Earth Syst. Dynam. Discuss.,
https://doi.org/10.5194/esd-2019-78-RC1, 2020


Earth System Dynamics Discussions



# *Interactive comment on* "Precipitation Ansatz dependent Future Sea Level Contribution by Antarctica based on CMIP5 Model Forcing" *by* Christian B. Rodehacke et al.

**Torsten Albrecht (Referee)**

torsten.albrecht@pik-potsdam.de

Received and published: 8 February 2020

**General comments:**

Rodehacke and colleagues investigate the effects of multiple climate model forcings (from CMIP5) in Antarctica. They assess the spatial heterogeneity in temperature and precipitation estimates over the period 1850-2100 for different emission scenarios and the spread among the 9 selected climate models. The ratio of precipitation anomalies and temperature anomalies is compared to paleo estimates at 6 ice core locations and regional variations from the spatial mean are discussed. Applied to the ice sheet model



Printer-friendly version

Discussion paper

PISM they run an ensemble of simulations up to the year 5000 with both the anomaly forcing fields from the climate models and the simplified (spatial mean) parameterization (as often used in previous studies) and find quite some differences in the projected ice mass changes (converted in units of sea-level equivalents).

While in this study the temperature-scaled precipitation results in long-term ice losses, the directly applied precipitation anomalies generate net mass gains. Given the numerous previous projection studies, this is a surprising result. However, for given model settings this discrepancy can to some extent be explained in the manuscript.

Overall, the study is well structured and the manuscript clearly-arranged. The main manuscript is separated into introduction, material and methods, results and discussions, conclusions and an appendix part. Due to its length of 42 pages including figures and references and 20 pages in the Appendix, it is sometimes difficult for the reader to follow the line of thought. The conclusions with almost 3 pages should be condensed, many discussed aspects could be merged into the introduction and discussion part. In general, the manuscript needs some additional work to improve the readability and to clarify the main key messages for the reader and avoid redundant informations. Also typos and the german-style syntax sometimes hampers the reader to fully grasp the content of the manuscript.

Figures have good quality and are informative, some are overloaded with up to 27 curves. Literature is sufficiently covered with 97 references. The investigation of the impact of climate boundary conditions on the future evolution of the Antarctic ice sheet supports the publication in ESD. However, as the main focus seems to be on the evaluation of climate model result and the systematic and comprehensive sensitivity analysis of the ice sheet model to the two different types of precipitation forcing, this study would also very well fit into a model-specific journal like GMD.

This study by Rodehacke et al. has the potential to be a valuable contribution to the scientific community of ice sheet modelers, as it considers relevant aspects of commonly used boundary conditions with potentially serious consequences for estimates of future sea-level change.

I encourage the authors to consider the following detailed suggestions and to improve the manuscript accordingly.

**Specific comments:**

1. The title should be refomulated. It is not easy to understand the content before having read the abstract. Also I wonder, if the more word “Ansatz” is commonly known in the wider scientific community apart from mathematicians. I would suggest: “Future sea-level contribution from the Antarctic Ice Sheet for different precipitation forcings based on CMIP5 models”

2. As a surprising result the simulated Antarctic Ice Sheet gains mass under future global warming for directly applied climate model anomalies (temperature and precipitation). As this part has some delicate political implications it needs a clear discussion of the responsible model settings.

2a. Although the equilibrium state fits well observations of ice thickness and grounding line, the involved mass fluxes may not. Total ice loss rates by melting and in particular by calving are overestimated by a factor of 2-3 depending on the used eigencalving rate constant. Hence also the surface mass balance seems to be overestimated accordingly. The authors imply that the uncertainties in the regional climate model results (RACMO), which are used as a present day reference field, are large enough to overestimate in particular the large slow-flowing and very dry inner-continental regions of the EAIS, where small absolute changes in precipitation can have large consequences for the total mass balance of the equilibrium state. Also, it is not clear from the description in the manuscript how the yearly cycle in the PDD scheme is estimated from the climate models (annual mean and summer temperatures) in order to obtain estimates of the





Printer-friendly version

Discussion paper

surface mass balance components for given air temperature and precipitation forcing. A potential misfit in boundary conditions may be compensated for by a well-chosen set of model parameters, such that the equilibrium state bounds observational constraints. However, this potential overfitting of the initial equilibrium state may then have consequences for the projected ice mass changes, as the authors already speculate. In general, the equilibrium state method favors rather stable ice sheet configurations, which may not be realistic.

2b. The authors state one main difference to previous studies related to the forcing after the year 2100, which is commonly extrapolated into the future, while in this study it remains quasi constant (within 30 years variability). There seems to be another important difference in the methodology of this study in comparison to other studies. All climate model anomalies are inferred with respect to a preindustrial control simulation. However, the reference climate of the 19th century does not really match the modern climate, which the used mean background fields (from RACMO as mean over period 1979–2011 and from World Ocean Atlas as climatological mean) are related to. This precedure minimized the shock at the beginning of each simulation at 1850, but it adds some anomaly to the present-day background field when arriving at present-day in the simulations and it overestimates the future temperatures and precipitation rates applied to the Antarctic Ice Sheet. I encourage the authors to run some test simulations with shifted anomaly (negative anomaly in the preindustrial era and vanishing anomaly in present-day period).

2c. Regarding the basal melt parameterization, no details on sensitivity can be found in this study nor in the cited study by Sutter et al., 2019. What technique is used to extrapolate ocean temperatures into the ice shelf cavities? Are basin-wise overflow depths considered? Are extrapolated ocean temperatures vertically interpolated at the ice shelf base? Can refreezing occur? A simimar melt parameterization with quadratic dependency on thermal forcing has been calibrated in Jourdain et al., 2019 (https://doi.org/10.5194/tc-2019-277). They show that the choice of the particular parameterization and the associate parameters can have a huge impact on the ice sheet response. The authors discuss that the used melt parameterization may underestimate the melting and therefore apply bias-corrected melt rates as a sensitivity check, which does not cause considerable changes in the ice sheet response. The effect of basal melt could be also strongly intensified by using the melt interpolation across the grounding line (optional in PISM).

3. The authors define different ways of expressing (integrated) mass changes in terms of sea-level equivalent changes and I would wish that it should be made clear when just a theoretical unit conversion is applied (potential sea level change) or when it is an actual sea-level contribution in terms of projected ice mass change. And if the latter it should be clearly defined whether only ice masses above flotation are considered. What diagnostic has been in fact used here?

4. The manuscript states that the used coarse resolution of 16km may have consequences for the adequate representation of ice stream dynamics. I assume that this model choice is a consequence of the initial equilibriumn state, which requires hundred thousands model years to evolve. The authors state that basal resistance is described by a Mohr-Coulomb law with plastic till, but they do not discuss relevant parameters involved, such as the till friction angle or the till water decay rate. What is the vertical resolution of the enthalpy module? These parameters can strongly affect the ice stream dynamics also for coarse resolutions.

5. The authors use a rather old PISM version (v0.7), most likely for consistency reasons (initMIP and other model intercomparisons). However, PISM has evolved over the last years and some relevant aspects have been improved, which may affect the results of this study. For instance, the authors mention a bug in the elastic part of the LC solid Earth model, but also the viscous part was flawed and considered changes in ice shelf thickness as loads. Accordingly strong melt would cause uplift of the cavity bed and hence result in a stabilized grounding line. Also the till water distribution along the grounding line has been fixed meanwhile causing a much higher grounding line

sensitivity. I guess also the sea-level potential diagnostic has been fixed meanwhile (now substracting the part below flotation). These are many good arguments in favor of a more recent PISM version and they suggest that Antarctic Ice Sheet simulations could respond with much higher sensitivity to the same forcing applied.

**Technical corrections:**

l.2: “heavier precipitation fallen on Antarctica will counteract any stronger iceberg discharge...”→ “precipitation will likely increase even more and may counteract stronger iceberg discharge...”

l.3: “from nine CMIP5 models future projections” → “future projections from nine CMIP5 models”

l.5 : “The spatial and temporal varying climate forcings drive ice-sheet simulations. Hence, our ensemble inherits all spatial and temporal climate patterns, which is in contrast to a spatial mean forcing.:” → “The spatially and temporally varying climatic forcing drive the ice-sheet simulations, such that all climate patterns are represented in our ensemble, which is fundamentally different from using spatial means as forcing.”

l.7: Regardless of the applied boundary condition and forcing, some areas will lose ice in the future, such as the glaciers from the West Antarctic Ice Sheet draining into the Amundsen Sea.” → ..., our ensemble study suggests, that some areas will lose ice in the future, ...

l.10: “This strip also shows...” instead of using “... too.”

l.25: “How strong the precipitation grows in a warming atmosphere, may be explained by the dissimilarity between the applied methods to describe the precipitation.” → The discrepancy of the simulation results between the applied methods to describe the precipitation illustrates the uncertainty of the possible range of future precipitation growth in a warming atmosphere.

l.30: "...impacts globally numerous economic activities..." → "...impacts numerous economic activities globally..."

l.31: "... or dedicated model simulations of, for instance, ice-sheet models." → "... or process-based model simulation, e.g. ice-sheet models."

l.34: "... are simplified descriptions by analytical equations" → "... are either simplified descriptions based on linear multiple-regression analysis ... or"

l.36: "The simplified forcing, which usually does not show a dedicated spatial structure" → As surface elevation is a key variable in those parameterizations, the geometry of the ice sheet in fact leave some characteristic spatial structure.

l.58: "temperature scaling" → "temperature scaling factor for precipitation" or "precipitation-temperature scaling "

l.71: Add comma before "probably"

l.124: Maybe omit "full" here.

l.126: As in the title, I would recommend to use: "The type of precipitation forcing" or "the used method for applying precipitation forcing" instead of "the Ansatz of the precipitation".

l.130: "The latter is common, while some keep the surface mass balance constant." → "The latter approach is commonly used, in particular in paleo applications, while some sensitivity studies keep the surface mass balance constant."

l.138: It could help the reader to have some definition of the piControl simulation here, e.g. "pre-industrial coupled atmosphere/ocean are performed at constant pre-industrial $CO_2$ levels for x model years".

l.140: "... differ commonly marginally." → "...show in general marginal differences."

l.144: How does this extrapolation works? Is there a diffusion scheme applied for each vertical ocean temperature level? What are the source regions, the continental shelf or also the deeper ocean regions (this is not so clear from Fig. 3e), which are separated from the deeper cavity regions by the continental shelf? There is also no detailed description in Sutter et al., 2019, even though sub-shelf melting is a key process here.

l.146: "... following the positive degree day (PDD) approach, where the annual 2m-air temperature standard deviation comes from daily CMIP5 model values." Does this mean that every year one different PDD standard deviation is applied to the whole computational setup or is it grid-cell wise? In l.143 it is mentioned that "annual mean forcing" is ued, but what about the summer temperature anomaly to estimate the yearly cycle?

l.148: "16 km" → What is the reason for this relatively coarse resolution, the availability of an equilibrium state?

l.149: "utilizes" → "applies"

l.151: Also the viscous part in v0.7 was somewhat unrealistic, as also ice shelf thickness change has been considered as loads in the LC bed deformation model, which has strong effects on grounding line sensitivity.

l.154: "... pressure-dependent melting temperature" → Add "...of the ice"

l.157: "...while the grounding line position is determined on a sub-grid space (Feldmann et al., 2014)." → Add "... to interpolate basal friction."

l.161: "...stress field divergence... " → "... divergence of the strain/velocity field" or "trace of the strain-rate field"

l.161: You should add units "m s" here as the Levermann et al. 2012 paper uses "m a".

l.162: "(PISM1Eq and PISM2Eq)" → This can be confusing, either you switch the order here or the order of the eigencalving constants in the sentence before.

l.163: "Ocean temperatures from the World Ocean Atlas 2009 (Locarnini et al., 2010) and the multi-year mean surface mass balance (SMB) from the RACMO 2.3/ANT model (Van Wessem et al., 2014) drive PISM during spin-up (Table 2)." $\rightarrow$ Hence, this is a present-day forcing equilibrium.

l.169: "... releasing less carbon dioxide." $\rightarrow$ Maybe add "(e.g. RCP2.6)."

l.171: "the RCP8.5 scenario path" $\rightarrow$ "the high emission RCP8.5 scenario path"

l.175: maybe add a "\," in the unit "\unit{cmyear−1}"

l.176: "...warms by nearly $1 \pm 0.18$ °C (Figure 3c)." $\rightarrow$ Add "in the same period"

l.177: "... these increases become stronger." $\rightarrow$ "this warming trend/rate becomes stronger."

l.179: "current trends" $\rightarrow$ "currently observed trends"

l.189: "Areas of heavy precipitation under the reference climate (Figure 2b) also receive the highest increments."

l.195: "Also, the Amundsen Sea in front of Pine Island Glacier and Thwaites Glacier is cold. Here, the temperature might be too cold, which justifies the applied melting correction." $\rightarrow$ Which melt correction did you use? And "too cold" with respect to World Ocean Atlas?

l.205: "...do not necessarily grow in parallel." $\rightarrow$ Do you mean they are "not necessarily correlated"?

l.209: "ice-sheet" $\rightarrow$ "Ice-sheet"

l.214: The unit of Eq. 1 should read % $K^{-1}$, hence $\Delta T$ should be in the denominator.

l.215: So P0 equals $P_{t=0}$ in Eq. 1?

l.217: Eq. 2 should have a number. And should $\Delta P$ be replaced by P0?

l.221: "...these locations. The difference is distinct for Vostok..." → "...ice core locations. The difference is most prominent for Vostok ice core..."

l.226: "Thus, we can safely restrict the analysis on the first 50 years." → of which simulation?

l.230: "Map 1" → "Map in Figure 1"

l.233: "... c-like area" → "...half-moon-shaped area" or just "... c-shaped area"

l.242:"We detect a slight trend to higher values if we restrict the analysis to ground ice." Maybe mention at this point that the difference results from excluded ice shelf regions, which are associated with x% of the total glacierized area and which are characterized by relatively shallow surface elevation along the ocean margin

l.243: "the difference between scenarios is more decisive" → "the impact of the choice of the scenarios is larger..."

l.245: "... Within their variability, many ensemble members are invariant against the applied scenario..." → "The sensitivity of many ensemble members to the range of applied scenario is within their variability..."

l.250: "... Antarctica's large-scale drainage basins." → Please provide a reference here, e.g. Zwally et al., 2015

l.251: "This division..." → "This chosen division..."

l.253: "...with a tendency of higher values..." → "...with a tendency towards higher values..."

l.261: "The region "Siple Coast" as a part of the "WAIS" region is different in many aspects. It has the smallest area.." → so it has a low weight in the spatial mean?! l.263: "...while the spread of trends among individual ensemble members is substantial." → Why not provide a number range at some points in the text?

l.267: “... trend in snow accumulation ...” → “... trend in observed snow accumulation...” to make sure that you switched from model results to observations in this paragraph

l.273: “... a unrealistic declining February sea ice trend” → “... an unrealistically declining February sea ice trend”

l.280: “which is also reflected by the maxima in these regions.” → maxima in scaling factors?

l.281: “Also, the Ross Ice Shelf and the adjacent Siple Coast feature on average the lowest scaling factors across the entire ice sheet. Some individual ensemble members project even negative scaling: precipitation deficit for rising temperatures.” Is this related to the Frieler et al., 2015 study or does this repeat the previous paragraph?

l.296: “The integrated precipitation shows a more pronounced temporal change, because the integral and not the mean precipitation is calculated, where the vast light precipitation regions lessen the average precipitation signal.” Isn’t the difference just a scaling factor, i.e. the considered area? I guess you are talking about a power-law distribution with a large weight of the continental areas with very low precipitation?

l.301: “... under the precipitation anomalies,” → “... for applied precipitation anomalies,”

l.306: “if we would apply this low scaling of 2 % $K^{-1}$.” Isn’t this mentioned in the beginning of the sentence?

l.316: “Over the entire Antarctic continent, precipitation and temperature grow simultaneously in climate model simulations of the future.” → To summarize, precipitation and temperature, as average over the entire Antarctic continent, grow simultaneously in climate model simulations of the future.”

l.320: “the on Antarctica accumulated snowfall” → “the snowfall accumulated on Antarctica”

l.325: “... the implemented precipitation boundary condition...” → “... the applied





Printer-friendly version

Discussion paper

precipitation boundary condition...” or “... the choice of the precipitation boundary condition...”

l.327: “These together constitute the ensemble of ice-sheet simulations.” → It would be nice to provide the size of the ensemble (3 sceanarios x 9 climate models x 2 reference periods x 2 precipitation forcing = 108 simulations?)

l.332: “...detected trend of about 2 mm decade−1 (sea-level equivalent) fades within the first 400 years...” → How can this trend be justified? Is the present-day reference forcing different from the one used in the spin-up? Or is this due to bed deformation? What figure shows this trend? It should be shown somewhere (Fig. 6?) as it amount to about 2cm after 100 model year and is substracted from the prejection results, right?

l.337: “ than the simulations” → than in the simulations

l.338: Insert comma

l.340: “A ring of a pronounced negative thickness difference follows the coast, where the precipitation anomaly (Figure 2e, h, k) is enhanced.” → “However, we find a negative thickness difference within a narrow band along the coast, where the precipitation anomalies (Figure 2e, h, k) suggest less accumulation that the scaling.”

l.344 “... are negative” Please be more precise in this paragraph, what quantity is negative.

l.347: K-1 superscript

l.349: “... the ice thicknesses of the ensemble means..” → “... the mean ice thickness of each of the respective sub ensembles...”

l.354: “This reduction marks those outlet glaciers and ice shelves that are extremely vulnerable.” Doesn’t it say that ice losses under global warming are larger than gains?

l.359: “... ice-shelf weakening, ice thinning ...” → “... ice-shelf weakening, as well as ice thinning ...”

l.365: “...and restrict ourselves first to the model year 2100, where the precipitation anomalies of the period 1850-2100 shape the ice-sheet thickness distribution of the year 2100.” → “the history of precipitation anomalies”

l.367: “Directly at margins apart from the vast ice shelves, the attributed model that drives either the maximum or minimum ice thickness shows a noisy small scale pattern, which is driven by the variety of the involved models (Figure 8d, e).” → I guess you want to say, that the maximum or minimum ice thickness in marginal regions cannot be associated with a particular climate model, while in contrast, for ice shelf regions...

l.372: “... while it also drives its thinning of the Ross Ice Shelf (Figure 8e) predominantly.” → “... while it causes predominantly thinning within the main Ross Ice Shelf (Figure 8e).”

l.373: “Since the spatial pattern of the atmospheric and ocean forcing that promotes or undermines the ice thickness is not necessarily aligned, this may explain the small scale noisy pattern along the coast.” → Maybe this explanation is not sufficient. The coastal regions is where most of the (nonlinear) dynamical changes on the considered time scales occur in response to both ocean and atmospheric forcing.

l.388: “NorESM1-M influences the WAIS, which is in accordance with the detected lowest scaling in the Siple Coast (Figure 5), CSIRO-Mk3-6-0 has an impact around the South Pole, MRI-CGCM3 has coastal zone in the EAIS, while the control of MPI-ESM-LR and, to a lesser extent, HadGEM2-ES spreads across the entire continent.” → The reader may get lost here by the wording. Make sure that you are talking about the attribution of the minimum ice thickness to different climate models. You could also add percentages of the Antarctic area in the text to quantify the dominance. Similar issue for the maximum in l.398 ff.

l.393: “If we now turn towards the temperature scaled model simulations, the mean, maximum, and minimum ice thickness distribution...” → “If we now turn towards those model simulations, in which the temperature-scaled precipitation forcing has been applied, both the mean, maximum, and minimum ice thickness distribution...”

l.396: “The latter shows that the ocean controls ice-shelf thickness changes in our simulations primarily.” → “The latter shows that primarily the ocean controls ice-shelf thickness changes in our simulations.” or “The latter shows that the ocean primarily controls ice-shelf thickness changes in our simulations.”

l.402: “precipitation driven” → “precipitation-driven”

l.409: Are you referring to all three scenarios here or just RCP8.5?

l.413: “...is quasi-constant until 2000 and declines afterward (Figure A15). For RCP8.5, the basal melting increases at the end of the 21st century quadratic.” → “...remains quasi-constant until 2000 and declines afterwards (Figure A15). For RCP8.5, the basal melting increases at the end of the 21st century quadratically.”

l.415: “... while the basal melting increases by approximately 33 % since the year 2000.” → until 2100?

l.417: “The basal melting rates for PISM1Eq and PISM2Eq are similar, however, the loss rates for PISM1Eq are slightly larger than PISM2Eq (Figure A13).” → This means more basal melting for smaller ice shelf area? What is the portion of refreezing?

l.420: “Since floating ice shelves nourish both ice losses, these ice losses do not impact the sea-level directly.” → “Although floating ice shelves are subject to both types of ice loss, these ice losses do not directly impact the sea-level.”

l.423: “ generates ” → “ would consequently generate ”

l.425: “is not a 1:1 relation.” → “is obviously not a 1:1 relation.”

l.426: Shouldn’t there be a time period involved, e.g. by 2100?

l.427: “It is less than integrated precipitation anomalies...” → “This is less than the integrated precipitation anomalies..., which explains the total mass gains.”

l.429: “Anyhow, the integrated basal melting rates are too low and the calving rates are too high compared to observational estimates in our ensemble of ice-sheet model simulations.” → What does too low and too high mean here, beyond observational uncertainty? Maybe quantify in terms of percent?

l.436: “ loses mass ” → “ lost mass ”

l.449: “the basal melting rated of grounded ice” → “the basal melt rate at he base of the grounded ice”

l.449: “Please note that this is not driven by any trend in the continued ice-sheet simulations under the reference climate (Table 2) since we have substracted this trend.” → “Please note that there is no drift involved, as we substracted the trend from the continued ice-sheet simulations under the reference climate (Table 2).”

l.451: “We also detect an amplified signal for the simulations driven by the precipitation anomalies than scaled precipitation, which corresponds to the above diagnosed sea-level impact of the precipitation (Figure 6).” → Please reformulate!

l.453: Maybe add “net mass gain”, which is associated with a negative sea-level contribution, but whether the global sea level falls is not only determined by Antarctica.

l.455: Please reformulate, such that the reader understands that you talk about a constant rate on the one hand and a linearly increasing integrated melt rate on the other hand.

l.456: “Ultimately, the more vibrant growth of the accumulation in comparison to the negligible increasing combined loss of iceberg calving and basal melting of ice shelves drive the falling sea level in our simulations after the year 2000 (Figure 12).” → “Also the combined loss of iceberg calving and basal melting of ice shelves does not vary much over the considered period. Consequently, the growth of the accumulation in our simulations explains the net mass gains and hence the negative sea-level contributions from Antarctica after the year 2000 (Figure 12).”

l.461: “ temperature scaled precipitation ” Add hyphen!

l.462: “As a consequence, these will contribute after the year 3200 (RCP8.5) and 3900 (RCP2.6) to a globally rising sea level on average in our simulations, which outruns the formerly fallen sea level since 1850.” → “As a consequence, these simulations produce on average a positive contribution to the global sea level after the year 3200 (RCP8.5) and 3900 (RCP2.6), which compensates for the negative contributions since 1850.”

l.470: “the deduced Antarctica’s sea level contribution” → Please reformulate

l.471: “representing the observational-based ocean-driven basal melting.” So you directly apply basal melt fluxes and no ocean-temperature based melt parameterization any more?

l.475: “Under the assumption that only a fraction of the adjusted basal mass contributes to the global sea level, we apply the simulated ratio of the sea level change to the total ice mass change.” → The authors should better motivate that this conversion serves to express mass changes in terms of sea-level equivalents.

l.478: “ sea level correction” Or do you mean “adjusted basal melt flux”?

l.480: Maybe omit “as its evolution, which considers the correction, highlights”

l.481: “..., we obtain too extensive corrections...” → “... we would obtained large corrections...” l.482: “This sea-level rise is larger” → “This corresponding sea-level rise would be larger”

l.485: “raises ” → “could raise”

l.486: “ do not impact the sea level.” → “ do not impact the sea level directly.”

l.487: “ration” → “ratio”

l.490: “ how the precipitation is implemented in ice-sheet simulations” → Better say: “ how precipitation forcing is applied/estimated in ice-sheet simulations” l.493: “ In this case, numerical projections” → “ In this case, our numerical projections”

l.498: “such as the ocean-ice-shelf-ice-sheet interactions.” → “such as the interaction between ocean, ice shelves and ice sheet.”

l.497: “ thence”

l.506: “ overwhelm ” or better overcompensate

l.508: “, the total amount would be identical,” → “, the average amount of precipitation change would be identical to the average precipitation anomaly,”

l.509: “proper” → “adequate” or “realistic”

l.510: “shall” → “should”

l.514: “... which have been identified across sixteen models” → You should add “within a recent model intercomparison exercise”

l.523: “This observed retreat and the related ice loss will continue in our simulations under RCP8.5.” → “This observed retreat and the related ice loss will continue, most likely represented in our simulations by the scenario RCP8.5.”

l.527: “ further to the west” → relative to where?

l.531: Maybe put references after “lose ice”, if they say so.

l.532: “according to our simulations.” → “which is consistent in our simulations.”

l.532: “ will thin in the future.” → reference or does the ensemble suggest so?

l.537: “ reproduces appropriate ” → “ adequately reproduces ”

l.548: “Even if we apply anomalies on top of the reference background fields, we can not exclude a shock-like behavior of the simulations entirely directly following the decades after the year 1850.“ → This is strange, could you quantify the variability around the 50-years mean?





Printer-friendly version

Discussion paper

l.853: “because the water masses of this range flow into the ice-sheet cavities and are in contact with large parts of ice shelve bases. “ → “because the water masses at this depth potentially can flow into the ice-sheet cavities and reach large parts of ice shelves’ bases. “

l.854: “Highest temperature increases occur in the Bellingshausen and Amundsen Seas...” → Is this an observation or does the climate models suggest so?

l.856: “ flow already ” → “already flow” as observations suggest?

l.857: “massive” → “largest”

l.865: “ Temperature Scaling” → “ Estimate of temperature scaling of precipitation from climate models”

l.868: “ depend on if we determine ” → “ depend on the time period we chose as a reference ”

l.871: “However, all these differences do not changes the spatial structure significantly, and they have a neglectable impact compared to the choice of the driving model.” → “However, these differences do not significantly change the spatial structure. Their impact is negligible compared to the choice of the driving model.”

l.877: “The detected precipitation deficit...” → Could you provide a definition here, is this negative scaling or just scaling below average?

l.880: “is small” → you could mention the relative size of the ice shelves, or you could account for ice shelves separately?

l.907: “while in both cases the thickness calving is active” → It would be very interesting if PISM could differentiate between the three calving styles in the reporting.

l.909: Make sure you the reader notices that you switched to observations.

l.919: “just termed basal melting rates” → why not “basal melt rates” l.919: “the second ice mass loss process” → second largest process or does this just relate to the previous paragraph?

l.920: “The basal melting rate anomaly is computed relative to the 50 years between 1951 and 2000.” Please indicate how this period compares to the observations of the World ocean atlas used as reference field?

l.921: “ We could identify immediately that the basal melting rates have risen between 10 % and 100 % since the 1850s (Figure A13)” → “The inferred an increase in basal melt rates by 10-100% over the period 1850-x?”

l.922: “independent of the initial state selection” → “independent of the selection of the initial state” or simply “independent of the initial state”

l.922: “ and reference to compute the” → “ as well as to the reference period selected for the computation of the”

l.925: “ subject to not negligible trend ” → Please be more precises!

l.926: “In the future, the basal melting rate will further increase between 10 % and more than 100 %.” → In future projections, the modeled basal melt rate further increases ... until the year x”

l.927: “ specialized ocean simulations” → “high-resolution ocean simulations”

l.931: “ is apparent.” → “ is clear/distinct.”

l.937: “ or reach a maximum of around 2100 and scenarios” → “and reach a maximum around the year 2100. Scenarios...” The maximum in basal melting in Fig. A13 and A14 seems to occur for all climate forcings a few decades before 2100, is there an explanation for this phenomenon?

l.939: “our approach works where the last 30 years of the forcing until 2100 is recurrently applied afterward.” Please reformulate l.942: “ show a minimum of around 3500 ” → “ show a minimum around the year 3500 ”

l.945: “ ocean temperature anomalies are warmer” → “ ocean temperature anomalies are larger” or “more pronounced”

l.948: “ and an average decrement for RCP4.5 ” → What does this mean?

l.954: “while the highest calving occurs under scenarios with a lower forcing.” → This is surprising, do you have ideas for an explanation? Might this be related to the much smaller ice shelf area and hence shorter ice shelf front? The sentence in l.964 is not so clear on this assessment.

l.967: “Starting from original simulated ablation flux...” → Please start even earlier and explain briefly what the intention of this correction is. You take the modeled fluxes, modify them and apply them in additional sensitivity simulations? Is the reference flux usually obtained from observations? Maybe provide a figure to visualize the magnitudes.

l.980: Please provide some motivation here: “In order to provide an estimate of how ice shelf mass changes result in equivalent sea-level changes...”?

l.998: “the sea level rise of 30 cm is larger than the actual sea level rise “ → “the corresponding sea level rise of 30 cm would be larger than the observed sea level rise“ Please make sure in the wording that this is just a unit conversion and no dynamical estimate.

l.1000: “rise the” → “contributes to the”

l.1001: omit “(Equation A5)”

l.1002: “If” → “Whether”

l.1006: “ losses” → “lose”

l.1009 and l.1010 and l.1012: “temperature scaled” → “temperature-scaled”

**Figures:**

Fig. 1: As this is the overview figure, the reader may expect the sector definitions of Table 4 visualized here, as done in Fig. 4.

Fig. 2: The color scale in panel a is somewhat counterintuitive with the coldest areas in red. Why not using a temperature colorscheme similar to panel c)?

Fig. 3: “is an extension into the sea” → maybe provide some estimate of the width. Also, the anomaly seems to be relative to the start period (at 1850), while for the ocean forcing, in l.920 in the Appendix a reference period 1950-2000 is indicated?

Fig. 4: Which are the dotted regions here? Sector outline seem to overlay each other.

Fig. 6: This figure is simply overloaded, I recommend to split somehow.

Fig. 11: You should mention that ice loss is the combination of calving and melt.

Fig. A1: You should mention in the caption that the 50 cm year−1 contour is larger than in previous figures.

Fig. A2: Where are the “white-grey lines” mentioned in the caption?

Fig. A3: Please increase the size of the climate model labels.

Fig. A4: It would help if the individual panels would use the same y-axis. Why is it important to distinguish between grounded ands glacierized here? Why not between grounded and floating?

Fig. A5: “where all additional mass loss rises immediately the sea level” → “assuming that all additional mass loss is converted into a sea-level equivalent”

Fig. A6: unit for y-axis is also m?

Fig. A7: Omit the in “of the each” in the caption.

Figs. A10+11: It would be nice to indicate that the difference is simply the eigencalving parameter and describe whether and where differences (in calving front location) occur.

Fig. A15: Could you state to what extent the trends can be attribute to grounding line retreat vs. calving front retreat?

**References:**

Frieler, Katja, Peter U. Clark, Feng He, Christo Buizert, Ronja Reese, Stefan RM Ligtenberg, Michiel R. Van Den Broeke, Ricarda Winkelmann, and Anders Levermann. "Consistent evidence of increasing Antarctic accumulation with warming." Nature Climate Change 5, no. 4 (2015): 348-352.

Jourdain, N. C., Asay-Davis, X., Hattermann, T., Straneo, F., Seroussi, H., Little, C. M., and Nowicki, S.: A protocol for calculating basal melt rates in the ISMIP6 Antarctic ice sheet projections, The Cryosphere Discuss., https://doi.org/10.5194/tc-2019-277, in review, 2019.

Levermann, A., Albrecht, T., Winkelmann, R., Martin, M. A., Haseloff, M., & Joughin, I. (2012). Kinematic first-order calving law implies potential for abrupt ice-shelf retreat. The Cryosphere, 6, 273-286.

Sutter, J., Fischer, H., Grosfeld, K., Karlsson, N. B., Kleiner, T., Van Liefferinge, B., & Eisen, O. (2019). Modelling the Antarctic Ice Sheet across the mid-Pleistocene transition–implications for Oldest Ice. The Cryosphere, 13(7), 2023-2041.

Zwally, H. Jay, Jun Li, John W. Robbins, Jack L. Saba, Donghui Yi, and Anita C. Brenner. "Mass gains of the Antarctic ice sheet exceed losses." Journal of Glaciology 61, no. 230 (2015): 1019-1036.

Interactive comment on Earth Syst. Dynam. Discuss., https://doi.org/10.5194/esd-2019-78, 2020.