figures:

Fig. 1: Does the grey mask in Fig. 1a also represent the AIS regions above 2000 m a.s.l. as in Fig. 4c? Please clarify in the caption. **L107:** Does the blue rectangle in Figs. 1a,c represent the integration domain of MAR? If so, “standard lateral boundaries of MAR (REFs for AIS and GrIS)”. **L112:** State the time period used for the “reference historical climatology”. In addition, move the titles of Figs. 1a and c upward so that they do not overlap with the figures.
Fig. 2: For consistency replace legend items “surf. bias” and “ocean bias” by “surface ocean” and “sub-surface ocean”. What do the vertical bars in Fig. 2a represent? Please, clarify. In Fig. 2b, add “ ΔT ” before DML, Amery, Totten, ... The authors should also explicitly state that the horizontal dashed line represents the median of the models. Add “(core)” after top3 and “(targeted)” after top6.

Fig. 5: Same comments as for Fig. 2. The blue legend item in Fig. 5a should be “sub-surface ocean”. In Fig. 5b, add “ ΔT ” before SPG, Baffin Bay ... In Fig. 5c, “zg500” instead of “zg550hPa”.

Fig. 4: For better contrast, I strongly suggest using a red line instead of the purple one for MIROC-ESM-CHEM. **Fig. 7:** Use a red line instead of the purple one for MIROC5.

Fig. 6: The figure titles and labels are too small and almost unreadable. Please, enlarge.

Figs. B1 and B2: As for Figs. 3 and 6, highlight the 3 core models in red and the 3 targeted models in yellow.

Additional references:

- 1) Shepherd et al. (2018): <https://www.nature.com/articles/s41586-018-0179-y>
- 2) Mouginitot et al. (2019): <https://www.pnas.org/content/116/19/9239>
- 3) Langen et al. (2017): <https://www.frontiersin.org/articles/10.3389/feart.2016.00110/full>
- 4) Niwano et al. (2018): <https://www.the-cryosphere.net/12/635/2018/>