High resolution modelling of the Greenland ice sheet surface mass balance using the regional climate MAR model coupled with a downscaling interface

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Abstract

We are developing a coupling interface downscaling the 25km-atmosphere fields simulated by the regional climate MAR (Modèle Atmosphérique Régional) model onto a 5km-grid in order to resolve the surface processes at high resolution with the SISVAT (Sea Ice Soil Vegetation Atmosphere Transfer) snow-ice module. This coupling interface improves the representation of the topography and ablation zone of the Greenland ice sheet (GrIS) in the MAR model, and therefore will provide higher resolution estimations of the GrIS surface mass balance (SMB) without additional computing time. By using outputs from previously-gauged global circulation models (GCM) as forcing fields, the MAR model coupled with the downscaling interface will then perform 5km future simulations of the GrIS SMB for different IPCC greenhouse gas emissions scenarios for the 21st century.

1) Introduction

• The regional climate MAR model has already been tuned and validated for Greenland at 25km resolution (Fettweis, 2007) with a snow-ice module solving the surface processes of ice sheet and tundra. Although the current horizontal resolution of the MAR model is much higher than global models, it remains relatively coarse compared to the highly rugged topography of the coastal areas in Greenland and the narrow ablation zone measuring less than 100km wide (Fig. 1).

• Unfortunately, higher-resolution runs of the MAR model would prove impractical due to the significant additional computing time (which would be multiplied by a factor 5³ on the same integration domain for 5km-resolution runs). Therefore we propose to implement a coupling interface for running the atmospheric module of the MAR model at 25km resolution, while forcing its snow-ice module at 5km resolution.

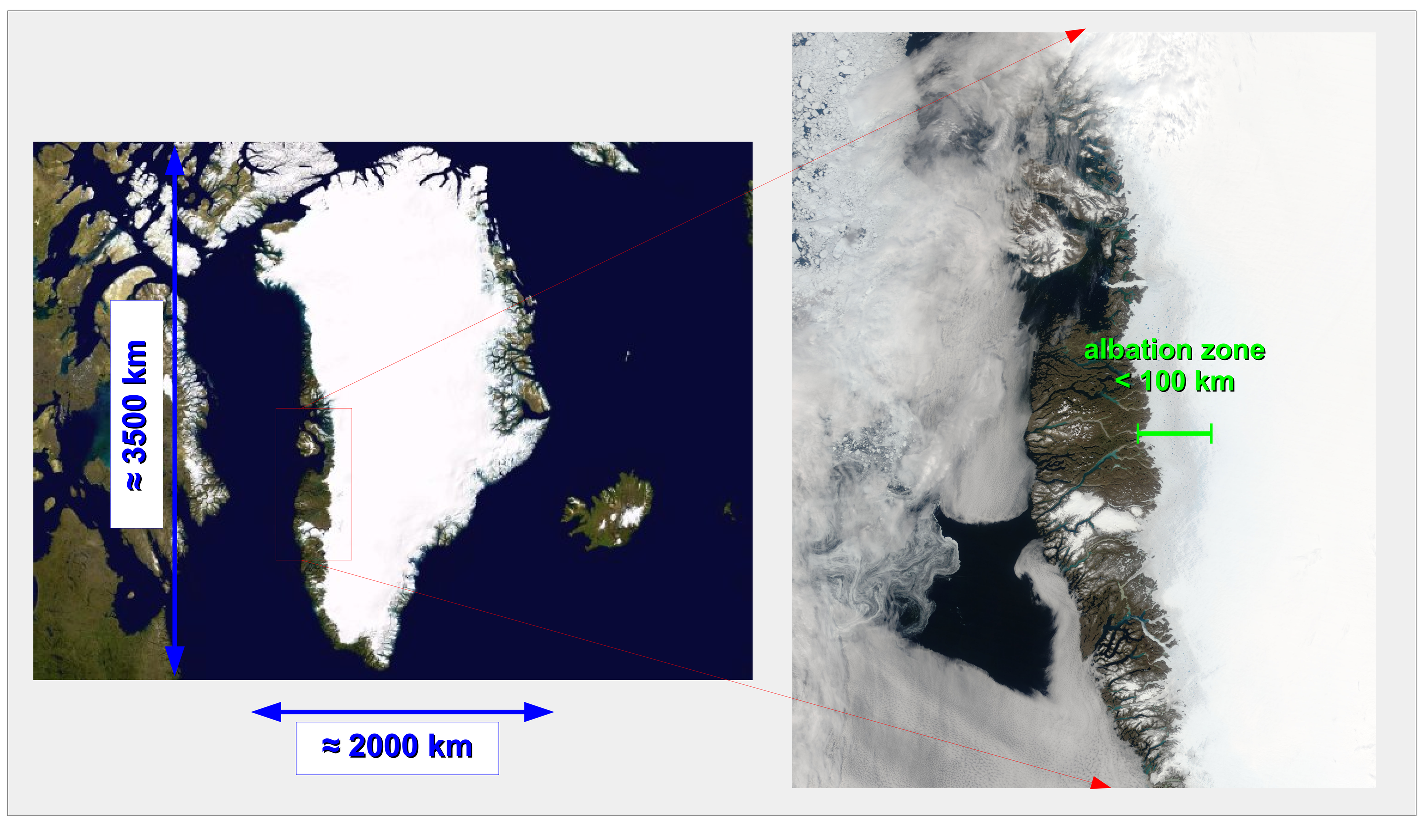

Fig. 1 : View of the Greenland domain with a focus on the ablation zone along the western margin of the ice sheet. Source : http://earthobservatory.nasa.gov/

2) Coupling interface

• First, the coupling interface (Fig. 2) forces the SISVAT module at a higher horizontal resolution by downscaling the 25km-resolution atmospheric fields (such as temperature, precipitation, radiative fluxes...) of the MAR model (Fig. 3) onto 5km grid points through IDW (Inverse Distance Weighting) interpolation (Fig. 3). Once the surface processes resolved by the SISVAT module at 5km resolution, the surface fields are then re-interpolated onto the 25km-resolution grid of the atmospheric module.

• With this two-way nesting at each time step of the runs, we take into account the different surface feedbacks on the atmosphere, such as the positive albedo feedback which explains much of the increased warming of polar regions induced by the global warming, and finally we will be able to simulate the current GrIS SMB at high horizontal resolution.

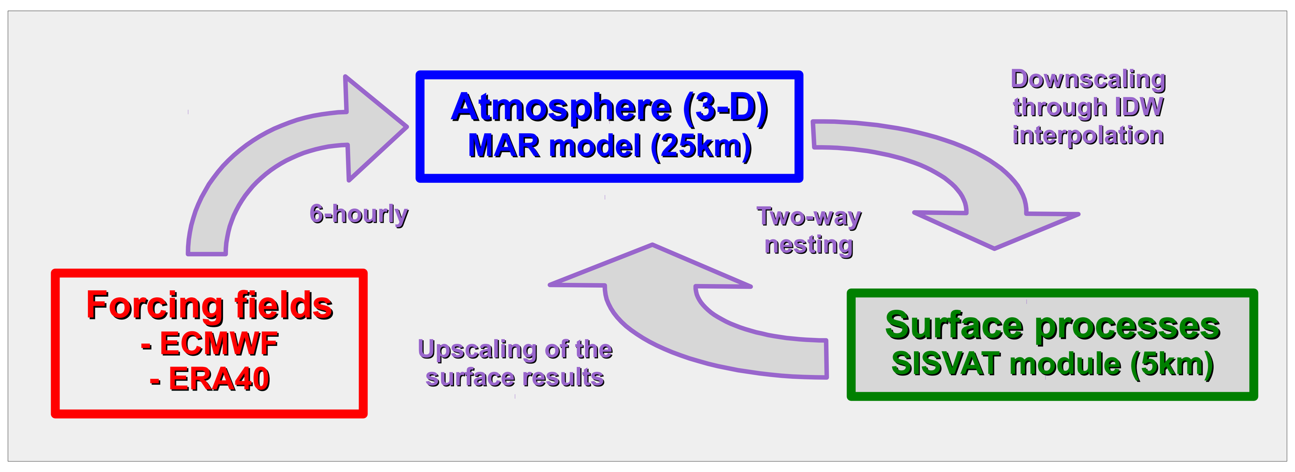

Fig. 2 : Operating principle of the coupling interface between the atmospheric module and the SISVAT module of the MAR model.

Fig. 3 : IDW interpolation used to downscale the atmospheric fields with :
- X an interpolated point
- X_k an interpolating point
- d distance from X_k to X
- p the power parameter
- u(x) an interpolated value
- u_k an interpolating value

$$u(x)=\frac{\sum_{k=0}^{N} w_k(x)u_k}{\sum_{k=0}^{N} w_k(x)} \quad \text{with} \quad w_k(x)=\frac{1}{d(x,x_k)^p}$$

3) Enhanced 5km-resolution topography

• However, the IDW interpolation of the 25km-resolution topography (Fig. 4a) of the MAR model provides too smoothed results on the 5km grid points (Fig. 4b), especially at the ice sheet margins. Therefore we produce an enhanced 5km-resolution topography for the SISVAT module by interpolating the Bamber's 5km-resolution topography (Bamber et al., 2001), based on radar imagery, onto the MAR grid. The results give a more realistic representation of the Greenland topography at high resolution (Fig. 4c).

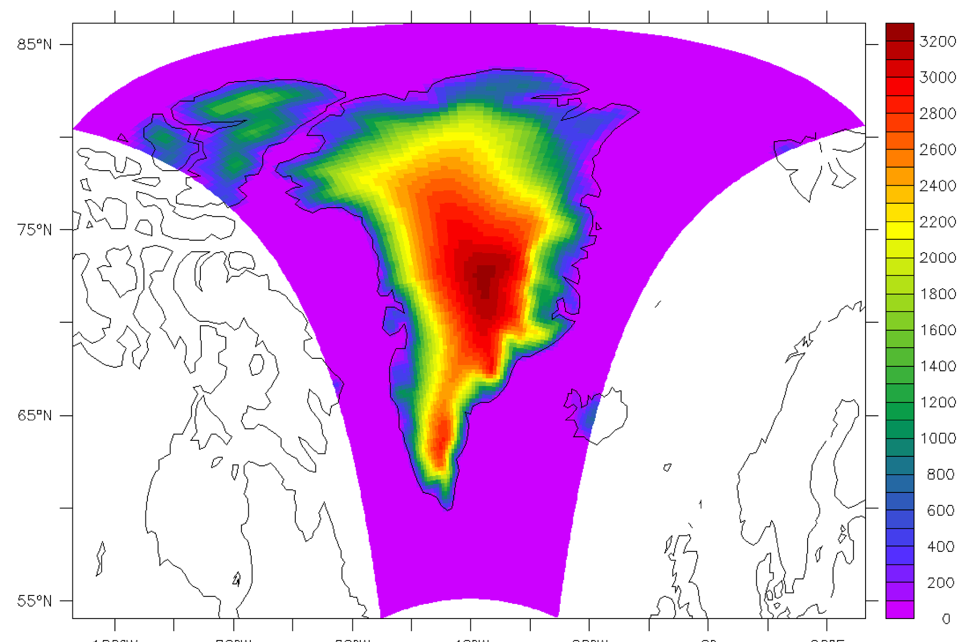

Fig. 4a : The 25km-resolution topography (in meters) of the MAR model.

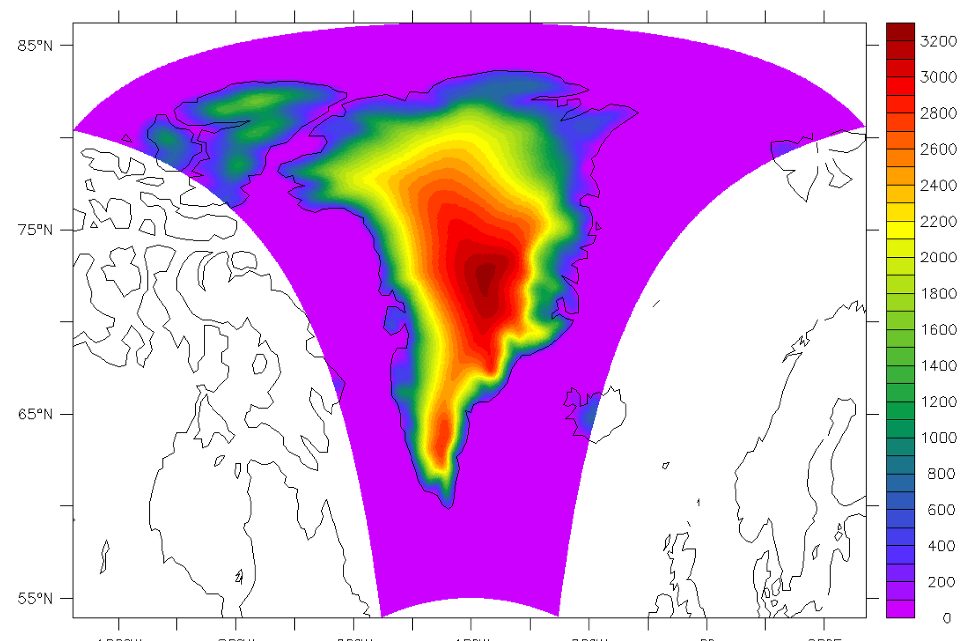

Fig. 4b : The 25km-resolution topography (in meters) of the MAR model interpolated onto the 5km-resolution grid for the SISVAT module.

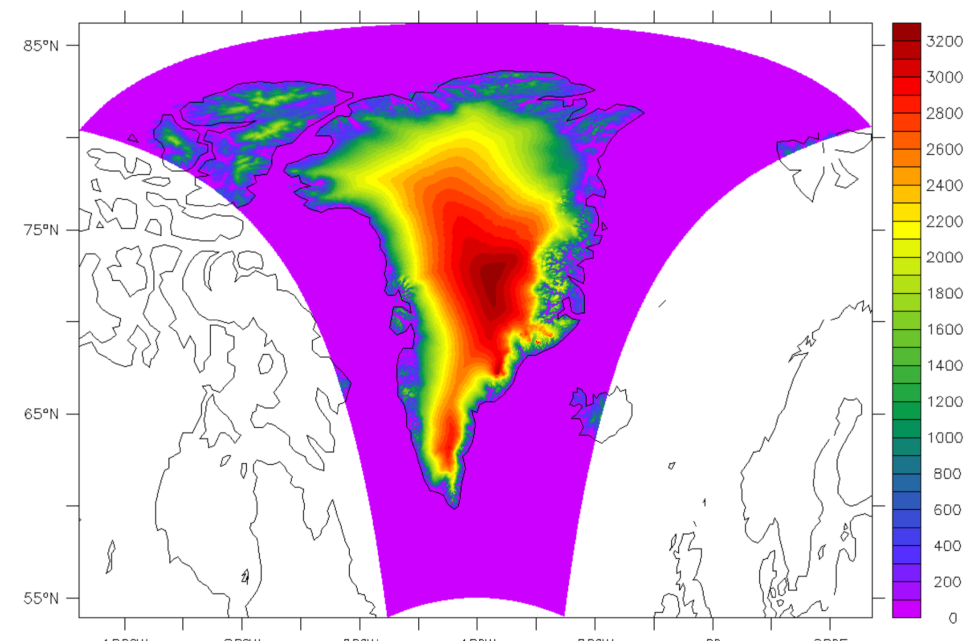

Fig. 4c : The Bamber's 5km-resolution topography (in meters) interpolated onto the 5km-resolution grid for the SISVAT module.

4) 5km-resolution mask of the GrIS

• On the same way, we provide a more accurate mask of the ice sheet for the SISVAT module by interpolating the Box's surface classification mask (Burgess et al., 2010) (Fig. 5a), based on MODIS calibrated radiances imagery and available at 1.25km resolution, onto the 5km-resolution MAR grid (Fig. 5b).

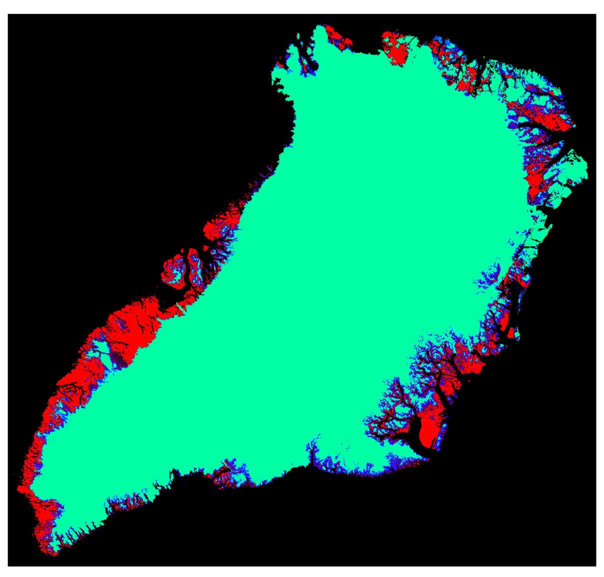

Fig. 5a : Greenland land surface classification mask from Box at 1.25km resolution, with the ice sheet (in green) and the tundra (in red).
Source : http://bprc.osu.edu/wiki/Jason_Box_Datasets

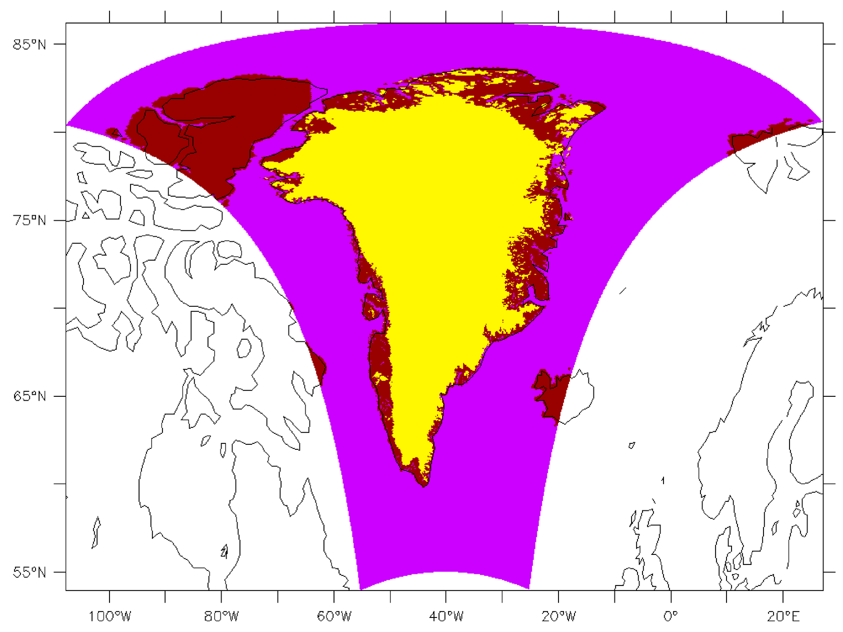

Fig. 5b : Box's surface classification mask interpolated onto the 5km-resolution grid of the MAR model, with the GrIS (in yellow) and the tundra (in red).

5) Further steps

• As the coupling interface, the MAR model and the SISVAT module are only based on physical equations (not statistics), they could be used under a climate different from the present-day climate. Indeed, we cannot certify that statistical downscaling implemented for the present-day climate is still reliable for future climate simulations.

• In further steps, we propose to force the MAR model (coupled with the downscaling interface) with the outputs from previously-gauged GCMs (Franco et al., 2010) in order to perform high-resolution simulations of the GrIS SMB for the 21st century, according to the IPCC greenhouse gas emissions scenarios. These estimates will be used to assess the impact of the GrIS melting on the thermohaline circulation and global sea-level rise.

References

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