Modelling of the surface mass balance of Svalbard with the regional climate model MAR

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Abstract: We investigate here the impact of global warming on the cryosphere of Svalbard (74 to 81° lat N, with 60% of its area (about 62 000 km²) covered by glaciers and ice caps) using the regional climate model MAR (Modèle Atmosphérique Régional) fully coupled with a snow energy balance model.
Firstly, we evaluate outputs from MAR forced by the ERA-Interim reanalysis and the MIROC5 global model (from the CMIP5 database) over the current climate (1979-2012) by comparison with measurements of temperature, wind speed, precipitation and surface mass balance at several stations through the archipelago.

1. Simulations

★ **Model: MAR (M**odèle **A**tmosphérique **R**égional, Gallée and Schayes, 1994)
Regional climate model fully coupled with a snow energy balance model (SISVAT)
SISVAT = Soil **I**ce **S**now **V**egetation **A**tmosphere **T**ransfer
→ Modelling of the climate and surface mass balance of Svalbard

★ Two experiments

	Forcings	Period	Resolution
1	ERA-Interim	1979-2012	10 km
2	MIROC5*	1979-2003	10 km

Validation of MAR forced by ERA-Interim and MIROC5: climate and surface mass balance
Next step: future projections of the SMB modelled by MAR forced by MIROC5 (scenarios RCP 4.5 and 8.5)

* Fettweis et al, 2013b

2. Validation of MAR forced by ERA-Interim

In order to validate MAR forced by the ERA-Interim reanalysis, we have compared the model results to daily near-surface measurements (temperature and precipitation) coming from weather stations as well as surface mass balance measurements.

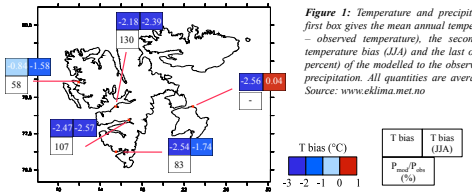

Figure 1: Temperature and precipitation validation. The first box gives the mean annual temperature bias (modelled – observed temperature), the second gives the summer temperature bias (JJA) and the last one gives the ratio (in percent) of the modelled to the observed mean total annual precipitation. All quantities are averaged over 1979-2003. Source: www.eklima.met.no

The daily modelled temperature is very well correlated to the observed temperature ($R^2 > 0.9$) but the MAR is too cold by about 2-3°. Summer temperature (JJA) has a greater influence on SMB than the annual temperature but is less well correlated to the observations ($R^2 < 0.75$ for the JJA daily values). The cold bias is similar to the one for the annual values. The total mean annual amount of precipitation is underestimated for two stations and overestimated for the other two.

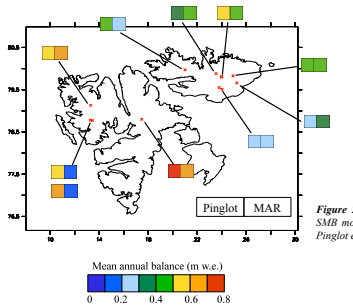

Figure 2 shows the comparison between the mean annual SMB modelled by the MAR and the measurements of Pinglot et al. (1999, 2001). The difference is inferior to 0.15 m w.e. in most of the cases.

Figure 2: Comparison between the mean annual SMB modelled by MAR and the measurements of Pinglot et al. (1999) and Pinglot et al. (2001).

3. Validation of MAR forced by MIROC5

We have then compared the results of MAR forced by the global model MIROC5 to the results of MAR forced by the ERA-Interim reanalysis.

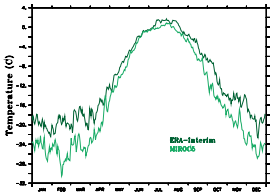

Figure 3: Mean annual temperature (1979-2003) averaged over the whole Svalbard for MAR forced by ERA-Interim (dark green) and MAR forced by MIROC5 (light green).

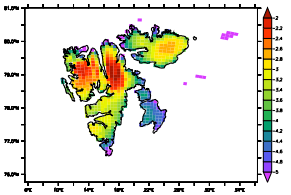

Figure 4: Mean annual temperature difference (°C) between MAR forced by MIROC5 and ERA-Interim (averaged over 1979-2003).

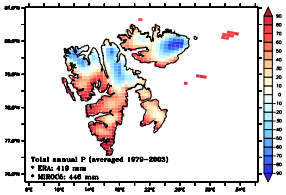

Figure 5: Mean total annual precipitation difference (mm) between MAR forced by MIROC5 and ERA-Interim (averaged over 1979-2003).

4. Present surface mass balance, temperature and precipitation

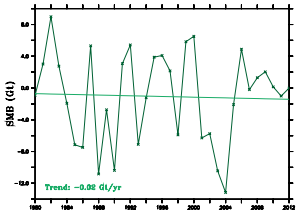

Figure 6: Evolution of the total (summed over all the ice pixels) annual surface mass balance and trend over 1979-2012.

The total SMB (summed over all the ice pixels) is highly variable from year to year and that variability is mainly due to the interannual variability of the meltwater runoff ($R^2 = 0.87$), which is mostly determined by the mean summer temperature variability ($R^2 = 0.81$).
On the other hand, the 1979-2012 temporal trend is very low (-0.02 Gt yr^{-1}) and not significant.

The average annual value is -1.13 Gt.

The lowest value (-13 Gt) is modelled in 2004 and followed by a series of positive or low negative values of the SMB. This is not observed in Greenland (where records of melt have been observed since 2007) and can be explained by a recent change in atmospheric flow frequencies causing more frequent northerly flows over Svalbard (Fettweis et al., 2013a).

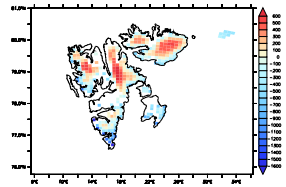

Figure 7: Mean annual surface mass balance (mm) over 1979-2012.

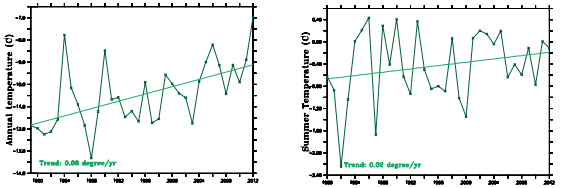

Figure 8: Evolution of the mean annual (left panel) and summer (right panel) temperature and trends over 1979-2012. The trends are not significant.

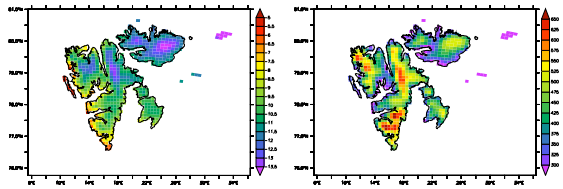

Figure 9: Mean annual temperature (°C, left panel) and mean total annual precipitation (mm, right panel) over 1979-2012.

Conclusion

MAR forced by ERA-Interim is about 2-3° too cold but gave satisfying results when comparing the modelled SMB to the results of Pinglot et al., 1999 and Pinglot et al., 2001. However, given the relatively coarse resolution, the elevation is underestimated in areas of steep topography and could cause a bias in the modelled climate and surface mass balance. Moreover, the resolution is not high enough to represent the small glaciers present in those mountain areas.
The modelled SMB has a great interannual variability driven by the variability of the meltwater runoff but the temporal trend over 1979-2012 is almost nil.
MAR forced by MIROC5 is colder than MAR forced by ERA-Interim but the bias decreases in summer and the spatial distribution of precipitation is different although the total amount is roughly the same.

References

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