Impact of ice sheet mask and resolution on estimating the surface mass balance of the Greenland ice sheet

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Abstract

*The impacts of the spatial resolution and the Greenland ice sheet (**GrIS**) mask on modeling the Surface Mass Balance (**SMB**) are studied with the regional climate model **MAR** coupled with a complex energy balance/snowpack model.*
1. Too coarse resolution prevents the model from resolving adequately the steep ice sheet margin and the ablation zone, not wider than 100 km in Greenland, where substantial seasonal melting occurs. The resolution affects also the precipitation modeling.
2. A too large ice sheet mask (i.e. with low-altitude ice pixels in the model, where there is no ice in reality) leads to an overestimation of the run-off. In addition, due to the albedo feedback, biases in the ice sheet mask have also consequences on the surface energy balance.

Impacts of the resolution (25km, 30km and 37km)

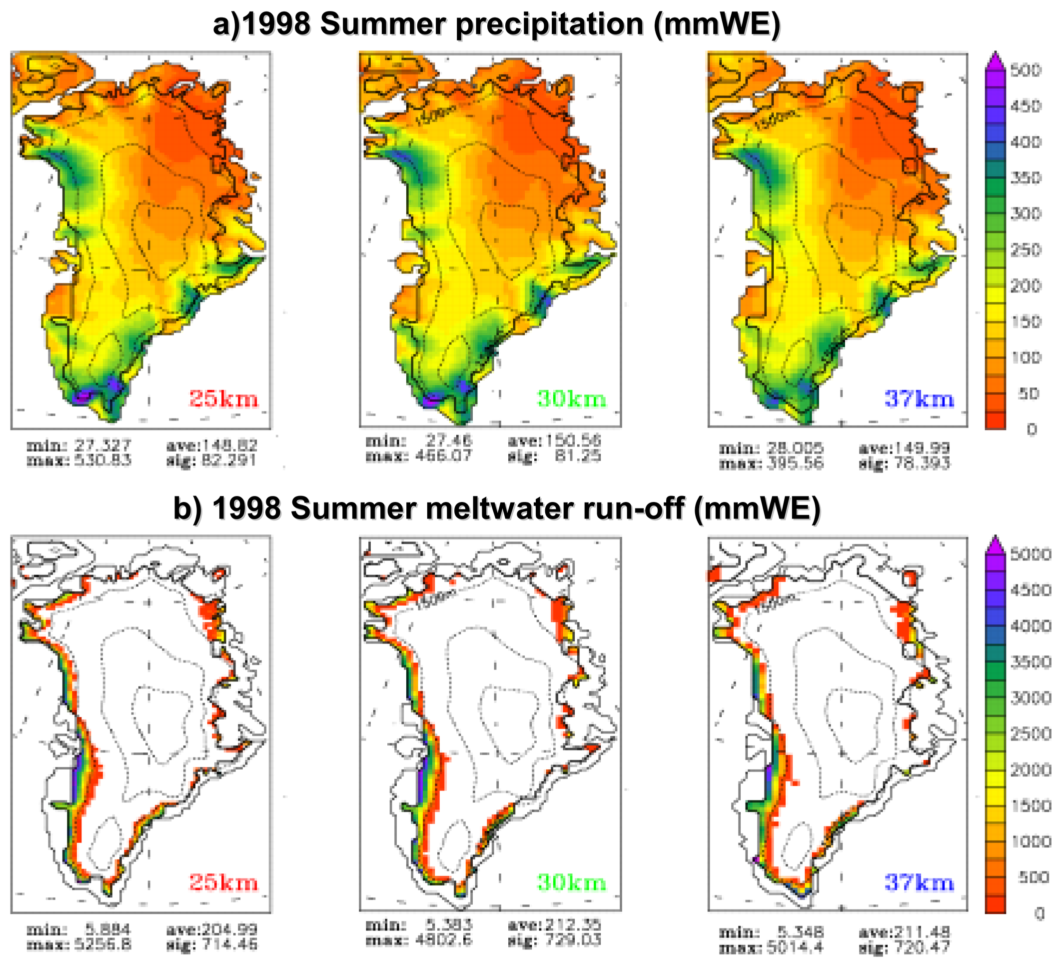


Fig 1 : The 1998 summer (1st of May to 30th Sept.) precipitation and meltwater run-off simulated by the MAR model at a resolution of 25 km, 30km and 37km.

GrIS Statistics	GrIS area (km²)	*Available meltwater (km³)*	*Meltwater run-off (km³ and %)*	*Snowfal (km³)*	*Rainfall (km³)*	*3-m summer (JJA) temperature (°C)*
MAR 25km	**1.702 x 10^6**	**761**	**358**	**231**	**23**	**-8.02**
MAR 30km	1.703 x 10^6	770	372	234	24	-7.93
MAR 37km	1.723 x 10^6	797	374	235	25	-7.69

• A well known impact of the spatial resolution is the simulation of the precipitation. Lower the resolution is, smoother the topography is, smoother the precipitation pattern is. This effect is clearly shown in the mountainous regions of the south of the Greenland (Fig 1a, Fig 3b). The spatial resolution impacts also the precipitation simulation over the Greenland plateau due to the "barrier effect" by the coastal relief.

• The spatial resolution impacts also the simulation of the meltwater run-off because the altitude (red arrow in Fig 3) and the localization (blue arrow in Fig 3) of the ice sheet margin (where the maximum of melt occurs) are different following the resolution.

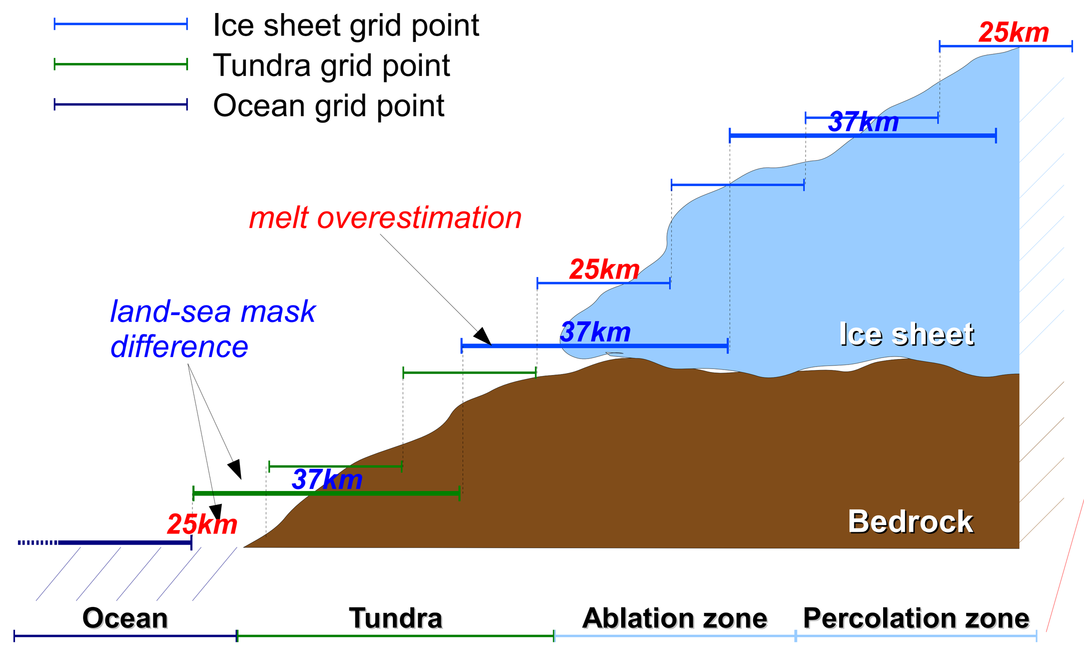
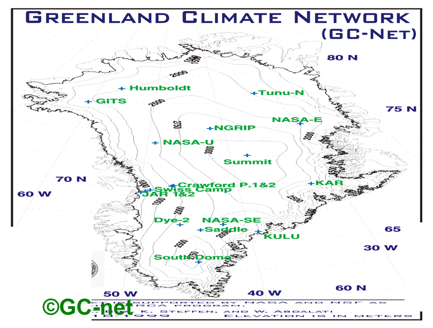


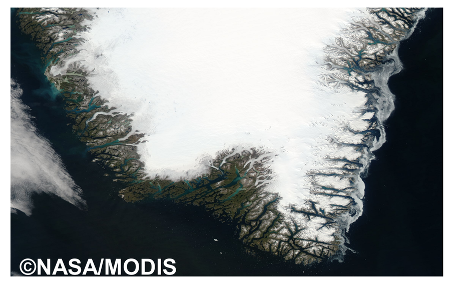
Fig 2 : A theoretical transversal profile of the GrIS west margin and its representation with two spatial resolutions.

• Three simulations were made at a horizontal resolution of 25 km, 30 km and 37 km with the model MAR to test the impact of the resolution on the SMB. All simulations start the 1st of September 1997 and last at the end of summer 1998. The setup is identical in the three simulations and is described in Fettweis (2007). The ERA-40 reanalysis is used to initialize and to force the model every 6 hours at its lateral boundaries.

Reference: Fettweis, X. (2007), Reconstruction of the 1979–2006 Greenland ice sheet surface mass balance using the regional climate model MAR, *The Cryosphere*, 1, 21-40.

Zoom on the South of Greenland





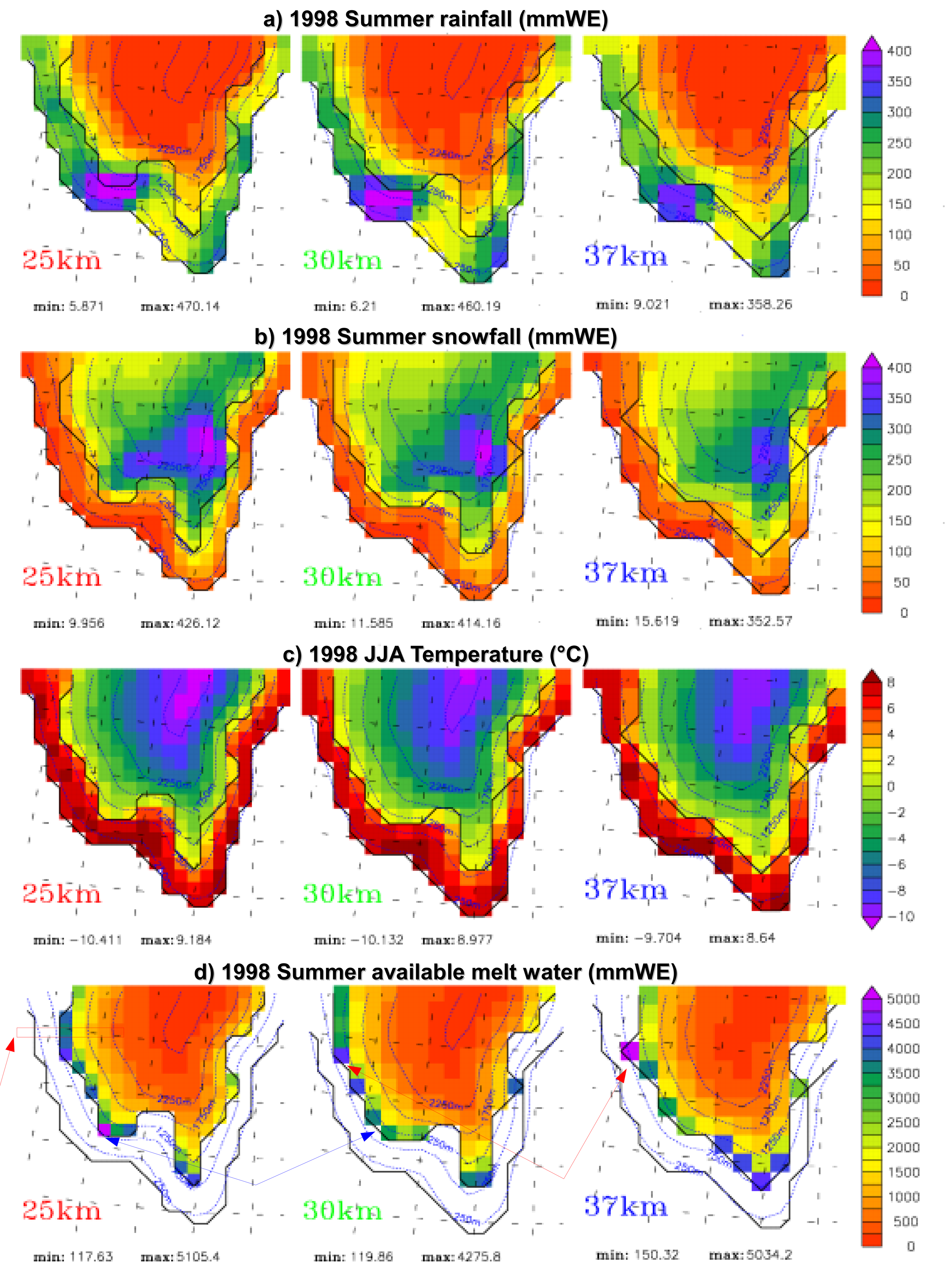


Fig 3 : The 1998 JJA 3-m Temperature, summer snowfall, rainfall and available meltwater simulated by the MAR model. Part of this meltwater is refrozen and does not reach the ocean.

Impacts of the ice sheet mask

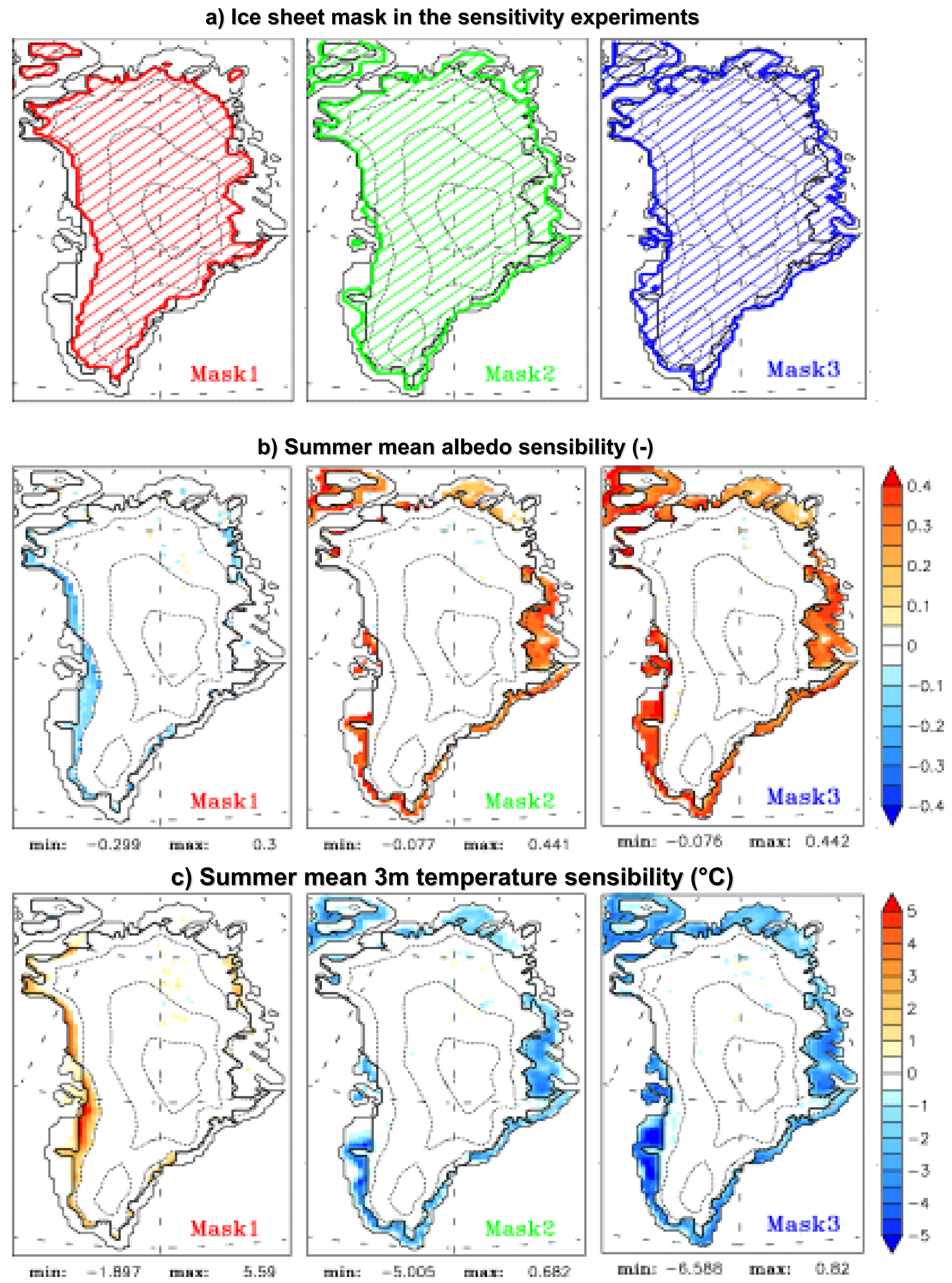


Fig 4 : Sensibility of the mean 1998 summer albedo and temperature to ice sheet mask changes in the MAR model. The ice sheet mask changes are plotted on the top figures.

Greenland statistics	*GrIS area (km²)*	*Available melt-water (km³)*	*Meltwater run-off (km³ and %)*	*Snowfal (km³)*	*Rainfall (km³)*	*3-m summer (JJA) temperature (°C)*
Mask1	1.558 x 10^6	718	153	260	68	-9.1
CTRL	***1.702 x 10^6***	***993***	***399***	***261***	***64***	***-9.5***
Mask2	1.935 x 10^6	1131	431	262	56	-9.9
Mask3	2.087 x 10^6	1266	449	264	50	-10.2

• The resulted temperature changes do not impact the total Greenland snowfall (see table) but well the spatial localization of the snowfall on Greenland (see Fig5a). In case of an increase of the ice sheet area, there is more snowfall along the coast and less in the Greenland interior. As shown in Fig 5b, the heavier snowfall along the coast is due to a transformation of rainfall to solid precipitation due to the temperature decrease resulting from the new snow/ice covered areas.

• The changes in the meltwater production result directly from changes in temperature and rainfall. However, it should be noted that the ice/snow mass is not conserved between the sensitivity experiments.

• Three simulations were made at a horizontal resolution of 25 km with the model MAR to test the impact of the ice sheet mask on the SMB. The sensitivity simulations start the 1st of May 1998 with the control run (***CTRL=MAR-25km***) outputs as initial conditions and last at the end of summer 1998. The only difference with the ***CTRL*** run is the snow height at the beginning of the 1998 summer.

Description of the ice sheet masks:

0. The ice sheet margin of the control run (***CTRL***) is drawn in black in Fig. 4a. Around the GrIS, there is tundra with the 1997-1998 winter accumulated snow pack at the beginning of summer 1998.
1. The ***mask1*** is performed by removing the permanent ice pack in the ablation zone of the control run as if it is tundra. Consequently, grass surfaces (instead of ice pack) appear in this zone once all winter snow pack has melted away.
2. The ***mask2*** is made by multiplying by 20 the 1997-1998 winter snow pack height in the tundra for the MAR grid points higher than 500m a.s.l. which gives snow pack heights higher than 5m!
3. For the ***mask3***, it is the same than mask2 but for the grid points higher than 250m a.s.l.

• The main impact of ice sheet mask changes is obviously the albedo when the winter snow pack has completely melted and the ice pack or the grass appears.

• Higher albedo decreases the solar energy captured by the surface and then the temperature. In addition, the surface temperature of model grid points covered by snow/ice is limited to 0°C.

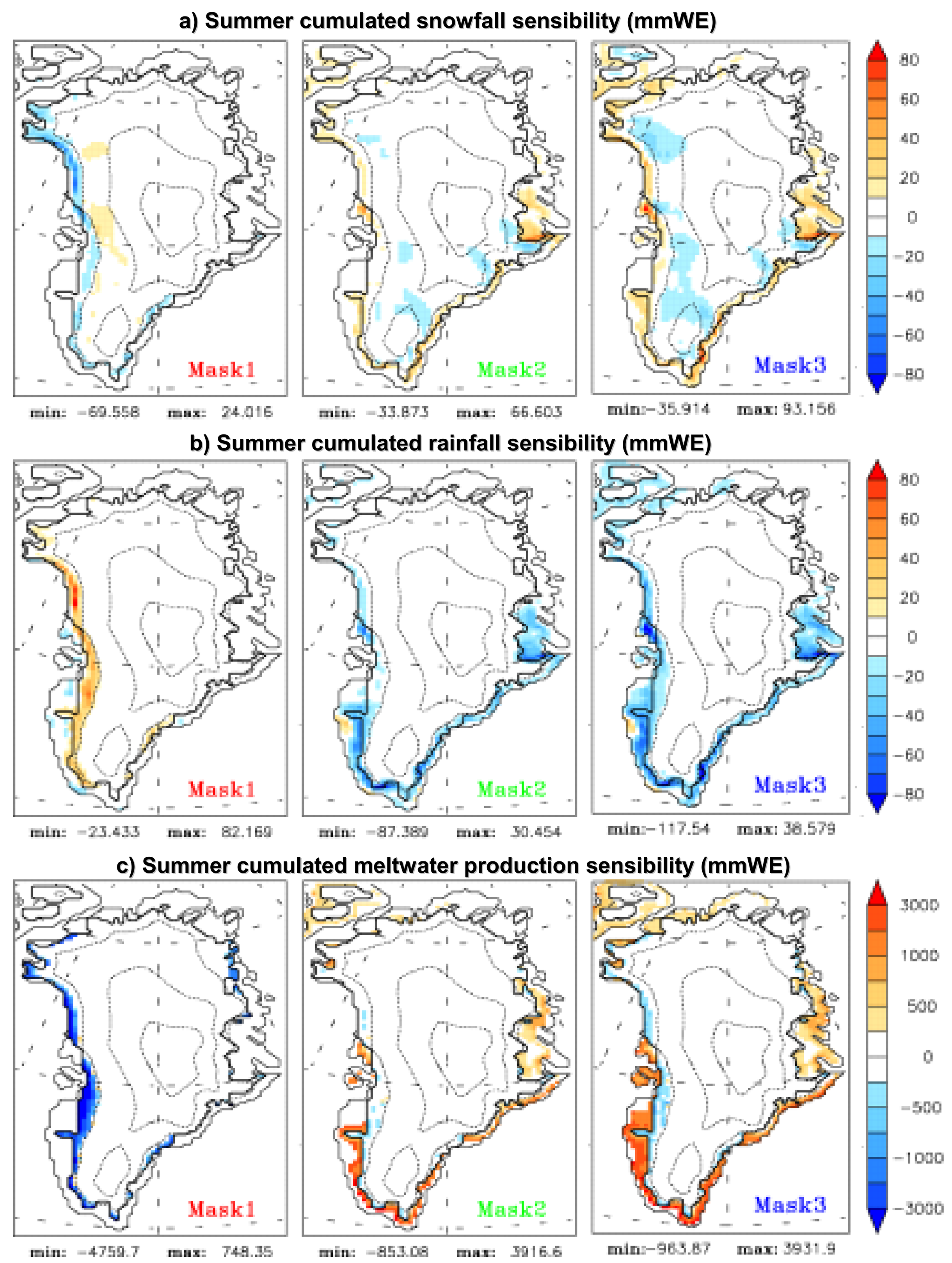


Fig 5 : Sensitivity of the cumulated 1998 summer snowfall, rainfall and meltwater production to changes in the ice sheet mask.