Evaluation of the regional climate model WRF over Svalbard

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Abstract: It is well known that high latitude zones are very sensitive to climate change. As a result of global warming, ice sheet melting has increased which in turn has an influence on climate through modifications of the thermohaline circulation, feedback of ice albedo, sea level rise, … Svalbard is an archipelago between 74 and 81°lat N and 60 percent of its area (62 248 km²) is covered with glaciers and ice sheets. The impact of global warming on the Svalbard cryosphere can be estimated with climate models. However, we need to use regional climate models as they offer the possibility of a higher resolution than general circulation models. We have ran two regional climate models (MAR and WRF) at a 10-kilometre resolution between 2006 and 2010 over Svalbard and compared their simulated climate to near surface measurements at several weather stations through the archipelago in order to determine which one of them could best represent the Svalbard climate.

1. Context of the work

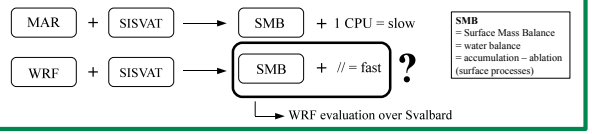
Models

Model	Hydrostatic options	Parallelized	Snow module
MAR Modèle Atmosphérique Régional	Hydrostatic	Coming soon	Yes*
WRF Weather Reasearch Forecasting	Hydrostatic Non-hydrostatic	Yes	No

Simulations

- 10-km resolution, 2006-2010
- Forcings: ERA-Interim reanalysis (ECMWF)
- MAR (Gallée and Schayes, 1994) and WRF (Skamarock et al., 2008), polar version (Byrd Polar Reasearch Center, Ohio State University)

*** SISVAT = Soil Ice Snow Vegetation Atmosphere Transfert = surface model**



2. Validation

As validation, the model results have been compared to daily near-surface measurements (temperature, precipitation and wind speed) coming from the weather stations shown in figure 1 and listed in table 1.

Station	Elevation (m)		
	Station	MAR	WRF
Hopen	6	0.44	0
Hornsund	10	41	69
Kapp Heuglin	14	67	25
Ny-Ålesund	42	24	160
Svalbard Lufthavn	28	190	69
Sveagruva	9	139	281

***Table 1**: Weather stations used for validation. Station elevation and elevation of the pixel in the MAR and WRF models. Weather stations data source: www.eklima.met.no*

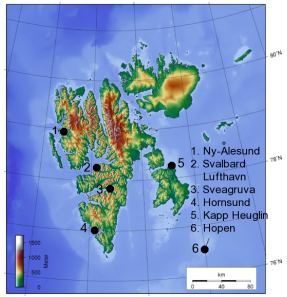
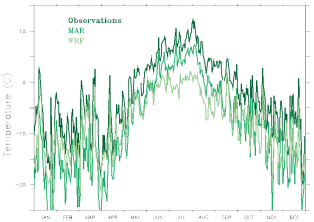


***Figure 1**: Location of Svalbard and weather stations used for validation. Source: http://commons.wikimedia.org/wiki/File:Svalbard-topo.png*

2.1 Mean annual temperature

Station	Tobs	Tmod		R²		RMSE		Bias	
		MAR	WRF	MAR	WRF	MAR	WRF	MAR	WRF
Hopen	-3.04	-5.51	-5.50	0.91	0.66	3.74	4.47	-2.47	-2.46
Hornsund	-2.85	-6.75	-7.77	0.92	0.82	5.08	5.59	-3.90	-4.92
Kapp Heuglin	-6.03	-9.40	-10.64	0.91	0.81	4.69	5.90	-3.37	-4.61
Ny-Ålesund	-4.19	-7.22	-13.88	0.94	0.86	4.02	10.07	-3.04	-9.70
Svalbard L	-3.55	-8.76	-9.00	0.92	0.56	5.82	7.65	-5.21	-5.45
Sveagruva	-5.04	-9.21	-8.61	0.92	0.54	5.13	7.07	-4.17	-3.57

***Table 2:** Temperature validation. Tobs is the mean annual measured temperature. Tmod is the mean annual modelled temperature. R² is the determination coefficient between the observed and the modelled series. RMSE is the root mean square error of the modelled values with respect to the observed ones. Biases are the difference between modelled and observed values.*



The modelled temperature is very well correlated to the measured temperature for the MAR model (R^2>0.9) and WRF can not represent the daily variability of temperature as well as the MAR does.
Both models are colder than the observations by a few degrees for most of the stations.

***Figure 2:** Daily evolution of the mean temperature measured at Svalbard Lufthavn during the year 2007 (dark green) and modelled mean temperature for the corresponding pixel in the MAR model and WRF (light green).*

2.2 Mean summer temperature

Station	Tobs	Tmod		R²		RMSE		Bias	
		MAR	WRF	MAR	WRF	MAR	WRF	MAR	WRF
Hopen	2.20	2.16	-0.83	0.54	0.10	1.31	3.79	-0.04	-3.03
Hornsund	3.59	3.05	-2.24	0.48	0.27	1.58	6.08	-0.54	-5.83
Kapp Heuglin	2.09	1.52	-3.72	0.63	0.09	1.61	6.36	-0.57	-5.82
Ny-Ålesund	4.05	2.89	-6.28	0.63	0.48	2.12	10.52	-1.16	-10.33
Svalbard L	5.50	2.38	-3.19	0.80	0.02	3.38	9.55	-3.11	-8.69
Sveagruva	4.65	2.56	-2.98	0.69	0.01	2.58	8.61	-2.09	-7.64

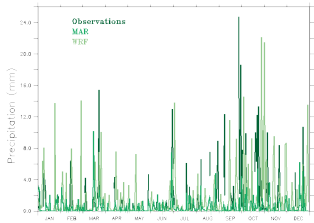
***Table 3**: Temperature validation. Same as table 2. Values are taken from June to August*

Modelled summer temperature, which has a greater influence on SMB than annual temperature, is less well correlated to the observations for both models but the MAR model is once more better than WRF. The negative bias is reduced in the case of the MAR model but increased for WRF. The impact of a lower temperature on the summer melt will therefore be moderate for the MAR model.

2.3 Precipitation

Station	Pobs	Pmod		R²		Difference	
		MAR	WRF	MAR	WRF	MAR	WRF
Hopen	243	175	393	0.12	0.01	-68	150
Hornsund	255	125	290	0.02	0.01	-130	35
Ny-Ålesund	339	133	390	0.04	0.01	-206	51
Svalbard L	141	177	374	0.07	0.00	36	233

***Table 4:** Precipitation validation. Difference is the difference between modelled and observed values.*



The variability of daily precipitation is very badly represented for MAR as well as for WRF.
In the case of the MAR model, mean annual precipitation is much lower than observed for most of the stations. This is also observed over Greenland (Fettweis, 2011).
On the contrary, WRF overestimates precipitation, which has also been observed for Greenland (Sacré, 2011)

***Figure 2:** Daily evolution of the precipitation measured at Hornsund during the year 2007 (dark green) and amount of precipitation for the corresponding pixel in the MAR model and WRF (light green).*

2.4 Wind speed

Station	Wobs	Wmod		R²		RMSE		Bias	
		MAR	WRF	MAR	WRF	MAR	WRF	MAR	WRF
Hopen	5.58	4.90	6.36	0.59	0.61	1.89	1.98	-0.68	0.78
Hornsund	5.77	5.63	6.82	0.68	0.66	2.00	2.64	-0.14	1.04
Kapp Heuglin	5.36	4.45	6.33	0.57	0.21	2.22	3.50	-0.91	0.97
Ny-Ålesund	3.77	4.21	6.14	0.34	0.27	2.44	3.80	0.44	2.37
Svalbard L	4.95	5.20	5.33	0.04	0.30	3.69	2.79	0.25	0.38
Sveagruva	5.01	4.29	5.58	0.60	0.07	1.98	3.69	-0.71	0.58

***Table 3**: Wind speed validation. Same as table 2.*

3. Modelled temperature and precipitation

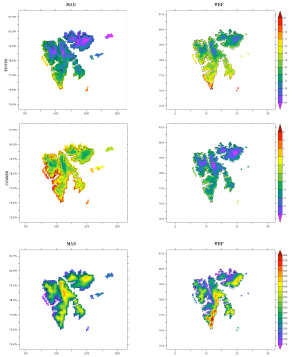


***Figure 4:** Mean winter (upper panel) and summer (lower panel) temperature over 2006-2010 modelled by the MAR (left) and WRF (right) models.*

***Figure 5:** Total annual precipitation averaged over 2006-2010 modelled by the MAR (left) and WRF (right) models.*

Conclusion

The MAR model is a little bit too cold and simulates too few precipitation. However, as the summer temperature is an important variable for our purpose (SMB modelling) and as WRF can not reproduce its variability and lowers even more the bias, the MAR model seems more appropriate.
Furthermore, the next version of the MAR model, which will be a parallelized version, is under development. This new version modifications include a better modelling of the humidity, which was too low. As a consequence, the winter temperature bias should be reduced (through the influence of the humidity on IR radiation, which was underestimated) and the amount of precipitation should be higher.
More tests will be carried on once this version is available before deciding if it is worth coupling WRF to SISVAT or if we should work with the parallelized version of the MAR model.

References

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