Last century Greenland ice sheet surface mass balance projections from IPCC AR4 global models

Laboratoire de climatologie
Université de Liège

Franco, B.[1] ; X. Fettweis[1] ; M. Erpicum[1]

(1) Laboratoire de climatologie, Université de Liège, Belgium, bruno.franco@ulg.ac.be. (Ph. D. student)

Abstract

*Results from atmosphere-ocean general circulation models (AOGCM's) for the IPCC 4th Assessment Report are used to investigate surface mass balance (**SMB**) future projections of the Greenland ice sheet (**GrIS**). The most efficient models for the GrIS climate modeling are chosen by comparison between the 1970-1999 outputs (averages and trends) from the 20C3M Experiment outputs, and the reanalyses (ECMWF, NCEP) as well as climatologies. The SMB is estimated from the summer temperature (from which is deduced the run-off) and annual snowfall from the well-adapted AOGCM's. It is validated with 1970-1999 results from the regional climate model MAR by interpolating the AOGCM's outputs on the MAR grid. However, large uncertainties remain in these SMB projections due to the simplified physic and coarse AOGCM's resolution. High resolution simulations made with the MAR model (which simulates explicitly the SMB by taking into account the surface feedbacks) forced at its boundaries by a GrIS well-adapted AOGCM could bring more precise brief replies.*

Selection of IPCC AR4 AOGCM's for GrIS modeling

• The AOGCM's are first selected for the GrIS modeling at the summit of the ice sheet by evaluating the precipitation and the temperature which depend mainly on the AOGCM's resolution. Once selected, the AOGCM's will be used to estimate the GrIS surface mass balance with the help of these parameters.

• We assume that the summer mean temperature at Summit of the ice sheet is representative for the GrIS climatic conditions. According to the outputs from the regional climate model MAR (who is validated and optimized for the Greenland) and *in situ* observation, the Summit JJA (June-July-August) temperature is about -14,5°C for the 1970-1999 period. The too warm or too cold models are discarded while they can be reliable along the GrIS margins.

• The altitude of Summit depends on the resolution of model which allows to eliminate the AOGCM's with a too coarse spatial resolution.

• The annual precipitation (snowfall and rainfall) influences the SMB but also the run-off. The models should simulate a maximum of precipitation along the South-East of Greenland and another lower maximum should occur along the west coast.

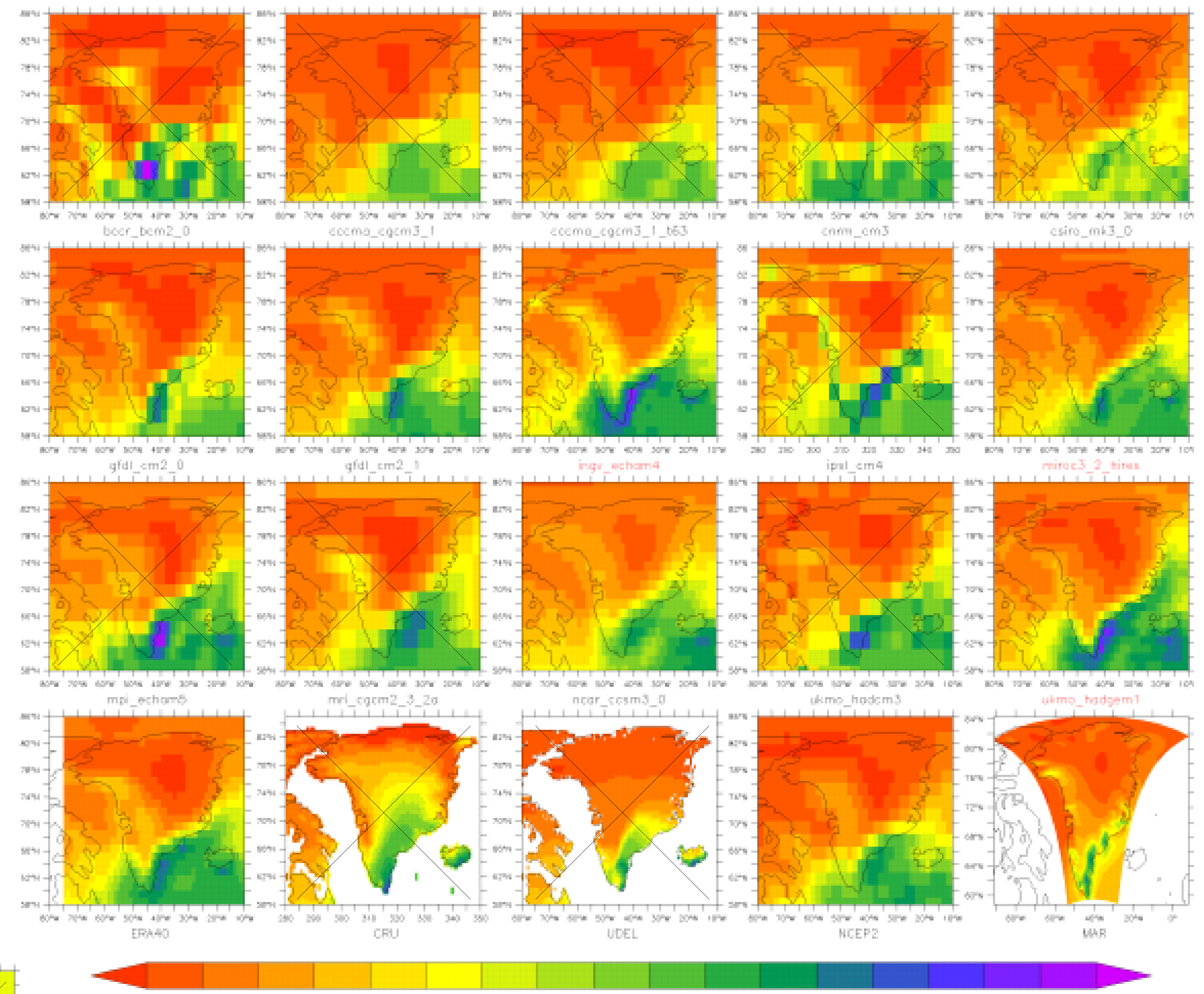

Fig 1 : Mean annual precipitation (mmWE) for the 1970-1999 period simulated by some IPCC AR4 AOGCM's, by reanalyses (ERA-40, NCEP2) and from climatological time series (CRU, UDEL) and simulated by the MAR model.

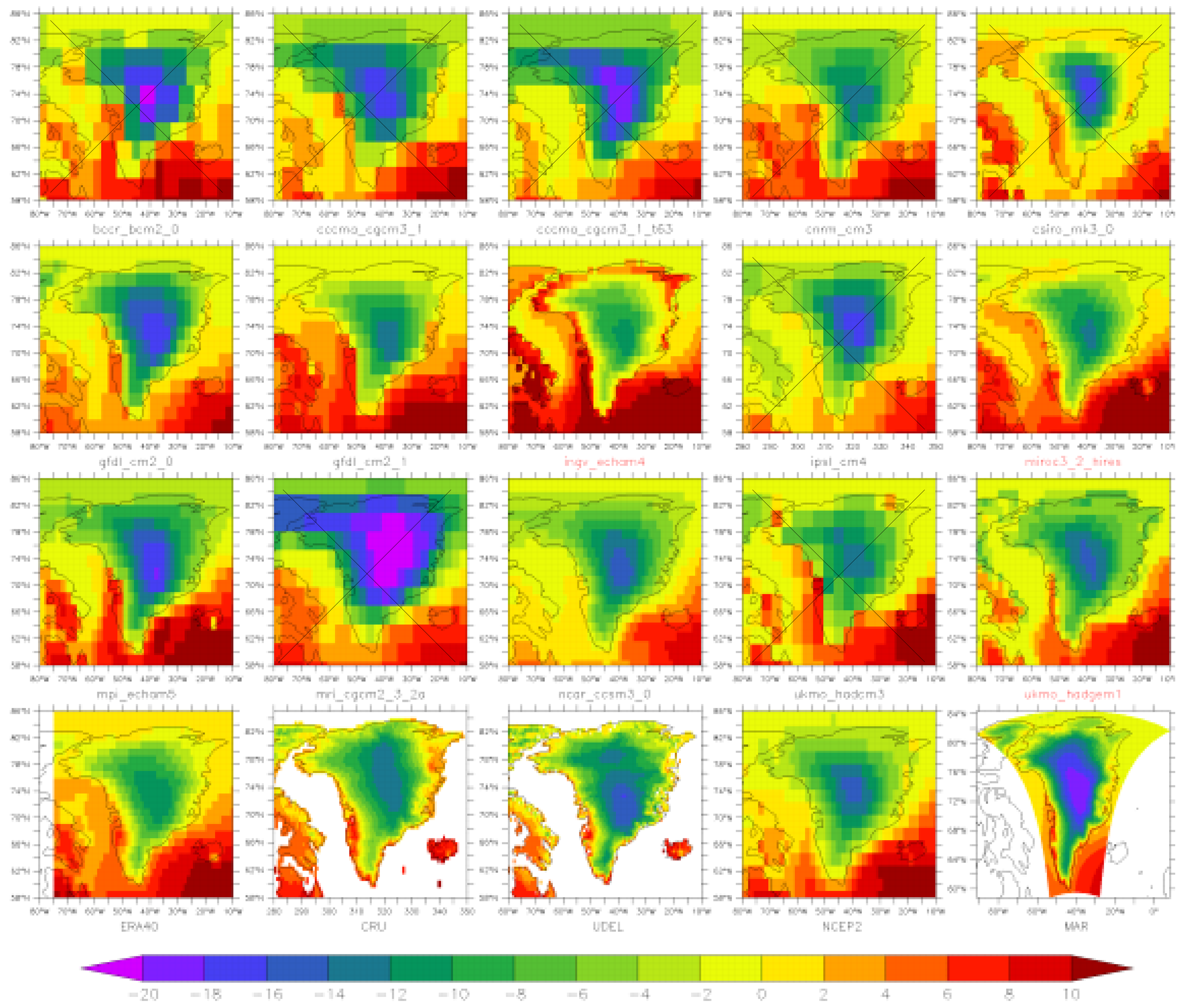

Fig 2 : Summer temperature (°C) for the 1970-1999 period simulated by some IPCC AR4 AOGCM's, by reanalyses (ERA-40, NCEP2) and from climatological time series (CRU, UDEL) and simulated by the MAR model.

Summit statistics	Altitude m	An. Precipitation mm	An. Precipitation trend	JJA Precipitation mm	JJA Precipitation trend	An. Temperature °C	An. Temperature trend	JJA Temperature °C	JJA Temperature trend
bccr_bcm2_0	3120,74	209,00	-0,5706	64,49	-0,1170	-35,45	-0,0692	-19,65	0,0277
cccma_cgcm3	2977,46	143,00	1,2120	48,99	0,5980	-31,55	0,0638	-17,55	0,0688
cccma_cgcm3_t63	3114,76	117,60	-0,0496	37,56	-0,2581	-33,15	0,0393	-19,15	0,0205
cnrm_cm3	3120,69	217,10	-0,2862	47,55	0,3553	-27,45	-0,0228	-12,65	0,0005
csiro_mk3_0	3489,87	99,87	0,0415	53,94	-0,0181	-30,55	0,0107	-15,75	0,0371
csiro_mk3_5	3489,87	132,40	0,1000	63,62	0,2540	-20,85	0,0125	-9,75	0,0424
gfdl_cm2_0	3094,99	103,20	0,3317	37,43	0,1510	-31,55	0,0670	-17,25	0,0205
gfdl_cm2_1	2985,87	158,20	0,8999	58,04	-0,0713	-27,65	0,0308	-12,95	0,0071
giss_aom	3089,20	562,00	-2,6240	154,50	-0,3839	-21,55	-0,0054	-10,35	-0,0027
giss_model_e_h	3055,86	508,80	-3,3930	113,60	-0,9480	-26,75	0,0205	-14,75	0,0420
giss_model_e_r	3055,86	508,30	-1,1460	126,70	0,7770	-26,45	0,0045	-15,35	0,0089
iap_fgoals1_0_g	2408,06	455,60	-0,7510	183,70	0,0790	-29,75	-0,0004	-12,25	0,0214
ingv_echam4	3215,49	207,90	0,5754	55,39	0,2310	-26,05	0,0165	-11,65	0,0107
ipsl_cm4	2951,91	103,80	0,3281	31,35	-0,0604	-29,85	0,0375	-16,55	0,0620
inmcm3_0	2814,71	616,90	2,0390	142,20	1,2190	-22,55	0,0620	-6,75	0,0134
miroc3_2_hires	3186,70	150,00	-0,0433	51,43	0,0057	-27,35	0,0353	-12,35	0,0464
miroc3_2_medres	2674,63	121,70	0,4705	39,24	0,0310	-26,65	0,0143	-9,05	-0,0165
miub_echo_g	2694,27	246,60	0,6067	56,63	-0,1715	-27,75	0,0571	-14,85	0,0357
mpi_echam5	3263,39	87,24	0,5337	26,51	0,1032	-29,35	0,0482	-18,15	0,0393
mri_cgcm2_3_2a	3146,27	145,40	-0,2210	31,77	0,2990	-28,15	-0,0103	-21,25	0,0299
ncar_ccsm3_0	3041,19	221,60	0,5741	78,72	-0,2763	-28,75	0,0531	-14,95	0,0273
ncar_pcm1	2889,68	172,40	-0,0223	81,26	0,1996	-24,15	-0,0112	-8,75	-0,0063
ukmo_hadcm3		225,10	0,4567	53,44	0,1559	-27,65	0,0509	-13,75	0,0491
ukmo_hadgem1	3243,82	126,00	0,1670	35,60	-0,0468	-27,05	0,0620	-14,45	0,0321
ERA-40		172,30	0,9326			-27,37	-0,0478	-11,53	0,0250
NCEP1		46,72	0,1847	31,31	0,1778	-23,91	0,0235	-8,77	0,0065
NCEP2		153,60	0,5498	72,16	0,1410	-26,85	0,0263	-13,45	0,0085
CRU		835,50	-1,7290	218,70	-0,2174	-22,27	0,0276	-12,07	0,0161
UDEL		362,80	-3,2940	101,70	-0,8000	-30,05	0,0190	-15,52	0,0234

Table 1 : Various parameters of comparison between the AOGCM's and climatological time series at Summit (72N, 38W).
a) too warm AOGCM's
b) too cold AOGCM's
c) the selected well-adapted AOGCM's

• Only three AOGCM's (INGC_ECHAM4, MIROC3_2_HIRES and UKMO_HADGEM1) seem to be well-adapted to the GrIS. In this poster, we will use only the MIROC model.

Greenland ice sheet SMB projections or this century

• The GrIS run-off for the 1970-1999 period is estimated according to Ohmura and al. (1996) who established a linear relation between the summer air temperature and the summer ablation. In our work, we add also a dependence of the run-off to the previous winter precipitation. The rapidity of the melt of the winter snow pack exposes sooner or not the bare ice (in the ablation zone) and old snow. This impacts the surface albedo and therefore the surface melt.

$$\Delta Ru = a \times \Delta T_{JJA} + b \times \Delta SF_{winter}$$

***Equation 1** : Relation used to estimate the runoff (**ΔRu**) from the summer temperature (**ΔT**) and the winter snowfall (**ΔSF**). The constants are chosen according to the presence of snow or ice at the surface.*

• Two relations were established to estimated the run-off with the 1970-1999 results simulated by MAR (**Equation 1**). A first one is calibrated for surfaces covered by snow. A second one is used for ice surface in ablation zone where the melt is accelerated due to a lower albedo than snow. In addition, a corrective factor takes into account the summer snowfall (which decreases the melt) and the rainfall (which accelerates the melt).

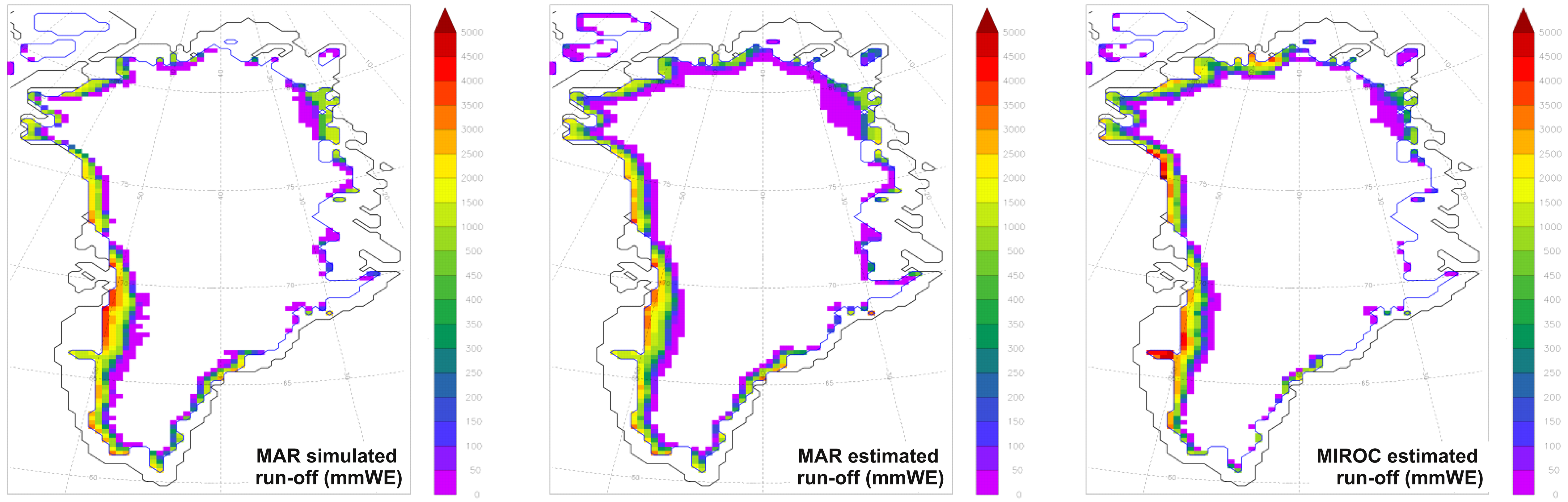

*Fig 5 : Run-off (mmWE) for the 1970-1999 period a) simulated by MAR, b) estimated by MAR (via **Equation 1**), c) estimated by interpolating the MIROC outputs on the MAR grid.*

• The run-off is estimated with the **Equation 1** from the JJA temperatures and the winter precipitation by interpolating the 1970-1999 MIROC outputs on the grid MAR. However, the interpolated temperature from the model MIROC were calibrated with the MAR temperature to be still coherent with the parameters of **Equation 1** while an important part of inaccuracies is due to the unknown gradient of temperature between the summit and the GrIS margins.

• The MAR model simulates a mean 1970-1999 GrIS run-off of 249 km³/yr. The **Equation 1** estimates the run-off to 237 km³/yr with the MAR outputs and to 251 km³/yr with the MIROC outputs. However, the estimated run-off is overestimated in the North as well as in the North-West and underestimated in the South-West despite the corrective factors.

• The **Equation 1** is applied to the MIROC outputs for the scenario A1B from IPCC. The results project an increase of the temperature at Summit of more than 4°C, a increase of the run-off, constant snowfall and a negative SMB.

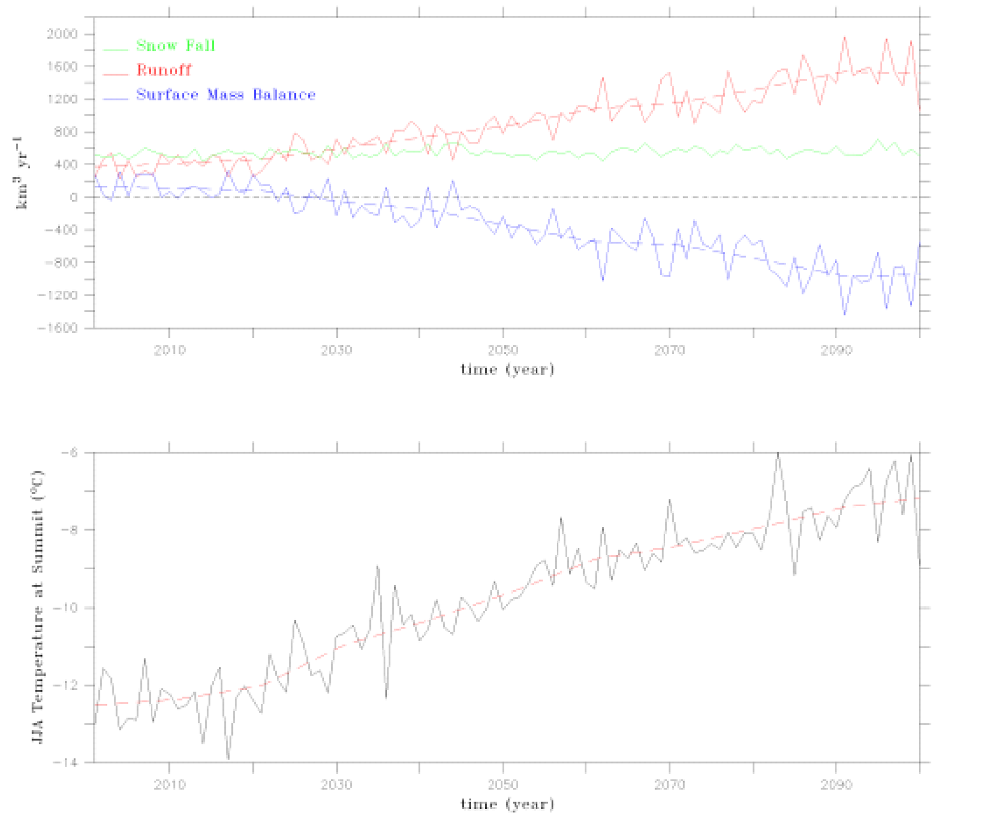

Fig 6 : According to A1B IPCC scenario :
a) GrIS Snowfall, Runoff and Surface Mass Balance projections (km³ /yr) ;
b) Summer temperature (°C) at Summit ; of the GrIS estimated by interpolating the MIROC outputs.

Conclusions

We estimate the GrIS run-off by using a relation based on the summer temperature and the precipitation of AOGCM's from the IPCC AR4. However large uncertainties remain in these SMB projections. High resolution simulations made with a regional model forced at its boundaries by a well-adapted AOGCM could bring more precise results. This work represents the first stage of Ph.D. researches dedicated to the SMB of the GrIS.

References :
- Estimation of the Greenland ice sheet surface mass balance during 20th and 21st centuries, X. Fettweis, E. Hanna, H. Gallée, P. Huybrechts, and M. Erpicum, The Cryosphere Discuss., 2, 225-254, 2008
- A possible change in mass balance of Greenland and Antartic ice sheets in the coming century, A. Ohmura, M. Wild, and L. Bengtsson, Journal of Climate, 9, 2124-2135, 1996