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Interactive comment on "Future projections of the climate and surface mass balance of Svalbard with the regional climate model MAR" *by* C. Lang et al.

Anonymous Referee #2

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General comments:

This manuscript presents the projected future evolution of the climate and mass balance of Svalbard glaciers, based on model experiments with the regional climate model MAR. The paper is well-structured, discusses a novel and relevant topic and provides useful insight into the possible future of the mass balance and climate of Svalbard. Nevertheless, I suggest substantial revisions are necessary before publication. My main concern (in line with the short comment by M. Möller) is that only one climate scenario is considered, which happens to be the most extreme warming scenario among the RCP projections. By considering only the most extreme possible scenario the paper gives a biased and one-sided view of the future for glaciers on Svalbard. I believe that it would substantially strengthen the paper if in addition to the RCP8.5 scenario, the

authors would analyze also the outcome for one or more less extreme climate scenarios. One option is to also run MAR, forced by MIROC5 using a RCP2.6 emission scenario, in order to cover a wide range of future projections with only one additional model run. In addition to this main concern, I found that the paper requires numerous textual revisions and would benefit from a thorough spelling and grammar check. More detailed comments are given below.

Specific comments:

P115 line 17: I don't think you can claim irreversible retreat here based on a negative mass balance all over Svalbard towards the end of the 21st century. The term "irreversible" applies to hysteresis theory in which the surface height – mass balance feedback leads to acceleration of mass loss of shrinking glaciers and ice caps beyond a certain critical point. Irreversibility of mass loss is hard to claim here as the tipping point beyond which unstable retreat occurs is not studied here. Please reformulate to mention that all glaciers and ice caps experience a negative mass balance towards the end of the century.

P117 line 3: Please remove "despite its low contribution to the sea level rise". This addition is irrelevant here.

P117 line 9-12: Please remove "However", start a new paragraph after "global ones" and remove "That is why". I also suggest to replace "high resolution" by "10-km resolution".

P117: It could be worth mentioning in the introduction that most previous work has been on analyzing the surface mass balance in the past and refer to a some relevant papers (e.g. the ones referred to in the companion paper).

P118: I suggest to change the title to "Models and climate forcing".

P118: It would be good to specify in more detail in section 2 what the RCP8.5 scenario implies and for sure it would be good to stress that this is the most extreme warming

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scenario. As mentioned in the general comments I suggest to repeat the whole experiment with a different (low-end) scenario to show the range of changes that can be expected in the future. At present the paper presents a very one-sided view of future projections.

P118: I don't think you need to include a supplement with a figure you also show in the companion paper. Please remove Fig. S1 and refer to the associated figure in the companion paper.

P118 line 15: Please remove "from -3000" and "in the most extreme cases". Also I don't see values reaching as low as -6000 mm w.e. per year in Fig. 1a, only values down to -4000. Is this a problem with the scale? If so, please change the colorbar scale.

P118 line 21: Please replace "snowfall accumulation" by either "snowfall" or "snow accumulation".

P118 line 24: Please replace "Along the coastline" by "At lower elevations" and replace "negative" by "mostly negative".

P118: You can compare the found increase in snowfall and precipitation to what is found in Forland et al (2011) as well as in the IPCC report.

P119 line 2: Consider using "is projected to" instead of "should become". This applies throughout the text.

P119 line 3: Please write "five" instead of "5".

P119 line 4: Replace "presented in the inset" by "around the archipelago".

P119 line 6: No need to start a new paragraph here.

P119 line 10: Replace "a bit" with "slightly".

P119 line 11: Replace "in a vast majority" with "primarily".

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P119 line 13: I suggest to start a new paragraph after "(Fig 3a and b).". The use of "For example" is inappropriate here. Please replace by "Nevertheless".

P119: There is no need to capitalize north, south, east and west. Please change throughout the manuscript.

P119: I suggest to add Fig S2a in the supplement to Fig. 3 in the actual manuscript.

P119 line 17: Based on Fig. 2a of the supplement, I also notice an acceleration of the temperature increase after 2050. So part of the acceleration of melt since 2050 can be ascribed to acceleration of air temperature. Please reformulate.

P119 line 25-26: The ocean around Svalbard is already under present climate conditions ice-free in summer, so higher cloud cover in summer is unlikely related to a reduction of sea-ice. Please reconsider.

P119 line 28: Please remove "available for melt" and the reference to Equation 1.

P119 line 29: Please remove "of JJA SWDnet" and "northern".

P120 line 1-5: I would suggest removing these sentences as it is of little relevance.

P120 line 7: No need to capitalize "Historical mean". This applies throughout the manuscript.

P120 line 8-9: The sentence "Note that . . . in water equivalent" is superfluous and can be removed.

P120 line 10: Replace "could" by "is projected to".

P120 line 13-14: This "shaky" statement needs to be revised. I suggest to replace "and all the permanent . . . end of the century" by "leading to rapid degradation of firn".

P120 line 19: See earlier comment about the inappropriate use of "irreversibility". Please reformulate.

P120 line 21: Please replace "a difference of" by "a mass loss of".

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P120 line 22: Please delete “for”.

P120 line 27-29: It is useful to mention here whether Marzelon et al. (2012) also used an extreme climate scenario.

P121 line 1: Add “the topography of” in front of “Svalbard”.

P121 line 2-5: The statement that the snowfall increase with rising temperatures is not captured by GCM’s is not motivated in any way. Please do so or remove the statement.

P121 line 9: It can be mentioned here that mass loss by calving will lead to even more glacier mass loss of ice mass in addition to surface mass loss.

P121 line 12: I suggest to remove “and some low altitude glaciers should not even exist in our 10 km grid”.

P121 line 14: Please remove “and ice mask” as this sentence only discusses the underestimation of topography.

P121 line 17: Replace “glaciers thinning” by “surface lowering”.

P121 line 17-19: I think the sentences between “As the glaciers. . .” and “. . .21st century” are superfluous and can be removed.

P121: It might be worthwhile to mention that as glaciers are typically concentrated at higher elevations the underestimation of mass loss due to underestimation of topography is likely even stronger.

P121 line 21: Please remove “increase once integrated over large areas”.

P121 line 22: Start a new sentence after “warmer climate” starting with “Additionally, the SLR contribution”. Also, replace “with huge projected melt increase” by “with relatively high mass loss”.

P121 line 24: Please reformulate. My suggestion is to replace “However . . . those three effects to” by “As the aforementioned effects partly” and replace “and to not” by

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“we expect a relatively minor”.

P121 line 29: Replace “evaluate precisely” by “yield insight in the magnitude of”.

P122 line 1: Please use “southern” here instead of “south”.

P122 line 2: Replace “we have glaciers rather than ice caps” by “glaciers rather than ice caps prevail”.

P122 line 7-8: This sentence can be removed as it is mentioned before.

P122 line 12: Add “which is” in front of “much larger . . .”

P122 line 15-16: The values 3.3 and 11.9 degrees C in Forland et al (2011) represent the 90% percentile. It is more useful to refer to the 50% percentile values here.

P122 line 19: Replace “normal” with “expected” and remove “a little bit”.

P122 line 20-21: I don’t think “comparable” is right word here as there are obvious offsets between the presented results and the values in Day et al. and Forland et al..

P123: I think it could be useful to combine Fig S3 with Fig 5 in the manuscript.

P123 line 10-11: Please replace “not form” by “retreat” and add “albedo” to “positive feedback”. Also consider replacing “warm the near surface atmosphere” by “transport warmer air”.

P123 line 12: Please consider removing “which will enhance the sea-ice formation decrease further more”.

P123 line 15: Please consider replacing “SIC/temperature contrast with our future projections” with “the projected increase”.

P123 line 17: Please add “the climate in” before “Svalbard”.

P123 line 23: Please add “maximum” after “our”.

P124 line 3: Please replace “0.2 day sooner” by “0.2 days earlier”.

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P124 line 10: Please replace “overcome” by “dominate”.

P124 line 11: Please replace “sooner” by “earlier”.

P124 line 22: I do see a small delay after 2030. Please rephrase.

P124 line 28: Please replace “the melting area is no longer covered with melting snow” with “a smaller fraction of the melting area is covered with snow”.

P125 line 1: Please clarify “impermeable snow pack” here, or remove if appropriate.

P125 line 7: Please remove “more”.

P125: I believe it is worthwhile to add a sentence to this paragraph mentioning that a reduction of the significance of refreezing, leading to a smaller offset between melt and runoff, has previously been quantified at smaller scale in Svalbard by Van Pelt et al. (2012) and Wright et al. (2007).

van Pelt, W. J. J., Oerlemans, J., Reijmer, C. H., Pohjola, V. A., Pettersson, R., and van Angelen, J. H.: Simulating melt, runoff and refreezing on Nordenskiöldbreen, Svalbard, using a coupled snow and energy balance model, The Cryosphere, 6, 641-659, doi:10.5194/tc-6-641-2012, 2012.

Wright, A. P., J. L. Wadham, M. J. Siegert, A. Luckman, J. Kohler, and A. M. Nuttall (2007), Modeling the refreezing of meltwater as superimposed ice on a high Arctic glacier: A comparison of approaches, J. Geophys. Res., 112, F04016, doi:10.1029/2007JF000818.

P125 line 12: Please replace “of less dependence on” with “that results do not depend on the choice of”.

P125: I suggest to move “Figure 8b . . . over Greenland (Franco et al., 2013)” to a new paragraph at line 2 of P126.

P125 line 16: Please add “s” to “follow”.

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P126 line 12: Please replace “be opposed to” with “partly compensates for” and remove “but will not be large enough to counterbalance it.”

P126 line 24-25: Please remove “and the atmosphere will give energy to the surface on average” as it is superfluous.

P126 line 25: I suggest to start a new paragraph here.

P126 line 29: Please replace “giving” by “contributing” and remove “hence a positive value of LHF”.

P127 line 4-5: Please replace “in opposition to the LHF effect on the melt” by “to oppose mass loss”.

P127 line 11: Please replace “last” by “weakest”.

P127 line 18: Please remove “zone” and replace “drive the evolution of the” with “amplify the warming induced”.

P127 line 23: Please replace “itself due” by “related” and remove “in the South than in the North”.

P128 line 1: Please replace “and” with “which” and “countrebalance” with “counterbalances”.

P128 line 3: Please remove “that” and add “but” in front of will.

P128 line 4: Please replace “and give energy to the surface” by “thereby heating the surface”.

P128 line 6: Please replace “advected on” by “advected over”.

P128 line 7: Please replace “oceanic conditions impacts Svalbard a lot” by “sea-ice conditions strongly impact the climate in Svalbard”.

P128 line 14-16: Please rephrase this sentence. E.g., “The decreasing SIC will therefore contribute to melt, both through an increase in down welling longwave radiation

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and turbulent fluxes."

P128 line 20-21: Please remove the sentence "But, even ... end of the century" for reasons stated in earlier comments.

P128 line 27-29 and P129 line 1-2: I think this needs to be rephrased. Please mention like is done in section 4 that at the beginning of the melt season the refreezing capacity is reducing in time and that the extent of the permanent snow zone at the maximum of melt is shrinking in time as the firn line retreats.

P128: In the final paragraph the third effect on P121, namely the underestimation of surface height after smoothing, is no longer mentioned, whereas the other two effects are. Please also mention the third effect here. I suppose the third effect will also reduce when the model is run at higher spatial resolution.

Figure 1: Note that the colorbar scale in (a) and (b) does not agree with the numbers mentioned in the text.

Figure 4: Here Svalbard seems to be stretched in the east-west direction. Please correct.

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