Impact of the spatial resolution on the Greenland Ice Sheet Surface Mass Balance modelling using the regional climate model MAR with the aim to force an ice sheet model

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Abstract

By using the regional climate model MAR (Modèle Atmosphérique Régional), validated for Greenland at 25km resolution and forced every 6 hours with the ERA-INTERIM reanalysis (Fettweis 2007, Fettweis et al. 2010), we have modelled the Greenland Ice Sheet (GrIS) Surface Mass Balance (SMB) at 20, 25, 30, 40 and 50km resolution to assess the impact of the spatial resolution. As part of the ICE2SEA project, the 25km-resolution SMB outputs of the MAR model are used as forcing fields for ice sheet models, in order to produce future projections of the GrIS contribution to sea-level rise over the next 200 years. Although the current spatial resolution of the MAR model (25km) is much higher than the general circulation models (GCM) resolution (150-300km), the ice sheet models often run at a higher resolution (typically 5-10km). Nevertheless, such higher-resolution runs of the MAR model on the same integration domain generate a significant additional computing time and are not doable until now. Moreover, conventional linear interpolations of the SMB outputs onto a higher-resolution grid, generally induce biases because ice sheet masks at different spatial resolutions do not match and the SMB is a very complex function of the spatial resolution and the topography . That is why several enhanced SMB interpolations are tested here in order to reduce biases when interpolating the MAR outputs onto higher resolution, in the framework of the ICE2SEA project.

1. Impact of the spatial resolution

Due to the rugged topography of Greenland and the narrow ablation zone (measuring less than 100km width) along the GrIS margin, the spatial resolution has an important impact on the GrIS SMB modelling. As seen in the Figure 1, the 20, 25, 30, 40 and 50 km-resolution MAR runs over the 1990-2009 period provide outputs with significant differences, especially along the ice sheet margins.

High-resolution MAR runs improve the representation of the topography, and hence the amount of precipitation (mainly snowfall) and the run-off of melt water (Fig. 1), the two main components of the SMB equation. Moreover, high-resolution simulations allow to reconstruct a more precise ice sheet mask, and thus provide more accurate GrIS SMB results.

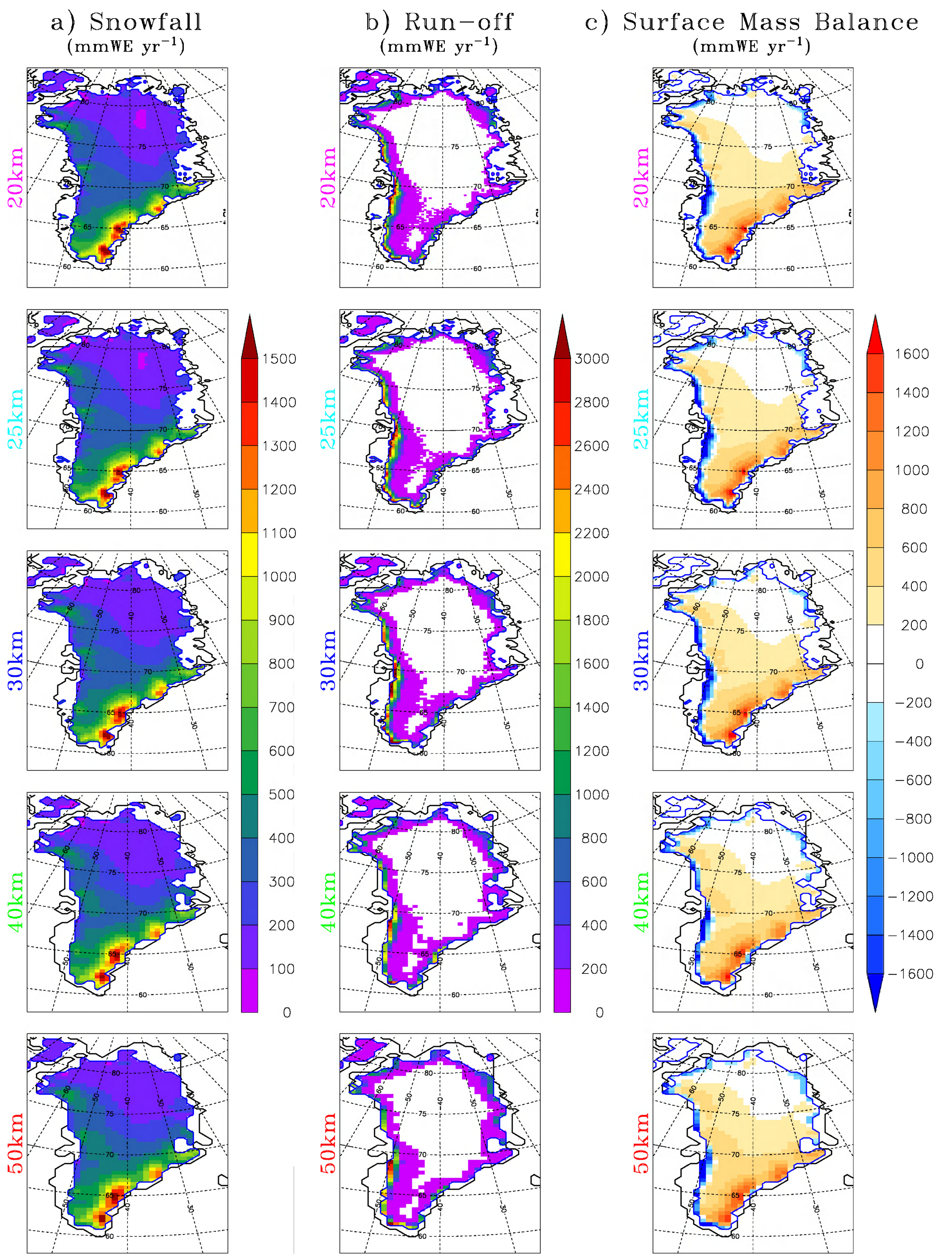


Figure 1 : a) Annual snowfall (mmWE/yr) simulated by the MAR model at 20, 25, 30, 40 and 50km resolution over the 1990-2009 period. b) Same as (a) for the annual run-off of melt water (mmWE/yr). c) Same as (a) for the annual SMB (mmWE/yr)

2. Validation along the K-transect

In order to validate the MAR results, we compare the 20, 25, ... km-resolution surface height and SMB outputs with the stations located along the Kangerlussuag-transect (K-transect), 67°N, in the western region of Greenland (van de Wall et al. 2005). The biases between the MAR topography and the surface height of the K-transect stations are generally weak, but the 25 up to 50km-resolution MAR runs tend to slightly overestimate the run-off of melt water (Fig. 2). Although the 20km-resolution MAR run is not fine enough to represent the GrIS SMB in the closest vicinity of the ice sheet margin, the 20km MAR results match the best with the K-transect SMB data (Fig. 2).

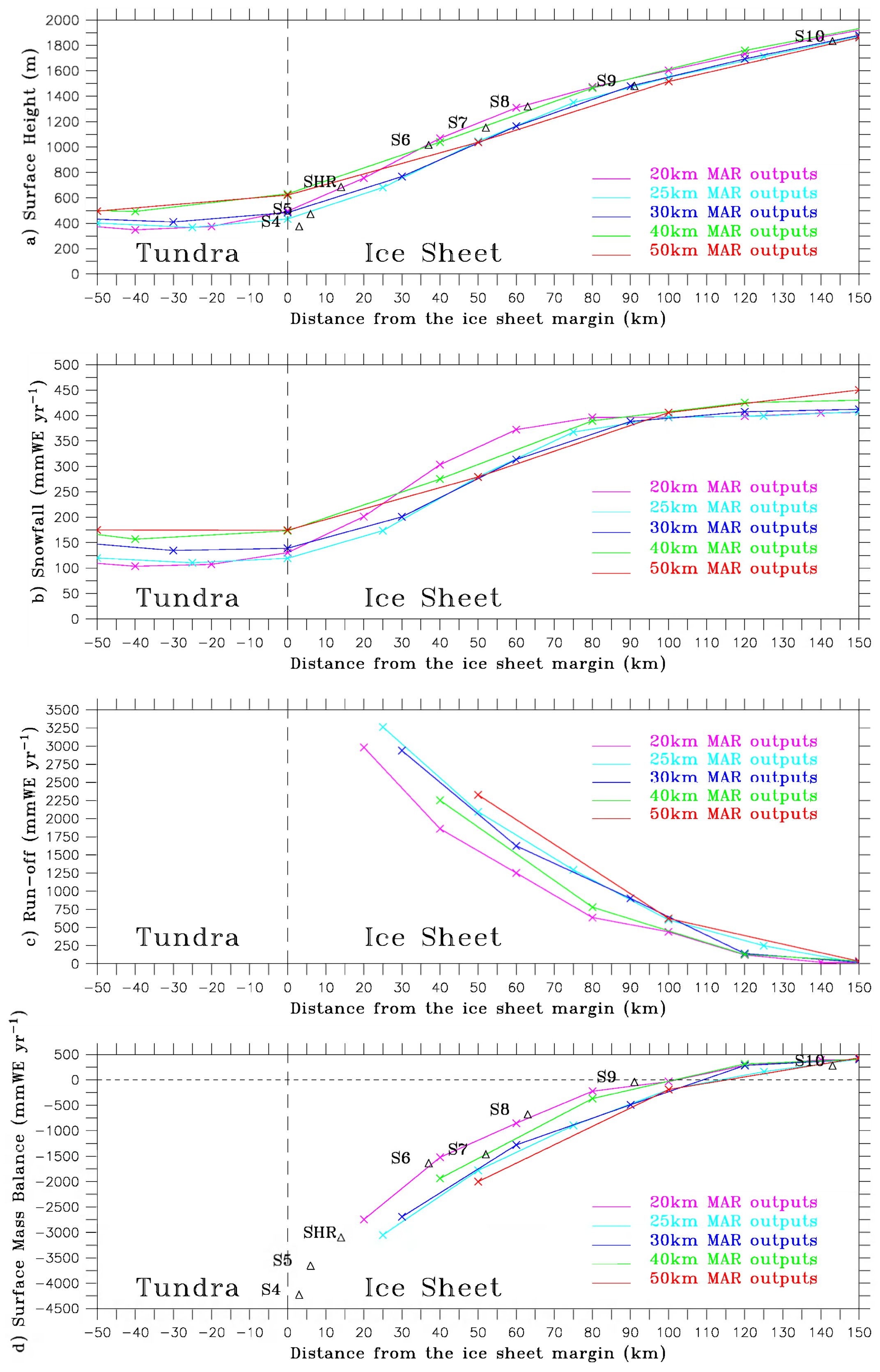
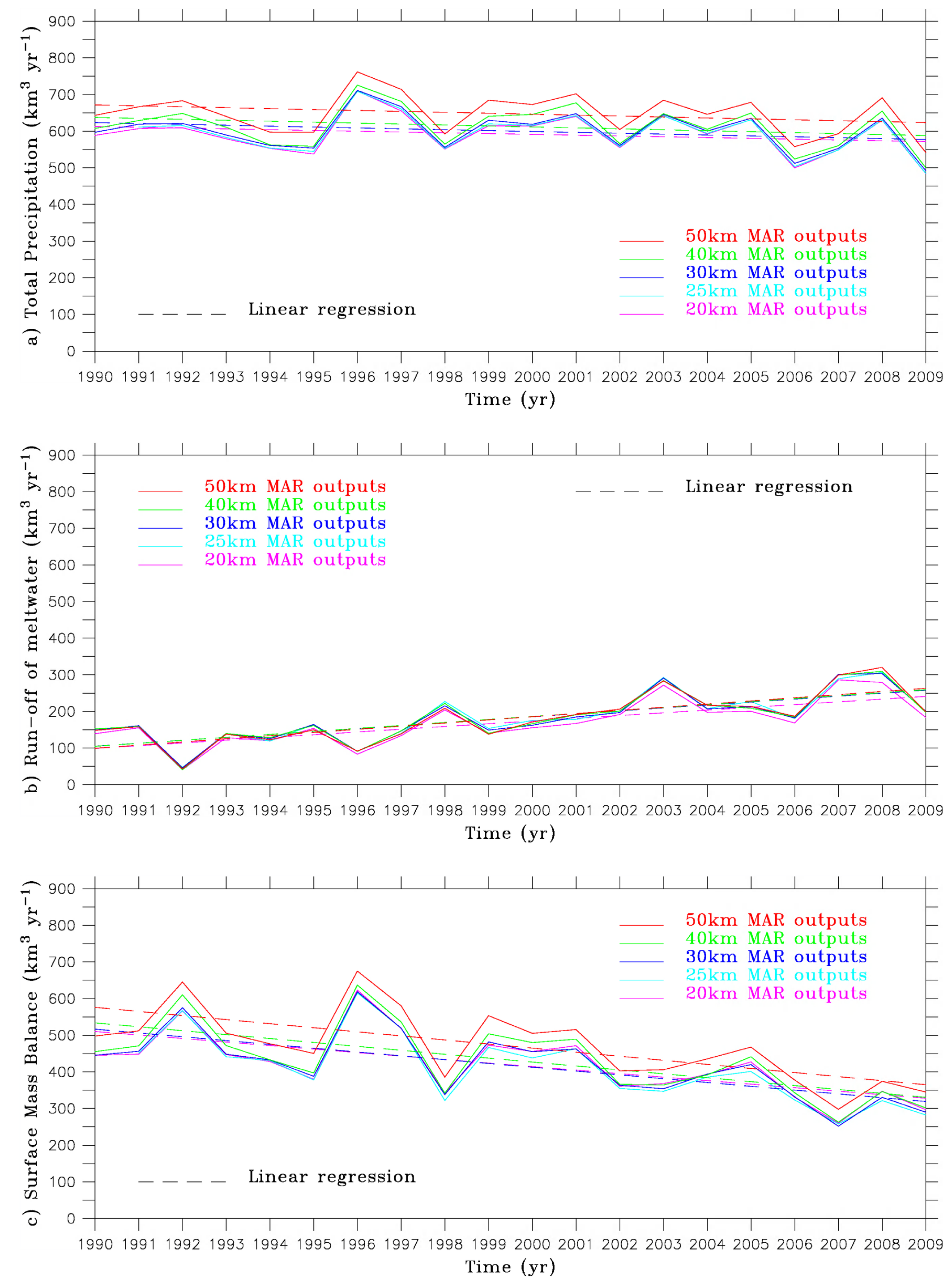


Figure 2 : Cross section of the surface height (m) through the GrIS along the K-transect (67°N, west Greenland) for 20, 25, 30, 40 and 50km-resolution MAR runs, with stations data of the K-transect (van de Wall et al. 2005). b) Same as (a) for the annual snowfall (mmWE/yr) over the 1990-2009 period. c) Same as (b) for the run-off of melt water (mmWE/yr). d) Same as (b) for the GrIS SMB (mmWE/yr)

3. Interpolation of the MAR outputs

In the aim to use MAR SMB outputs to force ice sheet models, we have interpolated the MAR results provided by the 20, 25, ... km-resolution MAR runs onto the 15km MAR grid (by using an interpolation based on the inverse distance weighting). After comparison over their common ice sheet mask, the interpolated MAR outputs onto higher-resolution grid show the same inter-annual variability (Fig. 3), although they come from MAR runs at different spatial resolutions. Moreover, the interpolated MAR outputs present the same trends (Fig. 3).



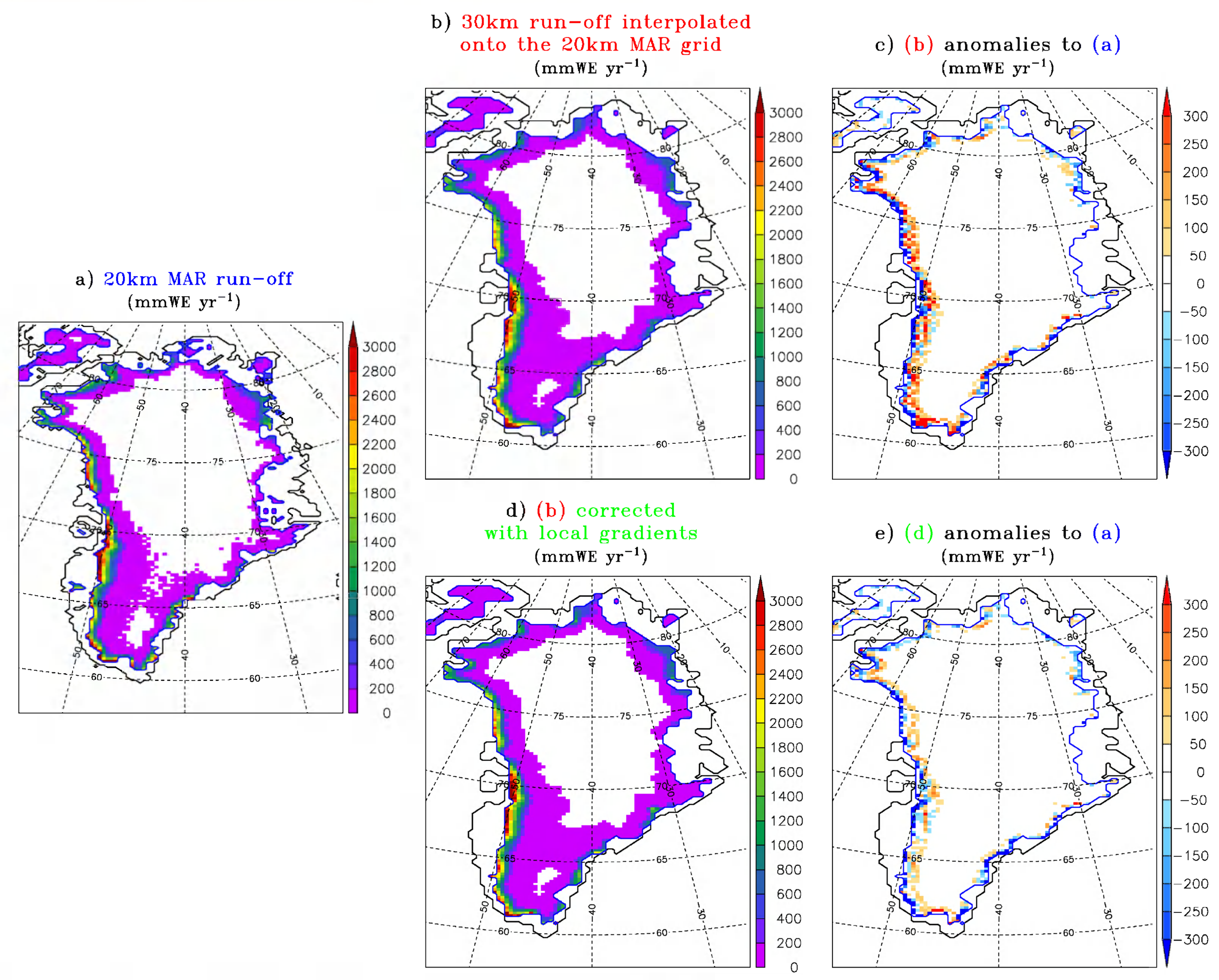


Figure 4 : a) Annual run-off of melt water (mmWE/yr) from 20km-resolution MAR runs over the 1990-2009 period. b) Annual run-off of melt water (mmWE/yr) from the 30km-resolution MAR runs over the 1990-2009 period, interpolated onto the 20km MAR grid. c) Anomalies (mmWE/yr) of (b) to (a). d) Annual run-off of melt water (mmWE/yr) from the 30km-resolution MAR runs over the 1990-2009 period, interpolated onto the 20km MAR grid and corrected with local gradients. e) Anomalies (mmWE/yr) of (d) to (a)

However, after comparison between 30km-resolution MAR outputs interpolated onto the 20km MAR grid and the MAR results provided by 20km-resolution runs, some biases have been observed (Fig. 4c), especially along the GrIS margin due to the highly rugged topography (up to 300mmWE/yr for the run-off of melt water). Therefore we have implemented a correction factor, applied to every grid points and based on the difference between the topography simulated by high-resolution MAR runs and the interpolated topography. The Figure 4 presents an example of correcting the interpolated MAR run-off of melt water (Fig. 4e) with specific local gradients calculated in the vicinity of each grid point, and we can observe here the dampening of the biases due to the correction factor. Nevertheless, some improvements are still needed along the ice sheet margin, as taking into account the edge effects of the ice sheet.

Figure 3 : a) Annual amount of precipitation (km³/yr) from the 20, 25, 30, 40 and 50km-resolution MAR runs over the common GrIS mask, interpolated onto the 15km MAR grid, with linear regression in dash line. b) Same as (a) for the annual run-off of melt water (km³/yr). c) Same as (a) for the annual GrIS SMB (km³/yr).

4. Conclusion

This work aims to assess the lack of accuracy when interpolating SMB outputs from the MAR model onto a higher-resolution grid, compared to results of MAR running at this higher resolution. We also try to determine which maximal resolution is required to force accurately ice sheet models instead of using SMB outputs coming directly from very high-resolution runs, taking into account the significant additional computing time needed for such simulations. Enhanced methods of spatial interpolation, combined with specific correction factors, can provide conclusive results. In the next stages, we plan to test other "intelligent" methods of spatial interpolation in order to improve the comparison between the interpolated outputs and the high-resolution MAR results.

References

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