Review of: "Sensitivity of the current Antarctic surface mass balance to sea surface conditions using MAR", by *C. Kittel et al.*, submitted to *The Cryosphere*.

Using the Modèle Atmosphérique Régional (MAR), the authors investigate the impact of perturbations in present-day sea surface conditions (SSC), i.e. changes in sea surface temperature (SST) and sea ice cover (SIC), on the surface mass balance (SMB) of the Antarctic Ice Sheet (AIS). To that end, the authors carry out a reference run at 50 km horizontal resolution, forced by ERA-Interim (1979-2015) reanalysis, as well as a set of sensitivity experiments perturbing SSC as prescribed by the reanalysis: SST ± 2-4ºC, SIC ± 3-6 MAR grid-cells and combined SST/SIC perturbations. In addition, the authors also force MAR by SSC prescribed from an ensemble average of CMIP5 models and two extreme members, characterized by colder (GISS-E2-H) and warmer (NorESM1-ME) oceanic conditions relative to the reference run. For these simulations, no feedbacks on the atmospheric conditions are considered to exclusively investigate the direct impact of SSC perturbations on the AIS SMB.

Comparing the reference simulation to these sensitivity experiments, the authors show that integrated precipitation, i.e. major contributor to the AIS SMB, significantly increases (resp. decreases) at the ice sheet margins for "warmer" (resp. "colder") SSC experiments, i.e. higher (resp. lower) SST and reduced (resp. increased) SIC, leading to significantly positive (resp. negative) SMB anomalies. This is even more pronounced for combined SSC perturbations (SST/SIC). This study suggests that AIS SMB is more sensitive to SST perturbations than SIC ones. For CMIP5-forced experiments, small and insignificant SMB anomalies are found compared to the reference run. Finally, the authors stress that SMB anomalies obtained from the most extreme SSC perturbation, i.e. SST+4ºC / SIC-6, stand in the lower range of the projected AIS SMB increase by 2100.

This is a sound study based on a well evaluated, state-of-the-art climate model. The sensitivity experiments are well designed and the use of CMIP5 ensemble and members gives an additional insight on how well GCMs currently resolve SSC, as well as biases to be expected when these modeled SSC are used for future projections of the AIS SMB. The paper is generally well written, and includes clear tables and figures. I deem that **minor revisions** are required before acceptance for publication in the Cryosphere. Hereunder the authors can find my comments and concerns that should be addressed before publication. Stylistic suggestions are also listed below.

General comments

1. At several instances, the authors acknowledge that a horizontal resolution of 50 km is inadequate to accurately resolve orographic-forced and local precipitation at the AIS rough margins and over the Antarctic Peninsula (AP): e.g. P7 L17-18, P9 L2-4, P11 L10-13. Although the authors are fair on this point, and justify the use of a coarse spatial resolution as a trade off between manageable computational time and the number of simulation carried out, while still resolving the AIS SMB reasonably well (see Fig. 2), they fail at estimating the associated biases and uncertainties. This is an important concern as most SMB anomalies are found in marginal (steep) regions where the authors suggest potentially large resolution-driven precipitation biases.

   To address this issue, the authors should present a 2D comparison between the 50 km reference run (this study) and the state-of-the-art 35 km run (Agosta et al., 2018), both forced by ERA-Interim (1979-2015). This would highlight the spatial distribution of precipitation/SMB biases and point out where large uncertainties, in both the reference run and sensitivity experiments, are likely to be found. This additional analysis would help the reader interpreting the significance of the SMB anomalies obtained in the sensitivity experiments; in other words, whether these SMB anomalies are larger/smaller than the local difference between the two MAR runs at 50 km and 35 km resolution.

2. As for comparison, the authors should also consider including a second scatterplot in Fig. 2 for the 35 km run, and list the associated statistics. Integrated values and uncertainty (standard deviation) derived from the 35 km run should also be listed in Table 1.

3. An additional Section 6 “Limitations” could discuss in more detail differences in SMB between the 50 km and 35 km simulations as well as related model limitations, i.e. unresolved or not well resolved foehn effect and orographic-enhancement affecting precipitation e.g. over the AP.

4. I would strongly advise to replace Fig. 3 by Fig. S2 in the main manuscript, as it displays all sensitivity experiments performed. Fig. S2 is otherwise redundant, and it is rather inefficient to move back and forth to the supplementary material to visualize and compare results from experiments not shown in the main manuscript.

Substantive Comments

Section 2.3.4: P5 L1-2: Here, I understand that monthly SSC (1979-2005) derived from CMIP5 ensemble average and two extreme members, as well as from ERA-Interim are interpolated to the MAR grid (50x50 km) using an inverse distance weighting method based on the four CMIP5 models/ERA-Interim cells nearest to the current MAR one. If so, please reformulate accordingly. **L5:** This is confusing, are the authors calculating monthly mean SIC-SST from CMIP5/ERA-Interim for 1979-2005 (12 values) or an annual mean (1 value). I understand that monthly SIC and SST anomalies are used, please clarify. **L6-10:** Are the new 6-hourly SST-SIC calculated as the sum of 6-hourly ERA-Interim (i.e. for a specific day of a certain month) and the corresponding monthly anomaly in SST-SIC from CMIP5 models? If so, please reformulate.

P7 L17-18: This is an important caveat that should be addressed in an additional section “Limitations”. A 2D map comparison between 50 km and 35 km simulations could help the reader understanding where large uncertainties are likely to be found at 50 km, see also general comments #1 and #3.

Point Comments

P1 L10: The authors refer to “warm SSC” or “cold SSC” several times across the manuscript. While it may sound obvious that warm (resp. cold) SSC represents combined low SIC and high SST (resp. high SIC and low SST), this should be explicitly stated in the manuscript, e.g. in Section 2.3.3 or more generally in Section 2.3.
P2 L29-30: What do the authors mean by “neither feedbacks involving sea ice and ocean”?
P3 L18: Could the authors briefly elaborate on the reasons why the drifting snow module is switched off? **L25:** Could the authors define OSTIA? **L31:** I guess the authors mean “[…] from a previous reference simulation”, or is the initialization based on multiple simulations, please clarify.
P4 L2: Could the authors mention the original resolution of their DEM?
P5 L7: I guess the authors mean (Fig. 1b). **L8:** (Fig. 1e).
P6 L3: Could the authors estimate by how many ºC on average these two extreme CMIP5 members are “colder” or “warmer” than ERA-Interim. **L4-5:** I guess the authors mean: (Fig. 1a,d) and (Fig. 1c,f.
P7 L4: Could the authors mention how many measurements were discarded from the evaluation?
P9 L2-7: Modeling limitations in the AP could be discussed in an additional “Limitations” section, see general comment #3.
P10 L11-12: Do the authors mean that the SMB from SIC(CMIP5) does not significantly differ from the reference, both spatially and integrated over the whole AIS? If so, please reformulate. **L16:** “SST+2/SIC-3”, same at **L27**. **L19-20:** I do not see snowfall decreasing over the AP in the supplementary figures, this rather seems to occur in the surrounding ocean. Please clarify. **L32:** The authors certainly mean (Fig. 1f). **L32-33:** “SST/SIC(CMIP5) suggests”, what do the authors mean by “as SIC and SST anomalies […] around the mean”? Please, clarify.
P11 L7-9: I am not sure to understand the links between unchanged inland temperature, coastal precipitation enhancement and downward (katabatic?) winds. Could the authors reformulate this

sentence? **L10-13:** This discussion should be moved to a new section "Limitations". **L29-31:** Please reformulate this sentence "present-climate […] 21st century", it reads better at **L18-19 of P14**.

Stylistic suggestions

P1 L2: […] boundary forcing fields prescribed by reanalyses […]. **L7:** Altering is rather negative, and suggests that data have been deteriorated. I would suggest: "by modifying the ERA-Interim SSC". **L10:** Replace "altering" by "affecting". **L17:** "exchange of gas". **L18:** Remove "behaviour"; "impacts" or "affects" instead of "alters". **L19:** "[…] water vapour loading of air masses, potentially […]". **L20:** Remove "as the Antarctic" and insert "that" after "(SMB)". **L23:** The authors could consider reformulating as follows: "[…] have experienced a significant increase since the 1970s (e.g. Massonnet et al., 2013), highly contrasting with the dramatic decline reported in the Arctic Ocean […]".
P2 L9: Maybe "[…] and increased precipitation […]". **L13:** I suggest: "[…] (e.g. Weatherly, 2014), with simplified physics resulting […]". **L14:** I suggest: "[…] (RCMs) forced by former and less reliable reanalyses (e.g. ERA-15 in Bromwich et al., 2007) over short periods […]". **L24:** "[…] with the 'Modèle Atmosphérique Régional' (MAR) for the period 1979-2015. This allows partitioning […]". **L27-31:** I suggest: "[…], this study only discusses the direct […]. This means that no feedback on the […] removal is considered […] Krinner et al. 2014). Only direct impacts on […] components are accounted for. Note that the general […]". **L34:** Replace "altered" by "perturbed".
P3 L7: Maybe "The effect of sea spray on […]". **L10:** I suggest: "[…] sub-modules, that simulate energy and […]". **L15:** Remove "Consequently,". **L16:** I suggest: "[…] and open-ocean fractions". **L21:** "forced by". **L27:** "[…] evolve as a function of accumulated snowfall and surface […]". **L29:** "we start". **L33:** "[…] moisture source for precipitation over the AIS […]".
P4 L1: Maybe "selected" instead of "chosen". **L2:** "extending 6 km above". **L5:** "[…] SMB to SSC perturbations is limited to the […] SIC anomalies within the MAR […]". **L9-10:** "perturbed" instead of "modified". **L13-16:** "for ice-free pixels", "converted into full ice-covered pixels if the SST drops […] (-2ºC). For an SST […] SIC value is set to […]". **L18:** Maybe "at the interface between […]". **L22:** "[…] and maintain SST of sea ice-covered pixels […]". **L25:** "in sea ice extent associated". **L29:** Replace "present climate" by "present-day" or "contemporary".
P5 L9: "[…] anomalies into the original […] enables to account for constant […]".
P6 L9: "perturbed" instead of "altered". **L10:** I suggest: "SST and/or SIA anomalies for JJA and DJF periods are 1.5 times as large as CMIP5 mean […]". **L14:** "brief" instead of "short". **L14:** This is rather negative, I would suggest: "to highlight the impact of using a coarser horizontal resolution on SMB representation". **L15:** Remove "the one described".
P7 L1: Replace "by" by "using". **L2:** "observations collected prior to our study period". **L3:** "for the same period.". **L6:** Add "the" before "observation locations". **L7:** I suggest: "(Agosta et al., 2012), unresolved at 50 km […]". **L8:** Replace "consequently" by "i.e." or by "or". **L13:** "noted" instead of "noticed". **L16:** "significantly smoothed topography".
P9 L1: "enhanced" instead of "stronger". **L7:** "This allows locating". **L12:** For consistency, "interannual variability". **L14:** "The warmer ocean leads to […] of similar magnitude as […] converting snowfall into rainfall." **L16:** "[…] higher temperature also causes […] SST+4 relative to the reference simulation (Fig. S7a-l)." **L18-20:** "[…] sublimation are larger in SST+4 (Fig. S6a) because […] temperature, increased precipitation dominates and the SMB anomaly is significantly positive (Fig. 3a and Table 2)." **L22:** "ocean surface and reduce the water vapour". **L26:** "Over the plateau, larger deposition combined with snowfall […] than for the reference run.". **L28-29:** "[…] colder ocean as lower SST also decrease the near-surface air temperature […]". **L31:** "revealing similar patterns as in SST+2 (Fig. S2m) although non-significant […]".
P10 L1: "smaller" instead of "lower". **L5-7:** "[…] decrease in precipitation is observed over the new ice-covered ocean […] act as an insulator […] 2-m air temperature by 10ºC". **L9:** Maybe "pronounced" instead of "strong"; "[…] SIC-6/SIC+6). This is likely due to the smaller magnitude […] SIC-3 compared to the magnitude of SIC extension […]". **L23:** "show similar anomalies as". **L24:** "larger anomalies […] Besides, the sensitivity of AIS SMB to SSC is non-linear".
P11 L2: Maybe "marginal" instead of "external". **L14-15:** I suggest: "opposite pattern: drier air masses have to rise up higher […] so that precipitation is generated further inland.". **L22:** "affect" instead of "modify". **L23:** "three times as large". **L29:** "perturbed SSC".

P13 L1: "are by far smaller". **L2:** Maybe "showing" instead of "with potential"; the authors could consider "[…] SMB anomalies do not significantly differ from observed SMB". **L4:** Replace "assess" by "evaluate". **L7:** Replace "driven" by "forced".
P14 L2: Replace "altering" by "perturbing" and move "unchanged" to the end of the sentence. **L3:** "The first set consists of […]". **L8:** "(resp. decreased) precipitation due to warmer (resp. colder) […]". **L12:** Maybe "leads to earlier/faster saturation as they rise […]". **L15:** I suggest: "However, comparing modelled SMB from sensitivity experiments with observations shows no significant difference, suggesting […]". **L18:** "with warmer (CMIP5-based) SSC reveal that SMB […] climate stand in the lower". **L20:** Remove "as demonstrated in this study". **L21:** "using potentially biased SSC as forcing". **L22:** Replace "produce new" by "carry out future".

Figures and Tables

Table 1: For the reference run, insert "0.00" or "-" to fill the blanks in the anomaly columns.
Table 2: Caption **L2**: "floating ice" instead of "not grounded ice". For comparison with the coarser resolution simulation, the authors should consider adding integrated numbers from the 35 km run discussed in Agosta et al. (2018). See also general comment #2.
Fig. 2: For comparison, the authors should consider including a second scatterplot showing outputs of the 35 km run.
Fig. 3: This figure could be replaced by Fig. S2. See also general comment #4.
Fig. S6: Caption **L1**: "minus" instead of "mines".