Very high resolution surface mass balance of Svalbard with the regional climate model MAR

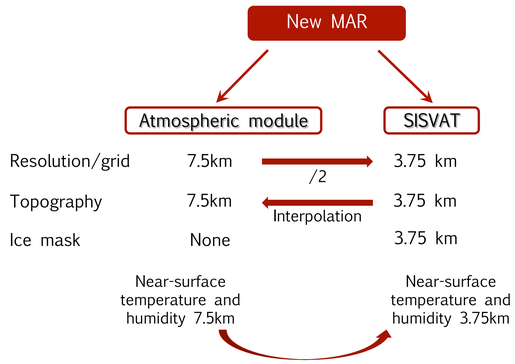
Charlotte Lang[1,2], Xavier Fettweis[1], Michel Erpicum[1]
[1]Laboratoire de Climatologie et Topoclimatologie, University of Liège, Belgium
[2]Fonds pour la formation à la Recherche dans l'Industrie et dans l'Agriculture, FRIA, Brussels, Belgium
Contact: Charlotte.Lang@ulg.ac.be

Introduction

We present climate and surface mass balance (SMB) results over Svalbard simulated by a new version of the regional climate model MAR allowing to reach ~km resolution without highly time-consuming runs.
Spitsbergen is the largest island of the Svalbard archipelago and has a very hilly topography. A high spatial resolution is therefore needed to accurately represent the SMB of Spitsbergen/Svalbard and its complex spatial distribution, as the SMB strongly depends on the local topography and ice distribution.
However, higher resolution simulations are also very time consuming. That is why we have developed a new version of the MAR model in which the snow/ice module runs at a resolution twice as high as the resolution of the atmospheric module.

Model and runs

★ Model: **MAR (Modèle Atmosphérique Régional**, Gallée and Schayes, 1994)
Regional climate model fully coupled with a snow energy balance model (SISVAT)
SISVAT = Soil Ice Snow Vegetation Atmosphere Transfer
→ Modelling climate and surface mass balance (SMB) of Svalbard



Simulations
★ 1979 – 2013
★ Forced by ERA-Interim
★ **Run 1:** 7.5km
★ **Run 2:** 7.5 - 3.75km with new MAR (interpolated simulation)

Topography and ice mask

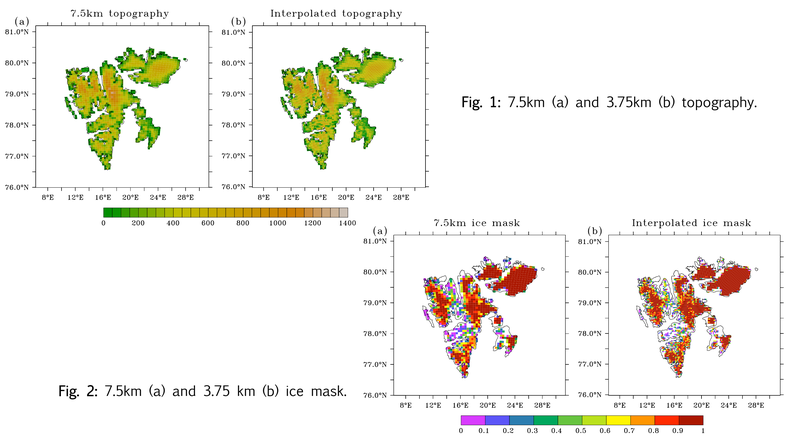


Fig. 1: 7.5km (a) and 3.75km (b) topography.

Fig. 2: 7.5km (a) and 3.75 km (b) ice mask.

Validation

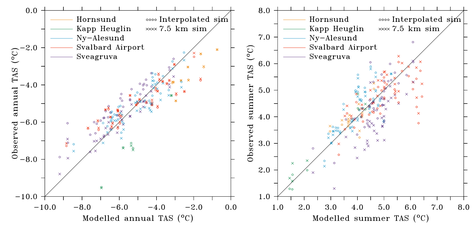


Fig. 3: Observed vs modelled annual (a) and summer (b) near surface temperature at 5 weather stations (fig. 4) for the 7.5km (x) and interpolated (o) simulations.

1. Much better agreement between the observations and the simulations than with a 10km resolution (Lang et al., 2015)
2. Interpolation and 7.5km simulations give similar results for near-surface temperature
   → Elevation difference between the 2 runs at the stations is very small.
3. A little bit too much humidity/precipitation in the interpolated run?

Station	Elevation station (m)	Elev. diff. (m)		RMSE annual (°C)		RMSE summer (°C)		Pmod/Pobs (%)	
		7.5 km	Interp.	7.5 km	Interp.	7.5 km	Interp.	7.5 km	Interp.
Honrsund	10	+16	+16	2.11	2.05	1.46	1.43	88	94
Kapp Heuglin	14	+27	+16	3.66	3.45	1.53	1.33	-	-
Ny-Ålesund	8	+32	-4	2.22	2.06	1.63	1.59	60	64
Svalbard Airport	28	-20	-17	2.59	2.57	1.56	1.59	124	150
Sveagruva	9	+261	+140	3.19	3.29	1.98	1.70	121	127

Table 1: Temperature and precipitation validation. Elevation of the stations and the corresponding MAR pixel. RMSE (°C) between the daily annual and summer modelled temperatures and the measured ones. Proportion (%) of the annual precipitation that is modelled by MAR.

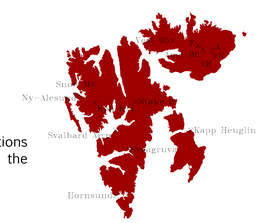


Fig. 4: Location of weather stations and SMB measurements used in the validation

We have compared the 7.5km MAR SMB to the measurements of Pinglot et al. (1999, 2001) (fig. 4). 7.5km MAR agrees better with the measurements than 10km MAR (Lang et al., 2015) or is comparable to the 10km MAR run for 8 of the 10 stakes (table 2, red numbers)

Stake	SMB Pinglot (m w.e. yr^{-1})	SMB MAR 7.5km (m w.e. yr^{-1})	SMB difference (m w.e.)	SMB difference %	Elevation (m) Stake	Elevation (m) MAR
Stake 8	0.75	0.74	-0.01	-1.3	1173	1061
KonK	0.48	0.38	-0.10	-21.3	639	825
KonL	0.62	0.40	-0.22	-36.0	726	825
SnowM	0.57	0.45	-0.12	-21.1	1170	883
Vest95	0.41	0.19	-0.22	-53.8	600	593
F	0.37	0.32	-0.05	-12.4	727	748
Aust98	0.52	0.42	-0.10	-18.5	740	753
A	0.42	0.38	-0.04	-10.5	729	722
N	0.20	0.18	-0.02	-9.2	491	460
R	0.23	0.27	0.04	+15.4	511	532

Table 2: Comparison between the 7.5km MAR simulation and the measurements from Pinglot et al. (1999, 2001). Red indicates that the 7.5km run error is lower or comparable to the 10km error.

Surface mass balance and SMB components

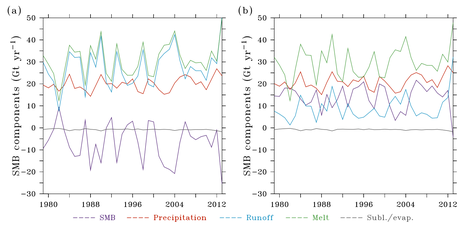


Fig. 5: 1979 – 2013 evolution of the SMB, precipitation, runoff, melt and sublimation and evaporation (Gt yr^{-1}) integrated over the permanent ice area for the 7.5km simulation (a) and the interpolated simulation (b)

- Both runs simulate the same amount of integrated melt, precipitation and sublimation and evaporation and the same evolution over the last 35 years.
- Runoff is much lower for the interpolated simulation because of the too short spin up time (only ½ year). The snowpack is not compacted yet and still covered with "fresh snow" and most of the meltwater percolates through it and refreezes.

→ SMB is much higher and positive for the interpolated run.

- The precipitation and sublimation and evaporation temporal linear trends are significant.
- The melt, SMB and runoff trends are not significant.

	Mean (Gt yr^{-1})		Trend (Gt yr^{-2})	
	7.5 km	Interp.	7.5 km	Interp.
Melt	30.8	29.8	0.20	0.18
SMB	-6.7	13.8	-0.14	-0.06
Precipitation	19.9	20.8	0.10	-0.10
Runoff	27.5	9.0	0.24	0.17
Sublim./evap.	-0.79	-0.80	-0.01	-0.01

Table 3: 1979 – 2013 mean melt, SMB, precipitation, runoff and sublimation and evaporation (Gt yr^{-1}) with their linear trends (Gt yr^{-2}) for the 7.5km and the interpolated simulations. The numbers in red indicate a significant trend.

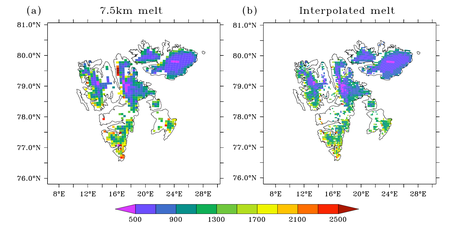


Fig. 6: 1979 – 2013 mean annual melt (Gt yr^{-1}) for the 7.5km (a) and interpolated (b) runs.

Conclusions

★ 7.5km simulation shows better agreement with measured SMB and temperature than previous study at 10km
★ Integrated melt, precipitation and sublimation and evaporation are the same for both runs
★ Need more spin up time to validate the interpolated run against SMB measurements

Work in progress...

References

[1] Gallée H., and Schayes G.,: *Development of a three-dimensional meso-γ primitive equation model: katabatic winds simulation in the area of Terra Nova Bay, Antarctica*, Monthly Weather Review, 122, 671-685, 1994
[2] Lang, C., Fettweis, X., and Erpicum, M.: *Stable climate and surface mass balance in Svalbard over 1979–2013 despite the Arctic warming*, The Cryosphere, 9, 83–101, doi:10.5194/tc-9-83-2015, 2015
[3] Pinglot, J. F., Pourchet, M., Lefauconnier, B., Hagen, J. O., Isaksson, E., Vaikmäe, R., and Kamiyama, K.: *Accumulation in Svalbard glaciers deduced from ice cores with nuclear tests and Chernobyl reference layers*, Polar Res., 18, 315–321, 1999
[4] Pinglot, J. F., Hagen, J. O., Melvold, K., and Eiken, T., and Vincent, C.: *A mean net accumulation pattern derived from radioactive layers and radar soundings on Austfonna, Nordaustlandet, Svalbard*, J. Glaciol., 47, 555–566, 2001

EGU General Assembly 2015 – Vienna, Austria – 12/17 April 2015