

Future projections of the climate and surface mass balance of Svalbard with the regional climate model MAR – tcd-9-115-2015

Author answer to the short comment of Marco Möller

Thank you very much for your comments and suggestions that will improve our paper a lot. We have included your comments in the revised version of the manuscript. We refer to our answer to reviewer#2 for a more detailed justification about our choice of showing only one global model and future RCP scenario.

1) The choice of the MIROC5 climate model and the RCP 8.5 scenario needs to be better motivated. The reader needs to know more about both the MIROC5 model and the different RCP scenarios (e.g. Moss et al., 2010). So far, not even the meaning of "RCP" is explained.

We have listed the main conclusions about the MIROC5/MAR forced by MIROC5 performance over current climate we made in the companion paper in the revised version instead of just refer to the companion paper and insisted more on the reasons we chose RCP8.5 as scenario.

Our reasons for using MIROC5 were:

- MIROC5 is one of the best CMIP5 GCMs simulating free atmosphere conditions and circulation over Greenland compared to ERA-Interim (Fettweis et al., 2013).
- MIROC5 works also well over Svalbard and the near-surface temperature MIROC5 bias (compared to ERA-Interim) is reduced and becomes insignificant over land in MAR forced by MIROC5 compared to MAR forced by ERA-Interim. As a result, SMB, precipitation and runoff modelled by MAR forced by ERA-Interim and MIROC5 are not significantly different over the current era. As mentioned by Fettweis et al. (2013), as the response of melt is not linearly dependant on temperature, it is very important to have a model that simulates well the present era climate before performing future projections. But it is clear that having a good model over current climate does not necessarily mean that it estimates well future changes. However, MIROC5 projected temperature increase is close to the CMIP5 ensemble mean and this gives us some confidence in our MIROC based future changes.

Concerning informations for the reader about MIROC5 and RCP scenarios, we have referred to several papers for MIROC5 and added your reference about RCP scenarios but, since we only used the outputs of MIROC5, we do not think we really need to explain what are RCP scenarios and how MIROC5 works.

2) It needs to be worked out explicitly whether the future SMB modelled by Lang et al. represent a "conservative" or an "aggressive" estimate for the future evolution. A recently published study on the future mass balance evolution of a large ice cap in northern Svalbard (Möller and Schneider, 2015) could be considered as a useful reference to set the Svalbard-wide SMB modelling of Lang et al. into perspective. In this study the future evolution of the mass balance of Vestfonna was modelled according to all four RCP scenarios represented by ten different climate models each. By this means, a reliable hold on potential scenario uncertainty and model uncertainties (Hawkins and Sutton, 2009) and the spread of potential future mass balance evolutions is given. Hence, it would be most useful to directly compare a spatial subset of the calculations of Lang et al. for the Vestfonna ice cap to the results of the study by Möller and Schneider and to discuss aspects of scenario uncertainty and model uncertainty with respect to the chosen combination of RCP8.5 and MIROC5.

We have compared the MAR SMB and AAR of Vestfonna (Fig. 1) to your projections. Our SMB is less negative and out of the range of your RCP8.5 projections (-2 m w.e. at the end of the century). MAR projects that the accumulation zone of Vestfonna will disappear around 2075 but will be

reduced to almost nothing as soon as 2065. This estimation is also out of the range of your RCP8.5 projections. The reason our projection is more "optimistic" compared to yours probably comes from the fact that the surface temperature of glaciated areas is limited to 0°C in MAR, which causes the MAR near-surface temperature increase to be lower than in the GCM's in which there is not such a limitation. For comparison, the summer near-surface temperature increase with respect to 1980 – 2005 over Svalbard at the end of the century is +5°C in MAR and +8°C in MIROC5 (Fig. 2). This issue has already been discussed in Goelzer et al. (2013).

Goelzer, H., Huybrechts, P., Fürst, J. J., Nick, F. M., Andersen, M.L., Edwards, T. L., Fettweis, X., Payne, A.J., and Shannon, S.: Sensitivity of Greenland ice sheet projections to model formulations, *J. Glaciol.*, 59, 733 – 749, doi:10.3189/2013JoG12J182, 2013

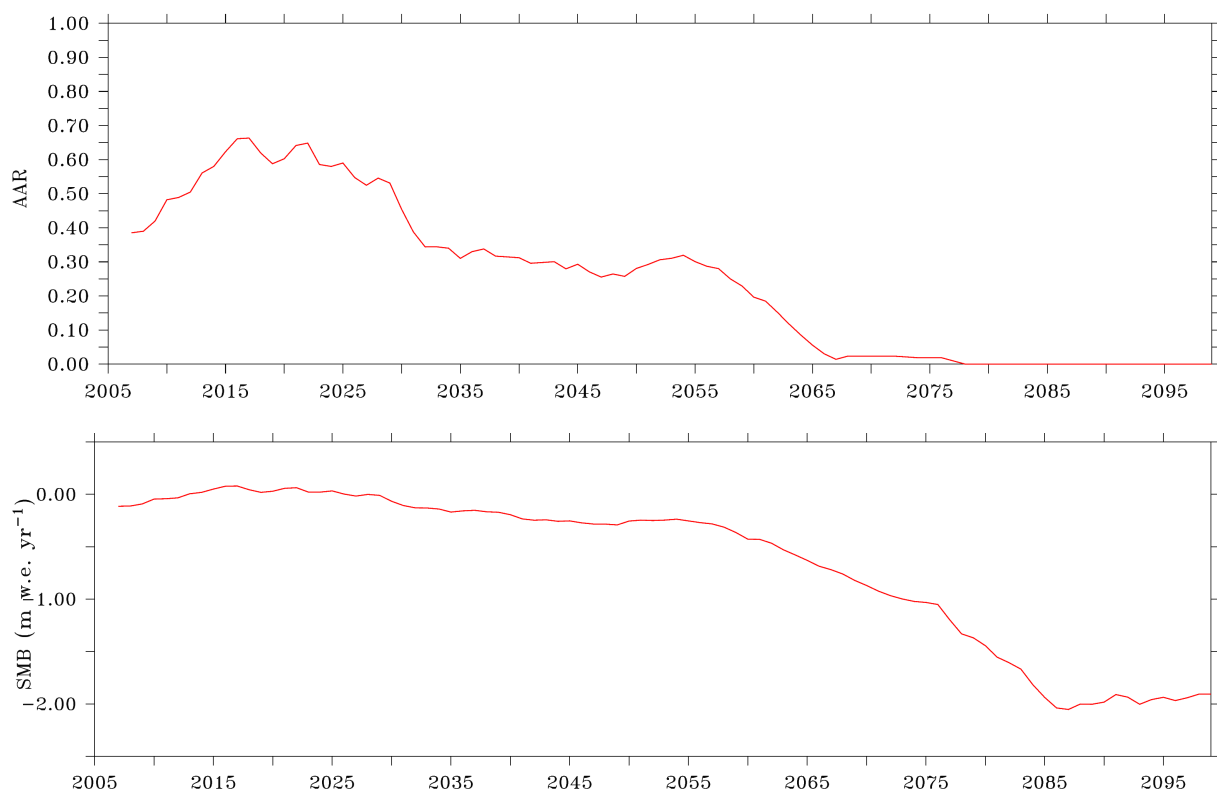


Figure 1: Top: Evolution of AAR for Vestfonna from 2007 to 2100 (10-year running mean). AAR = Accumulation Area Ratio. Bottom: Same for SMB (m w.e.).

Figure 2 shows the evolution of the summer and annual near-surface temperature anomaly (with respect to 1980 – 2005) for MIROC5 (red curve) compared to the other CMIP5 GCMs (grey curves). It shows that, until 2060, both MIROC5 summer and annual near-surface temperature anomaly are close to the ensemble mean (black curve). After 2060, however, the MIROC5 temperature increase is a little bit higher than the ensemble mean. This means that our future projection are quite aggressive over 2060 – 2100 with respect to the RCP85 ensemble mean. This discussion as well as the figures below have been added in the revised version of our manuscript.

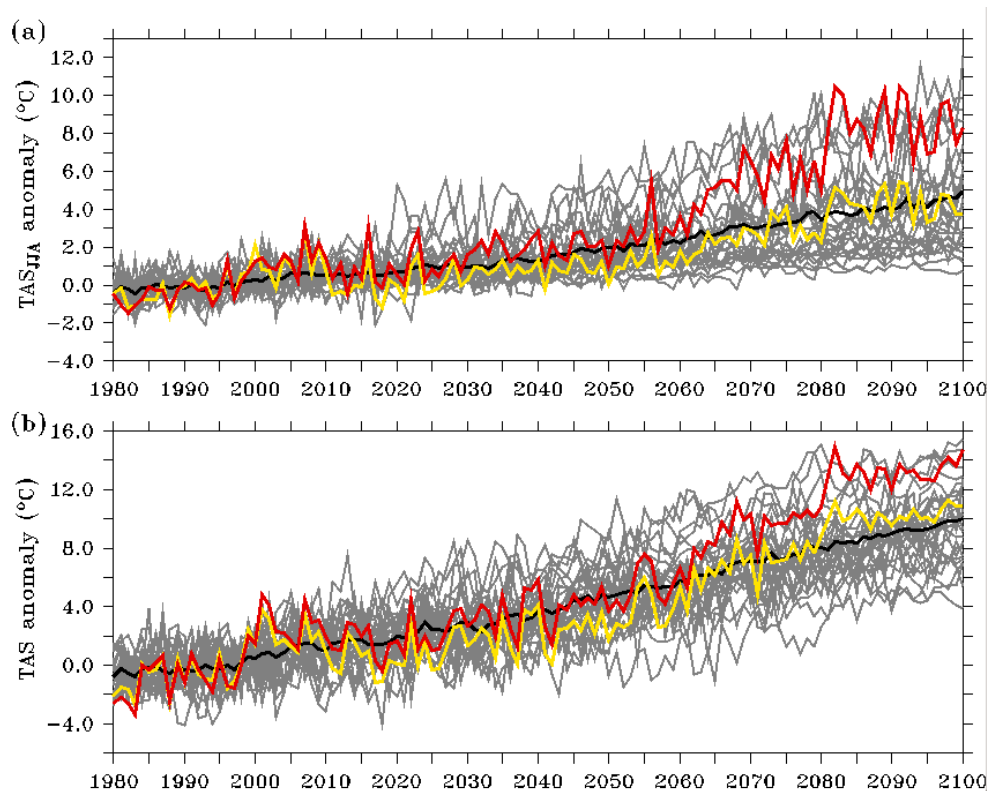


Figure 2: (a) 1980 – 2100 evolution of the anomaly of the JJA near-surface temperature of the CMIP5 GCMs (using RCP8.5 scenario) with respect to the 1980 – 2005 mean. The red curve represents the MIROC5 anomaly, the grey ones the other GCMs, the black one the ensemble mean and the yellow one the MAR anomaly. (b) Same as (a) but for the annual temperature.

Finally, we could also have estimated the SMB using the correlation between SMB and the temperature and snowfall as done in Fettweis et al. (2013). They calibrated a relation between the SMB modelled by MAR forced by different CPIM5 GCMs and the 600 hPa temperature and snowfall from the GCMs and then estimated SMB values for the other CMIP5 GCMs. However, as we explain below, our goal was to show a possible evolution of the Svalbard SMB under a warmer climate and not to do an extensive future projections exercise.

3) It should be explained why only one combination of model and scenario is presented and not an ensemble approach (which would yield much more reliable results). The limitations that are going along with this fact needs to be discussed and expressed clearly. With the choice of only one model and one scenario the outcome of the study by Lang et al. does only represent one single possibility in the universe of possible future mass balance evolutions on Svalbard. This needs to be stated much more prominently in both the abstract and the conclusion.

Our goal was not to do an extensive future projections exercise over Svalbard including all GCMs/scenarios but rather to show a possible outcome of the future of Svalbard cryosphere and its evolution under a warmer climate since it had never been done with a model explicitly computing the energy balance at the surface of the snowpack and taking into account atmosphere-surface feedback as it is done in MAR.

