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How results from the regional model MAR can be used to force ice sheet models at higher resolutions over the Greenland ice sheet ?

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Abstract. *With the aim of coupling the regional climate model MAR (Fettweis et., 2013) running at a resolution of 25 km with ice sheet models running at higher resolutions (5-10km) over the Greenland ice sheet (GrIS), the new version of MAR (MARv3.1) uses a fractional (0-100%) ice sheet mask. Over the tundra area surrounding the GrIS, the ice covered area is at least 0.01 % and MAR computes the surface mass balance (SMB) for these pixels as they are fully covered by tundra or permanent ice. This is particularly useful afterward to extrapolate the MAR based SMB results at higher resolution using an interpolation based on SMB vertical gradients vs surface height. Previously developed SMB "intelligent" interpolations allow to reconstruct with success the SMB at higher resolutions in the interior of the ice sheet. However, they fail along the ice sheet margin where the spatial variability is the highest and where the SMB exponentially decreases with altitude.*

We present here a comparison over 2002-2011 between MAR SMB results at 25 and 37.5 km of resolution interpolated into 12.5 km with SMB results computed at 12.5 km by MAR forced by ERA-INTERIM. By using the SMB components simulated over the tundra areas, we improve a lot the comparison along the ice sheet margin. This suggests that the MAR 25 km future projections can be reliably used to force ice sheet models at higher resolutions and using different ice sheet masks than MAR.

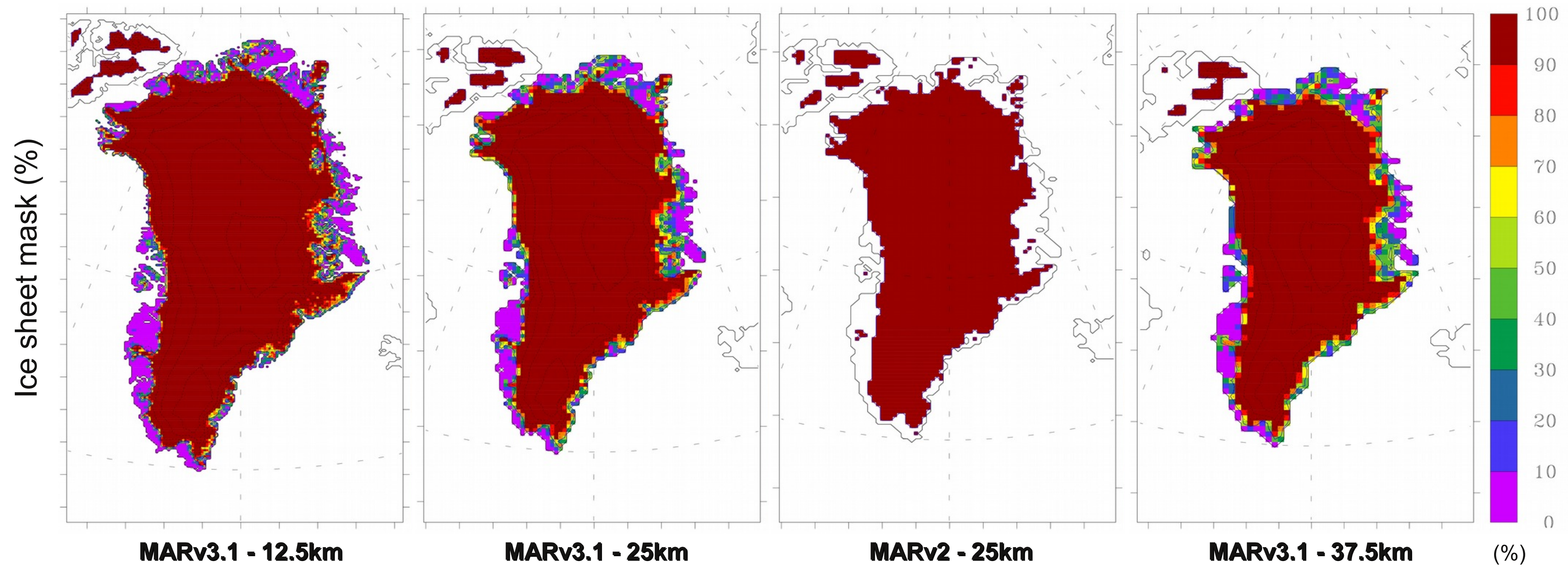


Fig. 1 *Integration domain and ice sheet mask (in %) used by MAR at a resolution of 12.5, 25 and 37.5 km. The ice sheet mask is based on Bamber et al. (2013) in MARv3.1.*

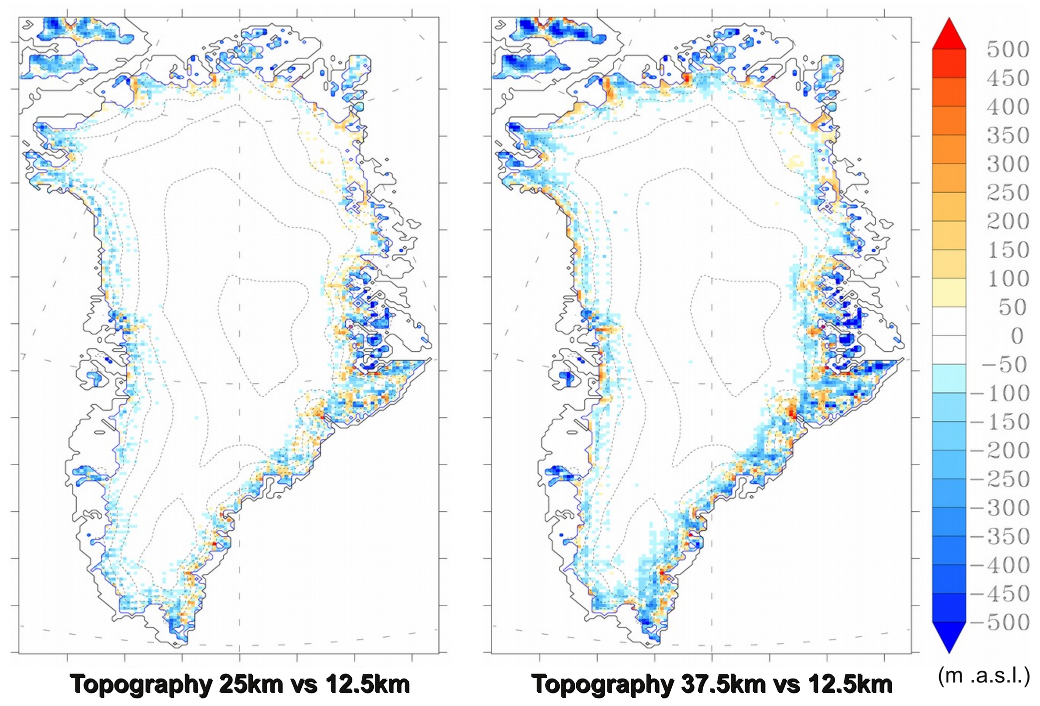


Fig. 2 *Surface height difference between the 25 and 37.5 km topography with the 12.5km topography. The ice sheet topography is based on Bamber et al. (2013). The 25 and 37.5 km topography have been linearly interpolated onto the 12.5 x 12.5 km grid by using an inverse distance weighting.*

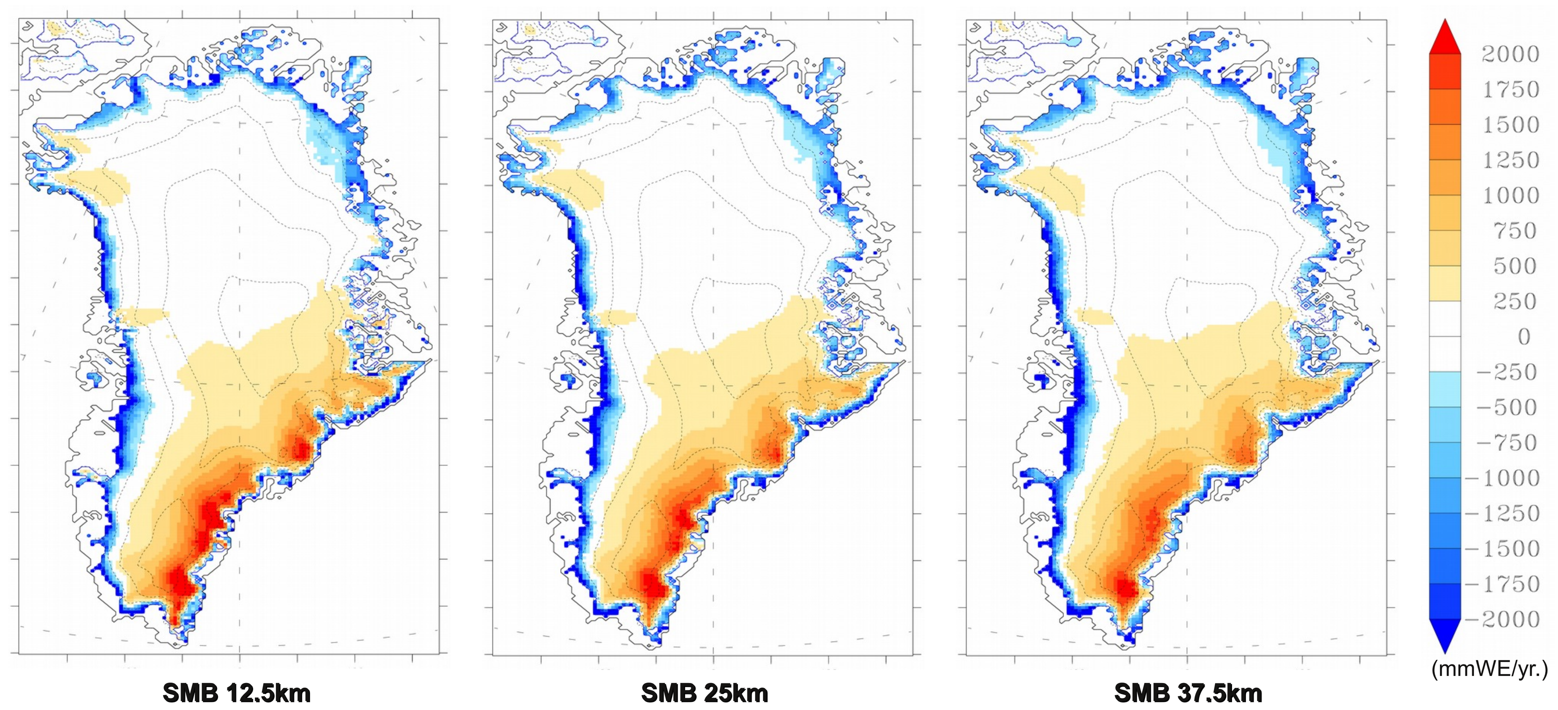
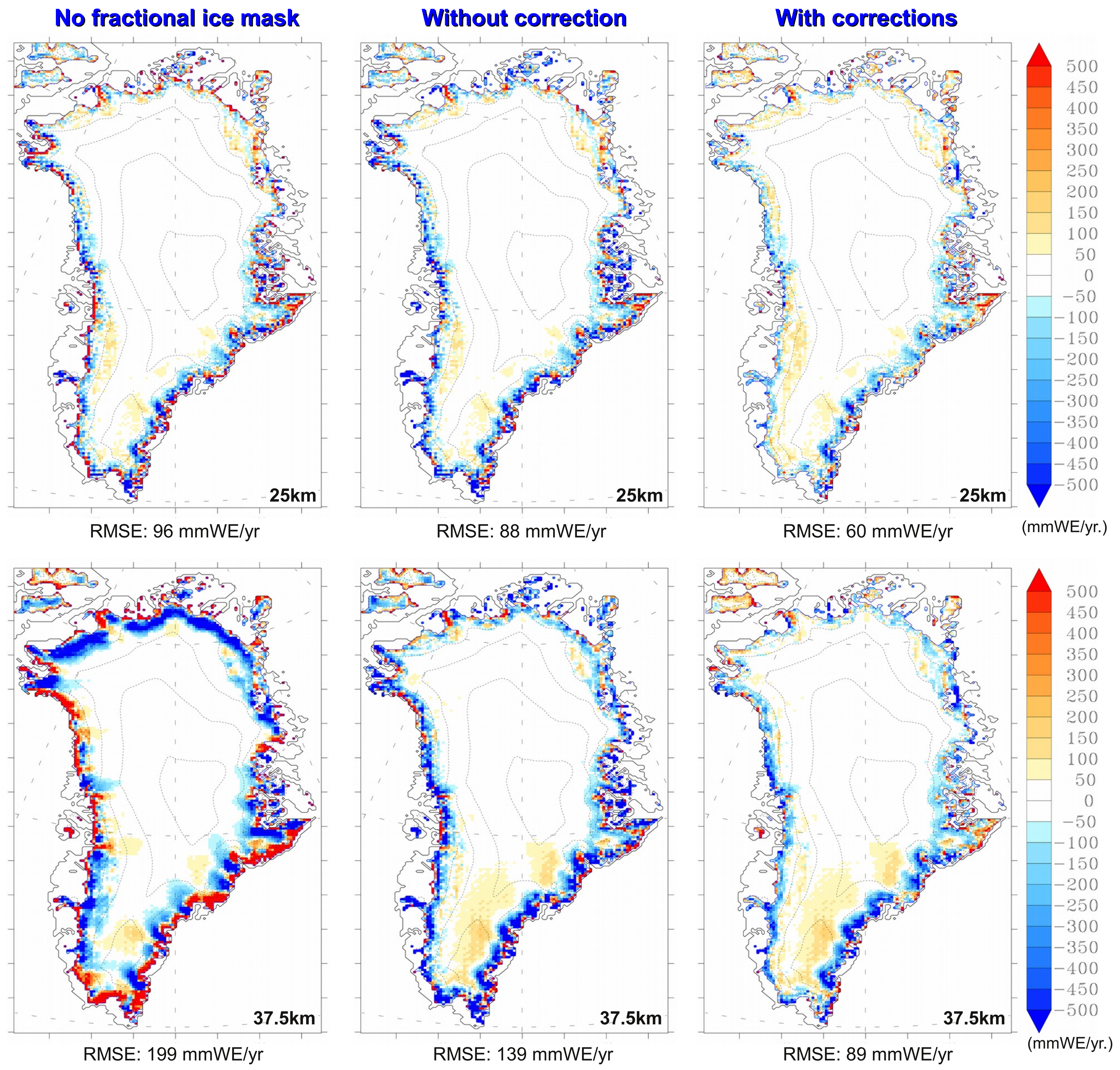


Fig. 3 *Mean annual SMB (in mmWE/yr) simulated by MAR forced by ERA-Interim over 2002-2011 at different spatial resolutions. The 25 and 37.5 km results have been linearly interpolated onto the 12.5 x 12.5 km grid by using an inverse distance weighting. Lower the resolution, higher the precipitation in the interior of the ice sheet is because the topography barrier effect along the south-eastern coast is underestimated at low resolution. In addition, we can see that the SMB of most of the peripheral glaciers and ice caps is negative everywhere at a resolution of 37.5 km because lower the resolution, not enough resolved the topography of these small ice caps is.*



At 20 km:	85 mmWE/yr	73 mmWE/yr	51 mmWE/yr
At 30 km:	150 mmWE/yr	111 mmWE/yr	76 mmWE/yr

Fig. 4 *Mean annual SMB anomaly (in mmWE/yr) simulated by MAR at a resolution of 25 and 37.5 km with respect to the 12.5 km run over 2002-2011.* ***Left)*** *By using a linear interpolation with the inverse distance weighting but without a fractional ice mask (only the pixel with ice mask > 50% are taken into account in the interpolation).* ***Middle)*** *By using a linear interpolation with the inverse distance weighting and with a fractional ice mask.* ***Right)*** *Same as middle but where the run-off and evaporation/sublimation have been corrected in function of the altitude difference with the 12.5 x 12.5 km grid with the help of a vertical gradient of these fields (Franco et al., 2012). The mean vertical gradient is calculated at a monthly time scale in the neighbourhood (2 x 25km) of each 25 x 25km grid point.*
E.g. $Runoff_{corrected} = Runoff_{interpolated} + (topo_{25km} - topo_{12.5km}) * gradient.$

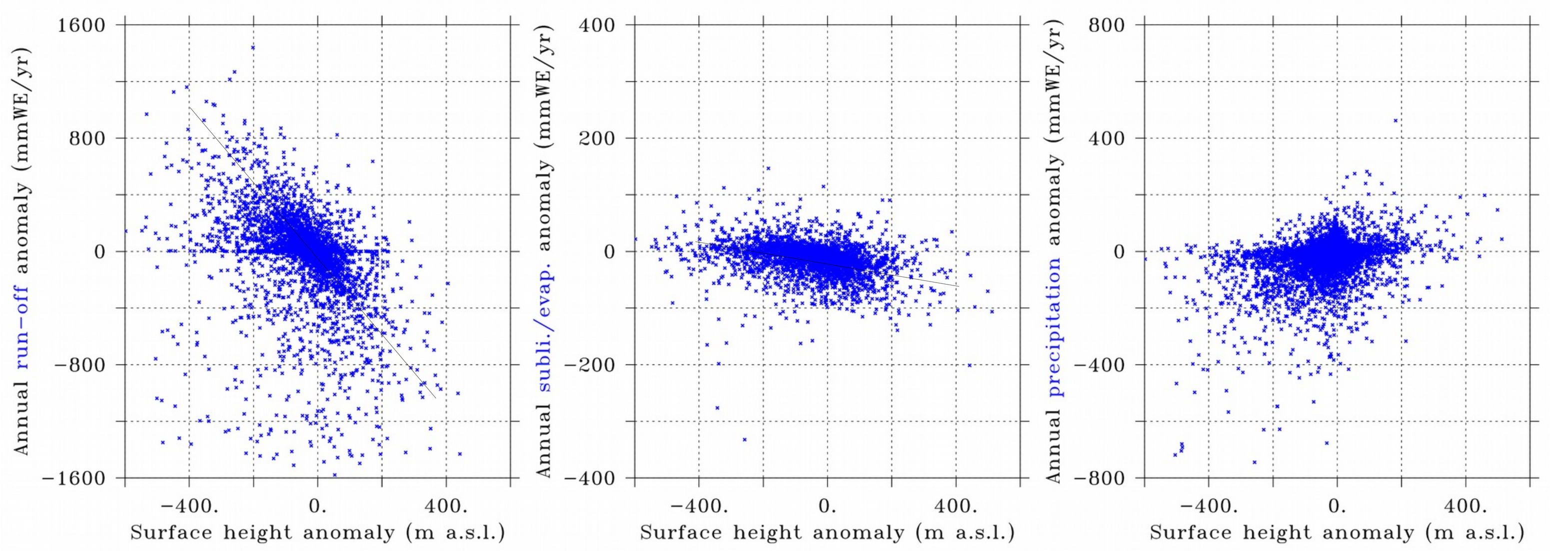


Fig. 5 *Scatter plot of annual run-off (left), sublimation/evaporation (middle) and precipitation (right) anomaly simulated by MAR at 25 km of resolution versus surface height anomaly with respect to the 12.5 km results over 2002-2011. We can see here that the precipitation anomalies are not linearly dependant of surface height changes.*

MARv3.1 vs. MARv2

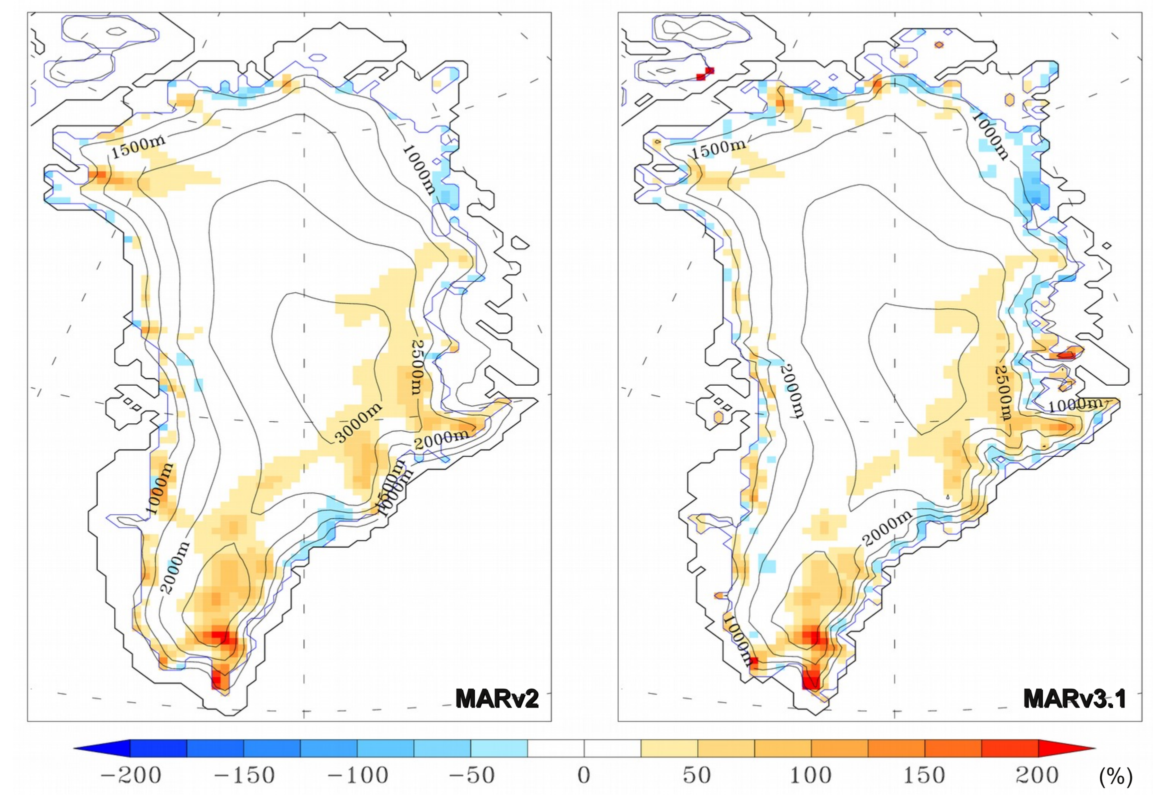


Fig. 6 *Mean annual accumulation anomaly (in %) simulated by MARv2 and MARv3.1 over 1960-1990 with respect to the estimations from Burgress et al. (2010). We can see here that MARv3.1 correct in part the precipitation overestimation found by Jason Box (Personal communication) near South-Dome.*

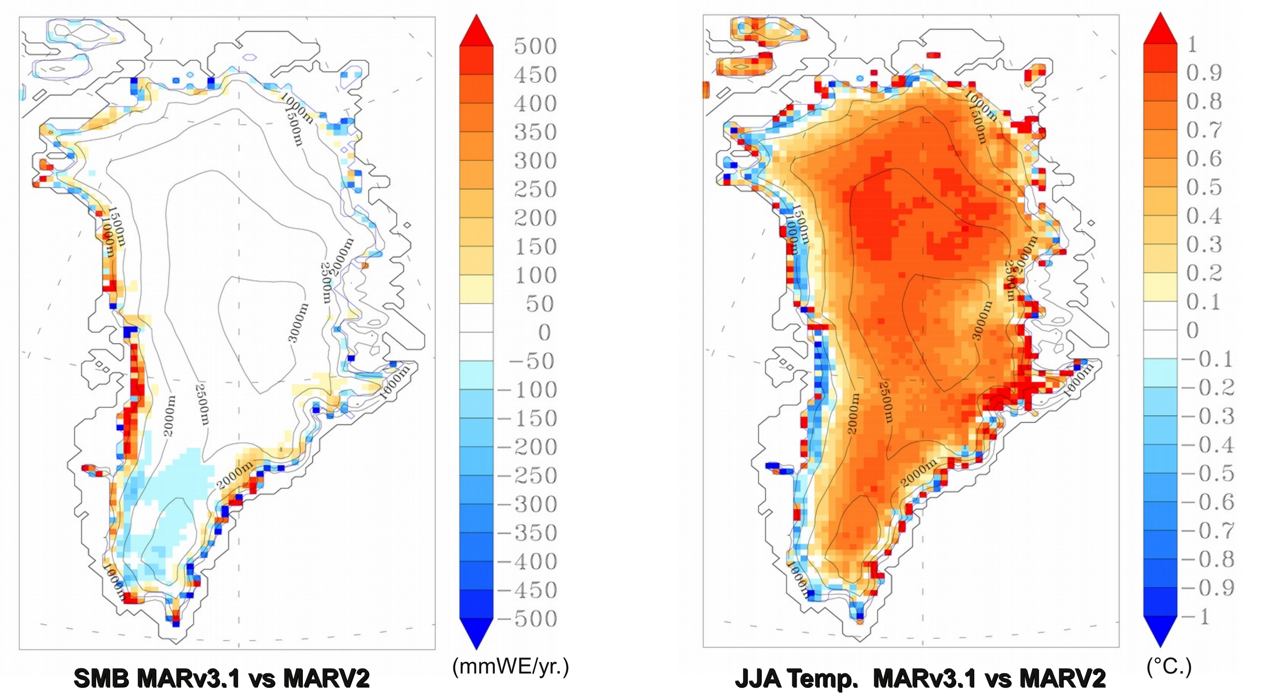


Fig. 7 *Mean annual SMB (in mmWE/yr) anomaly over 1960-1990 simulated by MARv3.1 vs MARv2. (Right) Same as left but for the JJA near-surface temperature in °C. This figure confirms that the precipitation overestimation near South-Dome is corrected in part by MARv3.1 as well as the cold bias (Box et. al., 2012) in summer in the interior of the ice sheet.*

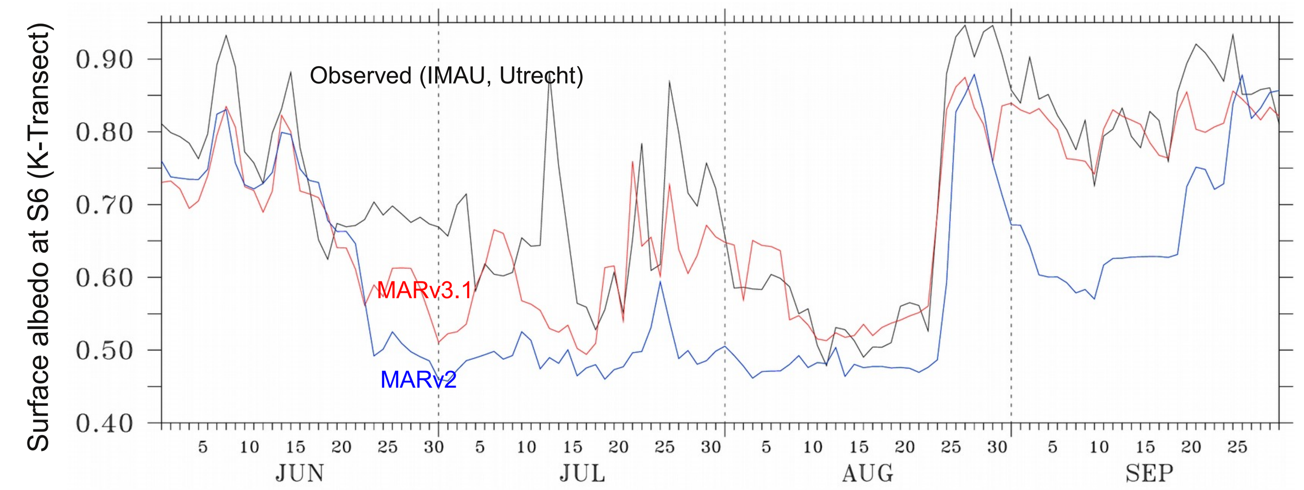


Fig. 8 *Time series of the surface albedo observed (in black) at S6 (K-transect, IMAU, Utrecht University) and simulated by MARv2 (blue) and MARv3.1 (red) in summer 2004. We can see that MARv3.1 better resolves the albedo risings/drops due to snowfall events over bare ice in summer.*

In addition to differences in the topography and ice sheet mask (Fig. 1), the new version (v3.1) of MAR (still in development) improves the simulation of precipitation (Fig. 6), surface snow/ice albedo (Fig. 8), summer temperature (Fig.7) and melt extent (not shown here) with respect to MARv2 (Fettweis et al., 2013).
We plan to carry out with MARv3.1 future projections at 25 x 25 km forced by the global model MIROC5 (the best performing CMIP5 model over Greenland) and BNU-ESM (the only CMIP5 model which projects circulation changes) (Fettweis et al., 2013). With the help of the SMB interpolation presented on this poster, these new outputs can be used to force ice sheet models at higher resolutions. In addition, we plan to couple this MAR version with ice sheet models to take into account the elevation feedback enhancing the surface melt acceleration.

Reference:

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