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Future projections of the Greenland ice sheet mass balance using the regional climate MAR model coupled with the GRISLI ice sheet model

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1. Introduction

Difficulties remain to assess the **Greenland ice sheet (GrIS) future contribution to sea level rise (SLR)** because of large uncertainties associated to the feedback between the surface mass balance (SMB) and GrIS topography changes (**SMB-elevation feedback**) (IPCC, 2013 ; Fettweis *et al.*, 2013). Due to surface melt increase, ice sheet are projected to thin, which would induce an additional warming accelerating the melt increase. Most of estimations of the GrIS future contribution are made by forcing ice sheet models (ISM), such as GRISLI, by global models (GCM) or regional circulation models (RCM) outputs, such as MAR outputs (Fig 1(a)). However, the SMB-elevation feedback is not considered in these estimations due to the use of static topography in GCM/RCM. A **RCM-ISM coupling**, such as the MAR-GRISLI coupling, allows a dynamic topography in RCM in the aim of taking into account the SMB-elevation feedback (Fig. 1(b)) (IPCC, 2013 ; Fettweis *et al.*, 2013).

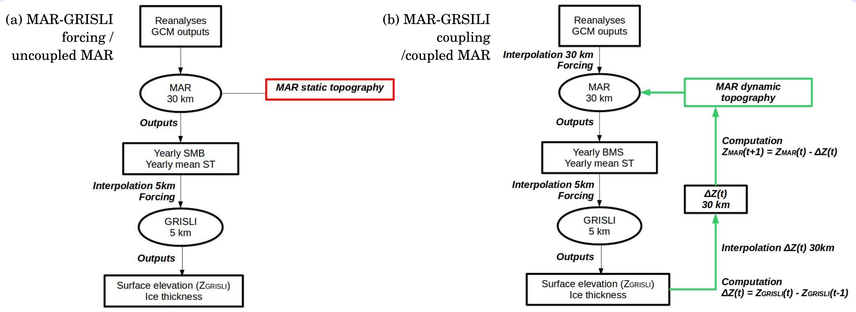


Fig. 1 : Forcing (a) vs Coupling (b) between the MAR RCM and the GRISLI ISM.

2. Methods

- **3 future projections** (2006-2100) under the RCP 8.5 scenario, with MAR forced by the MIROC5 GCM outputs and with GRISLI forced by MAR outputs, as shown by Fig. 1(a) :

  1) **Simulation 1 = reference simulation** : GRISLI forced by coupled MAR outputs using a dynamic topography

  → the SMB-elevation feedback is taken into account

  2) **Simulation 2** : GRISLI forced by uncoupled MAR outputs using a fixed topography

  → the SMB-elevation feedback is not taken into account

  3) **Simulation 3** : GRISLI forced by corrected uncoupled MAR outputs (Fig.2). In this case, MAR outputs are corrected with the Franco *et al.* (2012) interpolation technique to estimate the SMB-elevation feedback (Fig. 3).

→ The aim of this simulation is to **obtain the same results as the reference simulation by using uncoupled MAR outputs** and thus **avoid the MAR-GRISLI coupling**

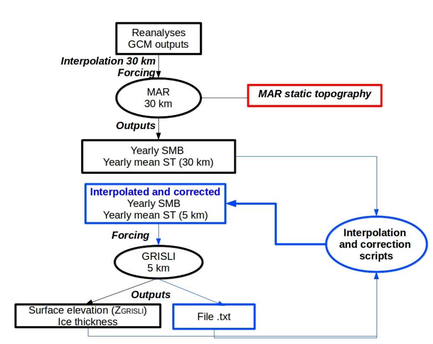


Fig. 2 : MAR-GRISLI forcing with interpolation and correction of the MAR outputs as a fonction of topography changes simulated by GRISLI.

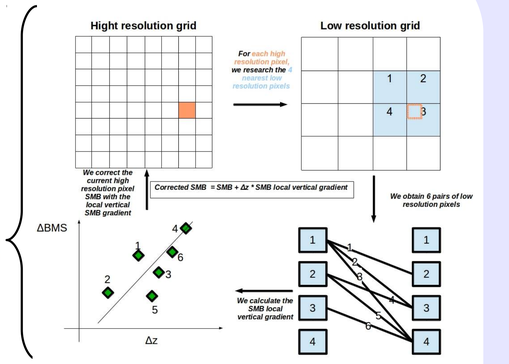


Fig. 3 : The Franco et al, (2012) interpolation which corrects SMB with respect to the local SMB gradient vs elevation.

3. Results

a) How GrIS could evolve in the future ?

- Thinning and retreat of the GrIS margins (Fig. 4)
- Decrease in ice discharge due to GrIS retreat (Fig. 5)
- Decrease in SMB because of increase in surface melting (Fig. 5)
- Negative SMB by the middle of the 21th century as a result of increasing surface melting overpassing snow falls (Fig. 5)
- Decrease in total mass balance (TMB), becoming more and more negative (Fig. 5)

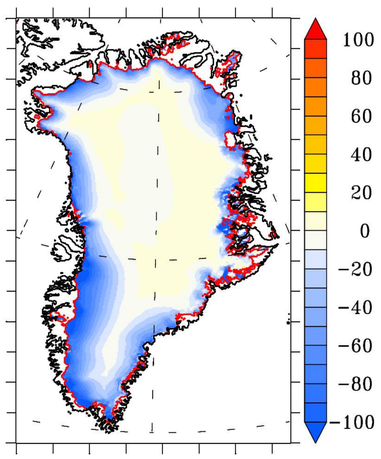


Fig. 4 : Difference between ice sheet topography modelled by the reference simulation in 2100 and in 1986-2005 (m).

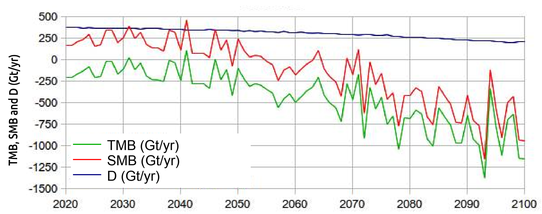
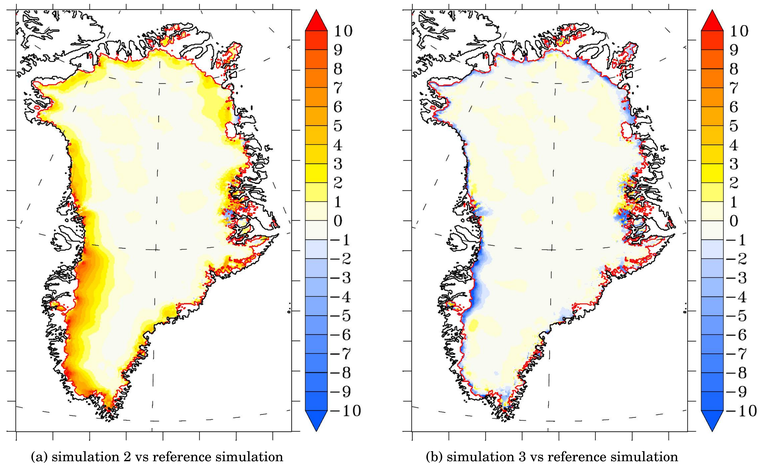


Fig. 5 : Evolution of the GrIS total mass balance (TMB) and its components (SMB and ice discharge (D)) modelled by the coupled MAR-GRISLI simulation (reference cimultion) between 2020 and 2100 (Gt/yr).

b) Can we avoid the MAR-GRISLI coupling ?

- If uncorrected uncoupled MAR outputs are used so that the SMB-elevation feedback is not taken into account, the GrIS margins ice thickness is overestimated by 10 % (Fig. 6(a)).
- When the uncoupled MAR outputs are corrected with the Franco *et al.* (2012) interpolation, we obtain almost the same results than with the coupled MAR outputs (Fig. 6 (b)).
- However, the correction applied to the uncoupled MAR outputs is slighty too large on the GrIS margins (about 5 %, Fig. 6(b)).



(a) simulation 2 vs reference simulation (b) simulation 3 vs reference simulation

Fig. 6 : Ice sheet topography difference in 2100 between (a) simulation 2 and reference simulation, and (b) simulation 3 and reference simulation (m).

4. Conclusion

- A **RCM-ISM coupling seems to be avoidable until 2100 under the RCP 8.5 scenario** thanks to the Franco *et al.* (2012) special interpolation of uncoupled MAR outputs.
- However, we need to reduce the MAR outputs correction on the GrIS margins.
- Further simulations are also needed in order to find out if the MAR-GRISLI coupling is avoidable beyond 2100.

References

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