Sensitivity of the Antarctic surface mass balance to oceanic perturbations

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1. Introduction

- The sea surface conditions (**SSC**) and more precisely Sea ice Concentration **(SIC**) and Sea Surface Temperatures (**SST**) influence the (radiative) properties of the surface, the exchanges of gases, momentum and fluxes between ocean and atmosphere.
- SSC are often used as boundary conditions in regional climate models (**RCM**) as they are not coupled to an ocean model. Nonetheless, these RCM appear to be as one of the best tools in order to study Antarctic climate due to their high spatial resolution and their ability to resolve polar processes such as the drifting snow.
- Besides, SSC simulated General Circulation Models (**GCM**) show significant biases for both SIC and SST in comparisons to reanalyses (Agosta *et al.*, 2015).
- Since, the implicit question is **how SSC (SST and SIC) can influence the Antarctic Ice Sheet climate and** by expansion **the Antarctic Surface Mass Balance (SMB) simulated by a RCM.**

2. Methods

- Simulations were performed with the MAR model (**Fig. 1**) at a resolution of 50km

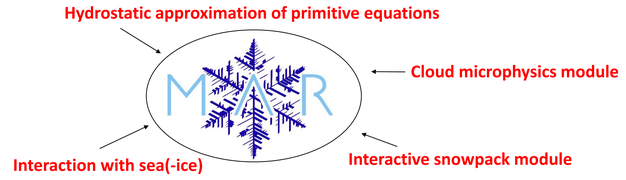


Fig. 1: Brief description of the MAR model (see Fettweis *et al.*, 2017 for last improvements and a more detailed description)

- Reference run (MAR forced every 6 hours by ERA-Interim) compared to sensitivity experiments where SSC from ERA-Interim were modified (**Fig. 2**)
  - Temperature anomalies, increase (resp. decrease) of SIC from the maximum (resp. minimum) value of neighbouring cells and combined experiments (following Noël *et al.*, 2014)
  - Temperature anomalies and correction of the SIC based on CMIP5 GCM biases (NorESM1, GISS-E2-H and $CMIP5_{average}$)

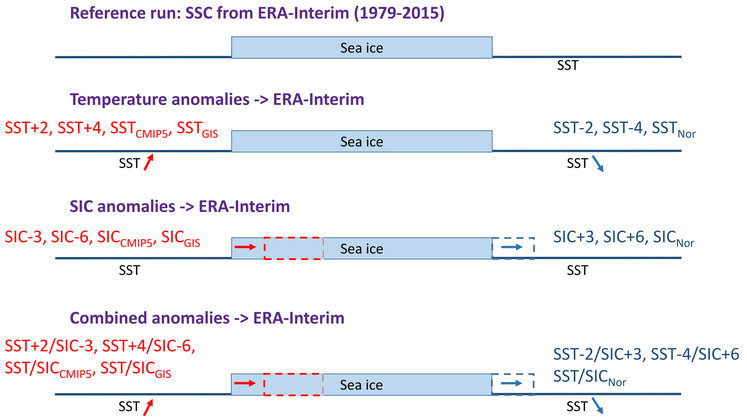
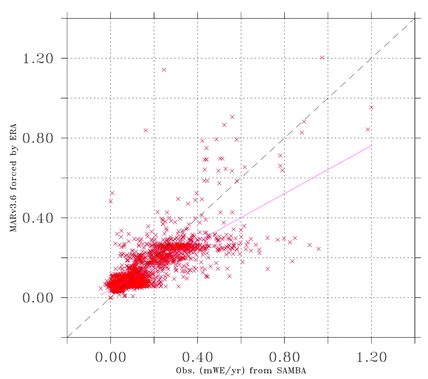


Fig.2: Reference and sensitivity runs where anomalies representative of a warm (resp. cold) ocean are in red (resp. blue)

3. Results

- **Evaluation of the reference run against the SAMBA database (Favier *et al.*, 2013) (Fig. 3** and **Tab.1**)



n=3030 obs	Bias (m.y)$^{-1}$	Correlation	RMSE (m.y^{-1})
Reference	-0.01	0.78	0.08
	$Mean_{obs}$= 0.14		Std_{obs}= 0.13

Fig.3 and Tab.1: Comparison of the reference run against the SAMBA database

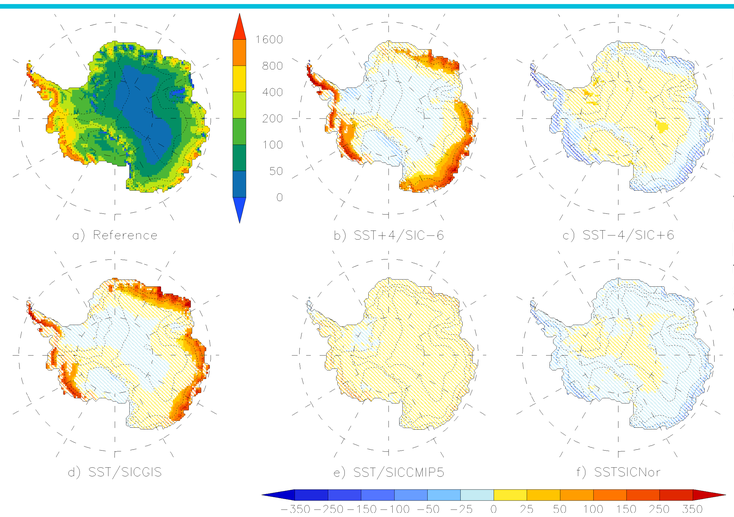


Fig.4: a) Mean SMB in the reference run for the period 1979 to 2015 (units= mm.we.yr^{-1}) b) Mean anomalies between the sensitivity experiment SST+4/SIC-6 and the reference run (units= mm.we.yr^{-1}). c) to f) idem but resp. for SST-4/SIC+6, SST/SICGIC, SST/SICCMIP5, SST/SICNor

Tab.4: Mean integrated SMB , its components (Snowfall, Rainfall, Water fluxes) and the melt water production in Gt.yr^{-1}. Anomalies are given in respect to the reference run. Red values indicate significant anomalies (evaluated by a one-sited Student's *t* test with a 95% degree of confidence).

Units= Gt.yr^{-1}	SMB	SMB%	Snowfall	Rainfall	Water fluxes	Melt water
Ref	2565 ± 115		2658	20	109	97
SST+4/SIC-6	**+325**	+12.7	**+304**	**+40**	+13	**+218**
SST-4/SIC+6	-121	-4.5	-133	-3	-15	+1
SST/SICGIS	**+357**	+13.9	**+353**	**+15**	+11	**+98**
SST/SICCMIP5	+103	+4.0	+104	+1	+2	+18
SST/SICNor	-104	-4.0	-102	-2	+0	+3

- **Warmer SST increase SMB due to an increase in precipitations over coastal areas** (Fig.4) **as air masses are warmed by the ocean and can contain more water vapour.**
- **Conversely, a sea-ice concentration decrease increases the evaporation and strengthen the effect of warmer SST.**
- **Inversely, a colder and more sea-ice covered ocean reduces the accumulation over the Antarctic Ice Sheet even tough the sensitivity is weaker and non statistically significant.** (Tab.4)

4. Conclusion

- **The SMB sensitivity is almost exclusively determined by the influence of the SSC on the snowfall.**

"Warmer ocean" increases the accumulation over the Ice Sheet while "colder ocean" decreases it.

- **Significant anomalies caused by SSC are limited to margins and are mainly caused by "warm" biases.**
- **Warm ocean representative biases induces anomalies as large as anomalies simulated by other RCMs or GCMs for the end of the 21st century showing the importance of large-scale SSC in future projection.**

References

- Agosta *et al.* 2015. Evaluation of the CMIP5 models in the aim of regional modelling of the Antarctic surface mass balance, *Cryosphere*, 9, 2311–2321.
- Favier *et al.* 2013. An updated and quality controlled surface mass balance dataset for Antarctica. *Cryosphere*, 7(2), 583–597.
- Fettweis *et al.* 2017. Reconstructions of the 1900-2015 Greenland ice sheet surface mass balance using the regional climate MAR model, *Cryosphere*, 11, 1015–1033.
- Noël *et al.* 2014.Sensitivity of Greenland Ice Sheet surface mass balance to perturbations in sea surface temperature and sea ice cover: a study with the regional climate model MAR, Cryosphere, 8, 1871–1883.