Supplementary Material

Ice flux evolution in fast flowing areas of the Greenland Ice Sheet over the 20th and 21st centuries

Daniele PEANO,[1,2] Florence COLLEONI,[2] Aurélien QUIQUET,[2,4]

Simona MASINA[2,3]

[1]*Ca' Foscari University, Venice, Italy*

[2]*Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC), Bologna, Italy*

[3]*Istituto Nazionale di Geofisica e Vulcanologia (INGV), Bologna, Italy*

[4]*Laboratoire des Sciences du Climat et de l'Environnement, LSCE/IPSL, CEA-CNRS-UVSQ, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France*

Correspondence: Daniele Peano <daniele.peano@cmcc.it>

This supplementary material contains:

- the correction terms added to the melting factors C_{snow} and C_{ice} during the spin-up simulations, following the method by Greve and others (2011) (Table S1);
- the mean values of accumulation, ablation and surface mass balance over the period 1980–1999 computed over the glaciated area of Greenland obtained with the complete set of CMIP5 climate forcing (Table S2);
- the values of accumulation, ablation and surface mass balance from previous literature works (Table S3);
- the basal drag map obtained by means of the iterative inverse method applied by Edwards and others (2014) (Figure S1);

Table S1. Latitude dependent PDD correction applied to each ISM to improve the spin-up simulations following Greve and others (2011). The longitudinal distinction between West and East Greenland is set at 44 °W. In general, values >1 are chosen in regions where the previous ice-sheet simulations produced thicker ice with respect to present-day topography, while values <1 are chosen where the previous ice-sheet simulations show thinner ice with respect to present-day topography.

Latitude	64 °N	70 °N	76 °N	79 °N
Corr. East	4.0	7.5	2.5	1.5
Corr. West	1.5	0.8	1.6	0.1

- the comparison between ice core vertical temperature structure and simulated vertical temperature structure at GRIP and DYE3 (Figure S2). Two spin-up simulations has been performed with GRISLI at a 20-km horizontal resolution: a 24 ka-long spin-up simulation and a 125 ka-long spin-up simulation. We obtain only small differences between the two simulations in the coastal area, i.e. DYE3. Conversely, in a central region, i.e. GRIP, the two simulations differ only at a depth higher than 1000 m;

- the time evolution of precipitation, temperature and summer temperature simulated by the complete set of CMIP5 AOGCMs (Figure S3);

- the comparison between the mean present-day (1980–1999) values of accumulation, ablation and surface mass balance simulated and previous literature works values (Figure S4);

- the comparison between the surface mass balance evolution simulated by GRISLI and simulated by MAR (Fettweis and others, 2013) in the period 1980–2005 (Figure S5);

- the present-day (1980–1999) regional distribution of accumulation, ablation and surface mass balance simulated with GRISLI (Figure S6);

- the comparison between observed (Joughin and others, 2010) and simulated velocities in the five studied regions (Figure S7);

- difference in precipitation, temperature and summer temperature between the MAR and ERA Interim climatologies, calculated over the period 1980–1999 (Figure S8).

Table S2. Present-day (1980–1999) mean values of accumulation, ablation and surface mass balance computed over the englaciated area of Greenland Ice Sheet. The values reported are the model realization averages, except for CMCC CM and IPSL which have only one realization. Values of accumulation (Acc), ablation (Abl) and surface mass balance (SMB) are given in Gt a^{-1}.

Model	**Acc**	**Abl**	**SMB**
CCSM4	634 ± 2	422 ± 8	212 ± 8
CESM1	622 ± 4	392 ± 8	229 ± 5
CMCC CM	624 ± 1	393 ± 1	230 ± 1
CNRM	629 ± 2	507 ± 60	122 ± 58
IPSL	632 ± 1	425 ± 1	206 ± 1
MIROC5	627 ± 4	379 ± 10	247 ± 8
MPI	634 ± 1	399 ± 2	234 ± 3

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Table S3. Reported estimate of accumulation (Acc), ablation (Abl) and surface mass balance (SMB) from literature. Values are given in Gt a^{-1}. Note that temperature and precipitation simulated with MAR by Fettweis and others (2013) are used as reference climate forcing in our simulations.

Paper	Model	Period	Acc	Abl	SMB
Hanna and others (2005)	ECMWF reanalysis	1958–2003	573 ± 70	280 ± 69	293 ± 104
Box and others (2006)	Polar MM5	1988–2004	543 ± 131	373 ± 66	170 ± 152
Fettweis (2007)	MAR	1979–2005	612 ± 55	304 ± 96	308 ± 125
Ettema and others (2009)	RACMO2/GR	1958–2007	743 ± 78	274 ± 67	469 ± 41
Fettweis and others (2013)	MAR (ERA Interim)	1980–1999	662 ± 55	274 ± 66	388 ± 103

57 Hanna E, Huybrechts P, Janssens I, Cappelen J, Steffen K and Stephens A (2005) Runoff and mass balance of the
58 Greenland ice sheet: 1958–2003. *J. Geophys. Res.*, **110**, D13108
59 Joughin I, Smith BE, Howat IM, Scambos T and Moon T (2010) Greenland flow variability from ice-sheet-wide
60 velocity mapping. *J. Glaciol.*, **56**(197), 415–430
61 Tedesco M and Fettweis X (2012) 21st century projections of surface mass balance changes for major drainage systems
62 of the Greenland ice sheet. *Environ. Res. Lett.*, **7**, 045405 (doi: 10.1088/1748-9326/7/4/045405)

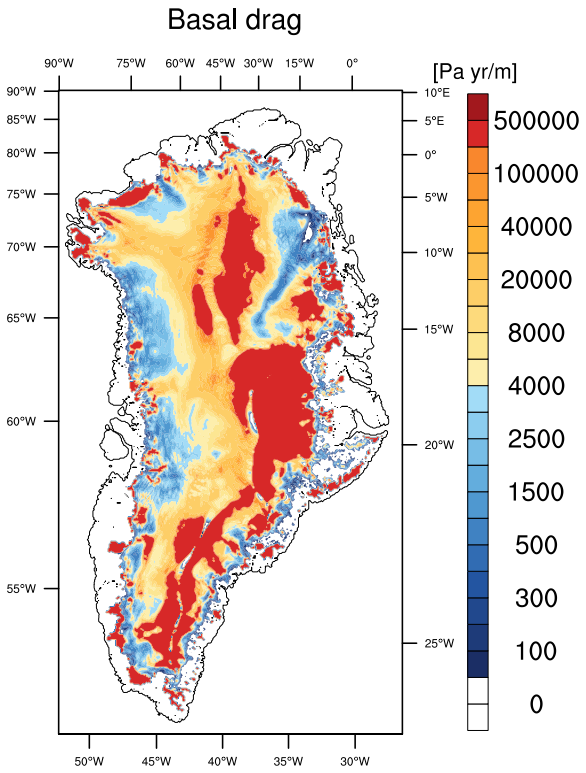

Fig. S1. Basal drag inferred from the iterative inverse method used in Edwards and others (2014).

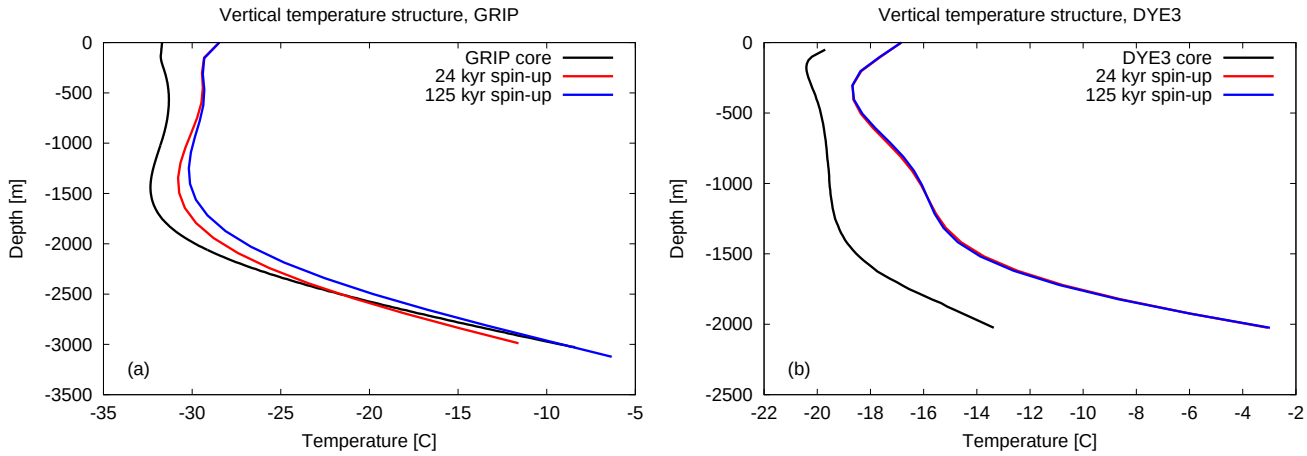

Fig. S2. Comparison between observed ice core vertical temperature structure and simulated vertical temperature structure at (a) GRIP (ice sheet internal area) and (b) DYE3 (ice sheet coastal region). The red lines represent a 24-ka spin-up performed with GRISLI at a 20-km horizontal resolution. The blue lines show a 125-ka spin-up performed with GRISLI at a 20-km horizontal resolution.

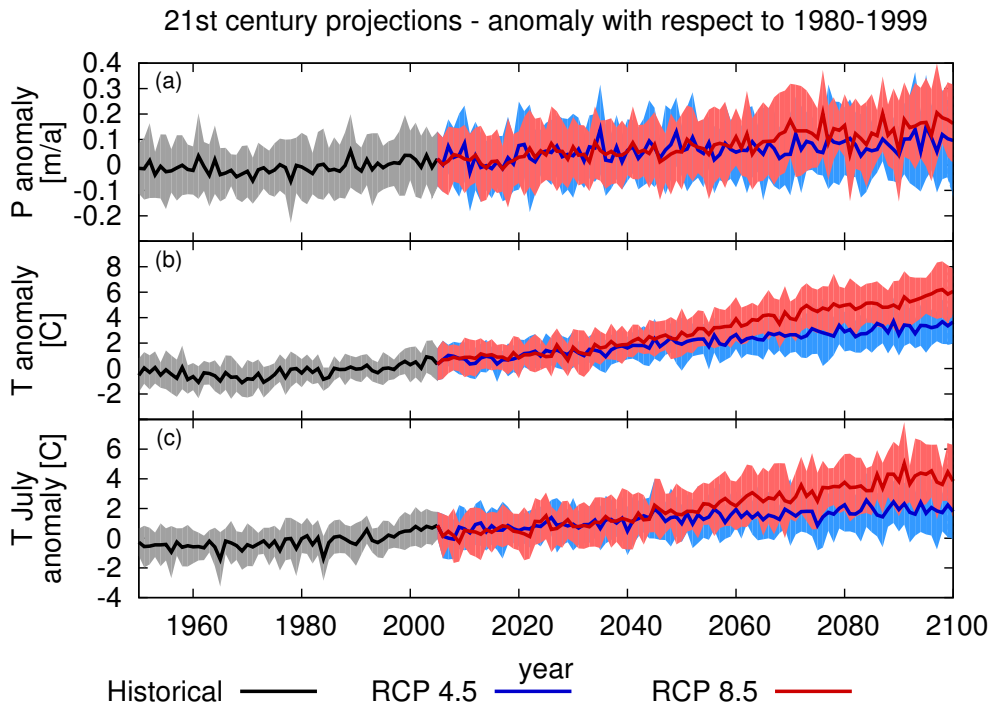

Fig. S3. Time series of (a) mean annual precipitation (m a^{-1}), (b) mean annual air surface temperature (°C), and (c) mean July air surface temperature (°C) anomalies with respect to the period 1980–1999. The values are averaged over the entire present-day ISMs domain. Shaded regions indicate the ensemble spread, while solid lines represent the multi-model ensemble means.

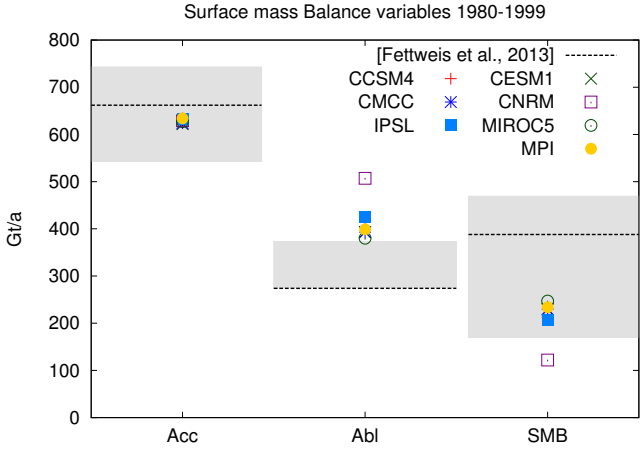

Fig. S4. Mean present-day (1980–1999) values of accumulation (Acc), ablation (Abl) and surface mass balance (SMB) simulated with GRISLI under the complete set of CMIP5 climate forcing. The grey areas show the values of Acc, Abl and SMB coming from literature (see Table S3), while the black dashed lines show the specific values from Fettweis and others (2013).

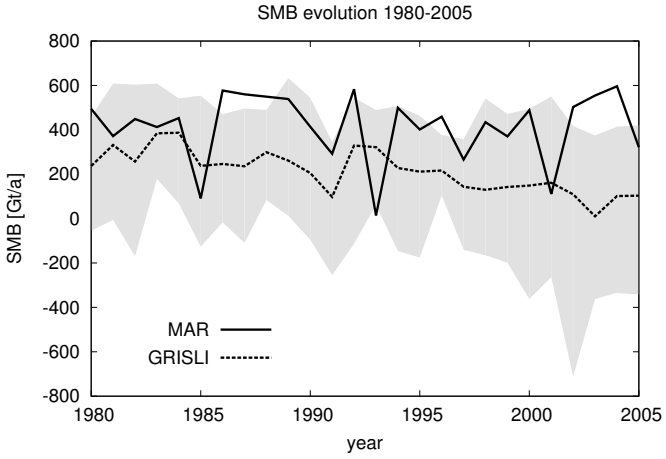

Fig. S5. Surface mass balance evolution during the period 1980–2005 simulated with MAR (black solid line Fettweis and others, 2013) and GRISLI forced with the CMIP5 AOGCM climate forcing described in the Methods (grey shaded area, and black dashed line for the multi-model ensemble mean).

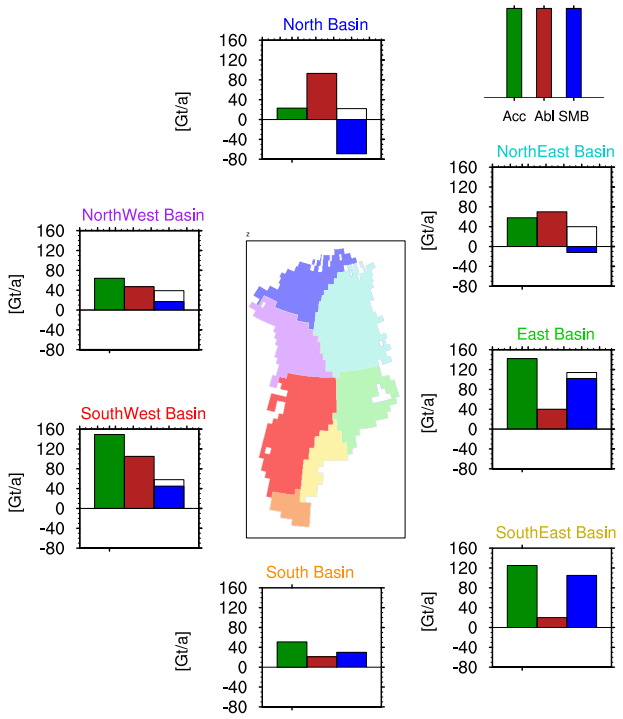

Fig. S6. Regional distribution of accumulation (green column), ablation (red column) and surface mass balance (blue column). The values are obtained from the multi-model ensemble mean of the complete set of simulations. The values are averaged over the period 1980–1999. The black empty columns exhibit the SMB values simulated with MAR by Tedesco and Fettweis (2012) over the period 1980–1999. The SMB values from Tedesco and Fettweis (2012) in the South and South-East basins are not shown, because they simulate these two basins together. We simulate about 135 Gt a^{-1} in these two basins together, while Tedesco and Fettweis (2012) simulate about 116 Gt a^{-1} in their south-eastern basin.

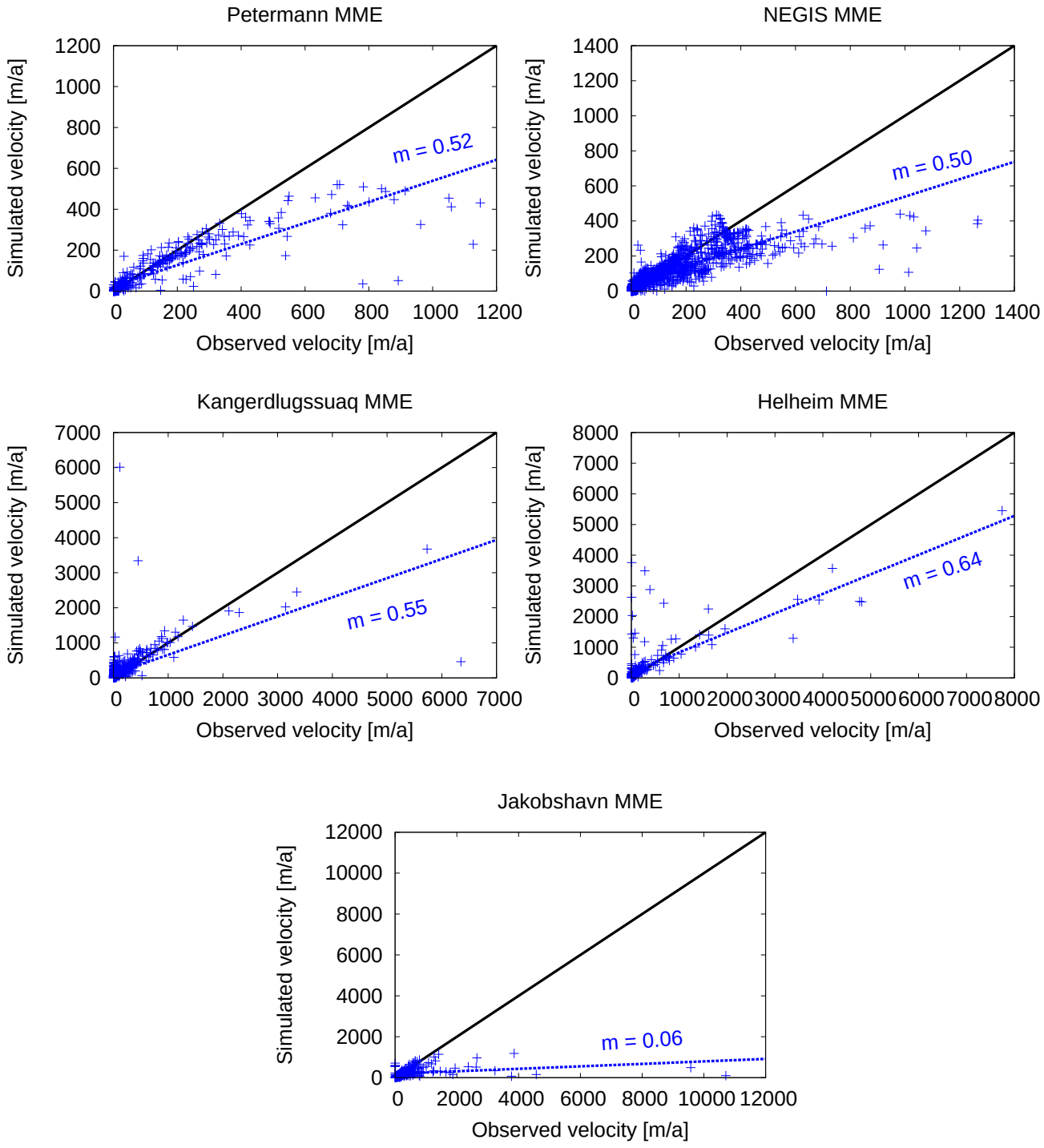

Fig. S7. Comparison between observed (Joughin and others, 2010) and simulated ice velocities in the five studied regions. The difference in slope between the blue and black lines displays the discrepancy between observed and simulated velocities. A slope of m=1 for the blue line should represent a perfect match with observed velocities.

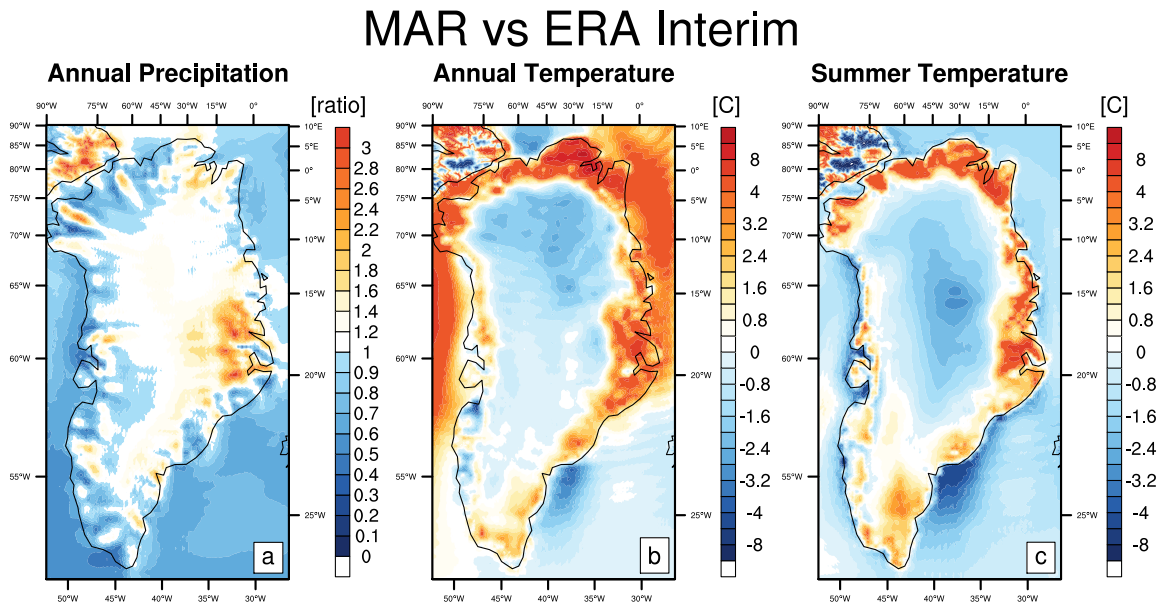

Fig. S8. Differences between MAR and ERA Interim (a) precipitation, (b) temperature and (c) summer temperature averaged over 1980–1999.