

UNIVERSITÉ DE LIÈGE

Present and future Greenland ice
sheet surface energy balances with
the help of the regional climate
MAR model

Thèse réalisée par

BRUNO FRANCO

sous la direction de

MICHEL ERPICUM (Université de Liège, UGPQ)

et

XAVIER FETTWEIS (Université de Liège, UGPQ)

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Jury de thèse composé de :

Prof. F. PETIT (Université de Liège, Président du jury),

Prof. M. ERPICUM (Université de Liège, Promoteur de thèse),

Dr. X. FETTWEIS (Université de Liège, Co-promoteur de thèse),

Dr. C. AGOSTA (Université de Liège, LGGE Grenoble),

Prof. L. FRANÇOIS (Université de Liège),

Prof. H. GALLÉE (LGGE Grenoble),

Prof. C. SCHNEIDER (RWTH Aachen)

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Abstract

(1) The Greenland ice sheet (GrIS) surface mass balance (SMB) was modelled at different spatial resolutions (15–50 km), using the regional climate model MAR (Modèle Atmosphérique Régional) forced by the ERA-INTERIM reanalysis over the 1990–2010 period. The comparison of these simulations revealed that (i) the inter-annual variability of the SMB components is consistent within the different resolutions investigated when they are integrated over the whole ice sheet, (ii) the MAR model simulates heavier precipitation on average over the GrIS with decreasing resolution, and (iii) the SMB components (except precipitation) can be derived from a lower-resolution simulation with an enhanced interpolation. This interpolation can also be used to approximate the SMB components over another topography/ice sheet mask of the GrIS. These results are valuable for the forcing of an ice dynamical model, needed to enable full projections of the GrIS mass balance contribution to sea-level rise (SLR) over the coming centuries. Moreover, this work showed that 25 km-resolution MAR simulation is a good compromise between computing time and results precision in the aim to perform afterwards 21st-century projections of the GrIS melt.

(2) The most suited atmosphere-ocean general circulation models (AOGCMs) for the GrIS current climate modelling were selected on the basis of comparison between the 1970–1999 outputs and reanalyses, showing that the representation quality of surface parameters (temperature, precipitation) are highly correlated to the atmospheric circulation and its inter-annual variability (North Atlantic oscillation). Future atmospheric circulation changes according to greenhouse gas (GHG) emissions scenarios were projected to dampen the zonal flow, enhance the meridional fluxes and provide additional heat and moisture to the GrIS, increasing temperature over the whole ice sheet and precipitation over its northeastern area. Moreover, future projections performed with the selected AOGCMs showed consistent anomalies to the present-day climate. The GrIS SMB anomalies from the A1B scenario amount to -300 Gt yr^{-1} with respect to 1970–1999, leading to a SLR of 5 cm by the end of the 21st century. This work helped to select the AOGCMs used as forcing fields in the MAR model to carry out future projections of the GrIS.

(3) 20th and 21st centuries MAR simulations at 25 km resolution forced by previously selected GCMs according to GHG scenarios were performed over the GrIS in order to investigate the projected changes of the surface energy balance (SEB) components driving the surface melt. Analysis of 2000–2100 melt anomalies to 1980–1999 results revealed an exponential relationship of the surface melt to the near-surface temperature anomalies, mainly due to the surface albedo positive feedback associated with the extension of bare ice areas in summer. On the GrIS margins, the future melt anomalies are driven by stronger sensible heat fluxes, induced by enhanced warm air advections. Over the central dry snow zone, the increase of melt surpasses the negative feedback from heavier snowfall

inducing a decrease of the summer surface albedo. In addition to the incoming longwave flux increase associated to the atmosphere warming, MAR projected an increase of the cloud cover decreasing the ratio of the incoming shortwave versus longwave radiation and dampening the albedo feedback. This trend of cloud cover is contrary to that simulated by reanalyses-forced MAR over current climate, where the observed melt increase since the 1990's is rather a consequence of more anticyclonic atmospheric conditions. No significant change was projected in the length of the melt season, highlighting the importance of solar radiation in the melt SEB.

Contents

1	General introduction to the Greenland ice sheet and the MAR model	1
	Introduction	1
1.1	Introduction	2
1.1.1	The Greenland ice sheet: overview	2
1.1.2	The Greenland ice sheet mass balance	3
1.1.3	The Greenland ice sheet under climate changes	5
1.2	Greenland ice sheet modelling	7
1.2.1	Regional climate models	7
1.2.2	The MAR model	8
1.3	Structure of this thesis	11
1.3.1	Impact of resolution on the GrIS SMB modelling	12
1.3.2	Present and future climates of the GrIS	13
1.3.3	Future projections of the GrIS SEB	14
2	Impact of spatial resolution on the modelling of the Greenland ice sheet surface mass balance between 1990–2010, using the regional climate model MAR	17
2.1	Introduction	18
2.2	The MAR model	18
2.3	Validation of the MAR simulations	19
2.4	Comparison of the MAR resolutions	23
2.4.1	Surface height anomalies	26

2.4.2	Annual precipitation anomalies	27
2.4.3	Anomalies of meltwater run-off	29
2.4.4	Anomalies in surface mass balance	30
2.4.5	Inter-annual variability	31
2.5	Impact of the domain size	33
2.6	Enhanced GrIS SMB interpolation	35
2.6.1	Method	35
2.6.2	Run-off of meltwater	37
2.6.3	Sublimation and evaporation	39
2.6.4	Snowfall and rainfall	39
2.6.5	Reconstructed GrIS SMB	40
2.7	Impact of a coarse topography	42
2.8	Discussion and conclusion	45
3	Present and future climates of the Greenland ice sheet according to general circulation models	49
3.1	Introduction	50
3.2	Data description	50
3.3	Current climate modelling	52
3.3.1	General circulation	52
3.3.2	Temperature pattern	57
3.3.3	Precipitation pattern	63
3.3.4	Selection of the most suitable AOGCMs for current climate modelling	68
3.4	Future projections based on IPCC GHG emission scenarios	68
3.4.1	Atmospheric circulation for the 2070–2099 period	69
3.4.2	Annual precipitation for the 2070–2099 period	70
3.4.3	Annual and summer temperatures for the 2070–2099 period	72
3.4.4	Future projections from non selected AOGCMs	74
3.5	GrIS SMB projected anomalies for the 21st century	76
3.6	Discussion and conclusion	79

4	Future projections of the Greenland ice sheet energy balance driving the surface melt, developed using the regional climate MAR model	83
4.1	Introduction	84
4.2	Data and method	85
4.2.1	The MAR model	85
4.2.2	Simulations	86
4.2.3	Surface Energy Budget	88
4.2.4	Mask of daily melt events	88
4.3	Validation of the MAR simulations	90
4.4	Projected melt anomalies of the GrIS	92
4.5	SEB component contributions to melt anomalies	95
4.5.1	Net Shortwave Flux (SW_{net})	96
4.5.2	Sensible Heat Flux (SHF)	98
4.5.3	Net Longwave Flux (LW_{net})	100
4.5.4	Latent Heat Flux (LHF)	101
4.6	Spatial distribution of SEB component anomalies	101
4.7	Surface albedo	104
4.8	SEB component anomalies over bare ice area	107
4.9	Discussion and conclusion	108
5	Conclusion and perspectives	111
	Conclusion	111
5.1	Conclusion	112
5.2	Perspectives	115
	References	123
6	Annex	139