Supplementary Material – Cloud- and ice-albedo feedbacks drive greater Greenland ice sheet sensitivity to warming in CMIP6 than in CMIP5

Idunn Aamnes Mostue[1*], Stefan Hofer[1], Trude Storelvmo[1] and Xavier Fettweis[2]

[1]Department of Geosciences, University of Oslo, Oslo, Norway
[2]Department of Geography, SPHERES research unit, University of Liège, Belgium

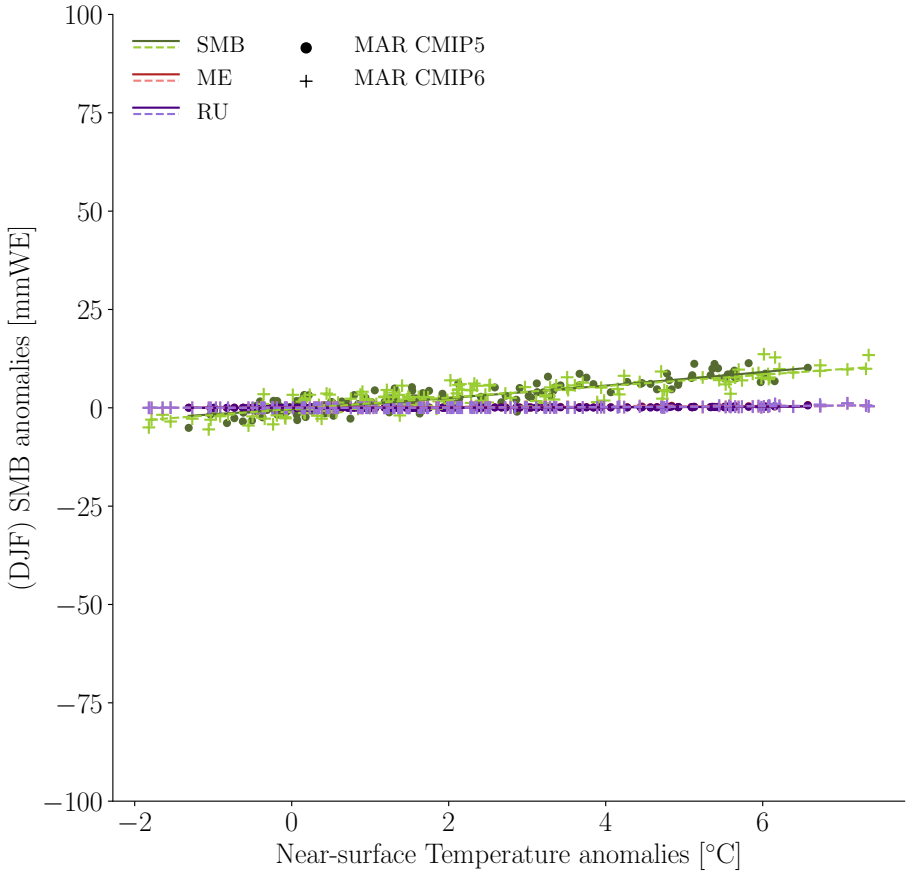
[*]Corresponding author: Idunn Aamnes Mostue, idunnam@uio.no

Simulation	Variable	Unit	Near-surface temperature anomaly (±std) (JJA) 5.4°C	(SON) 6.7°C
MAR CMIP5	ALB	%	-6.0 (± 0.2)	-0.8 (± 0.1)
MAR CMIP6	ALB	%	-6.2 (± 0.3)	-1.4 (± 0.1)
MAR CMIP5	CC	%	2.4 (± 0.9)	2.9 (± 0.8)
MAR CMIP6	CC	%	-2.2 (± 1.1)	-0.7 (± 0.9)
MAR CMIP5	COD		0.30 (± 0.02)	0.08 (± 0.01)
MAR CMIP6	COD		0.30 (± 0.03)	0.10 (± 0.01)
MAR CMIP5	LW_{net}	Wm^{-2}	6.8 (± 0.8)	2.5 (± 0.4)
MAR CMIP6	LW_{net}	Wm^{-2}	4.4 (± 1.1)	1.5 (± 0.5)
MAR CMIP5	LWD	Wm^{-2}	29.2 (± 1.0)	27.9 (± 0.4)
MAR CMIP6	LWD	Wm^{-2}	26.8 (± 0.9)	27.1 (± 0.5)
MAR CMIP5	LWU	Wm^{-2}	-22.4 (± 0.2)	-25.4 (± 0.1)
MAR CMIP6	LWU	Wm^{-2}	-22.2 (± 0.2)	-25.4 (± 0.1)
MAR CMIP5	ME	mmWE	215.9 (± 4.8)	14.0 (± 1.4)
MAR CMIP6	ME	mmWE	222.5 (± 7.7)	22.9 (± 3.6)
MAR CMIP5	Net_{rad}	Wm^{-2}	16.4 (± 0.5)	2.7 (± 0.3)
MAR CMIP6	Net_{rad}	Wm^{-2}	16.5 (± 0.9)	2.1 (± 0.5)
MAR CMIP5	RU	mmWE	193.8 (± 6.5)	19.4 (± 1.9)
MAR CMIP6	RU	mmWE	198.6 (± 9.5)	31.1 (± 4.3)
MAR CMIP5	SMB	mmWE	-162.2 (± 7.0)	-1.6 (± 3.1)
MAR CMIP6	SMB	mmWE	-170.7 (± 9.2)	-14.1 (± 4.8)
MAR CMIP5	SW_{net}	Wm^{-2}	9.6 (± 0.9)	0.2 (± 0.1)
MAR CMIP6	SW_{net}	Wm^{-2}	12.1 (± 1.7)	0.6 (± 0.2)
MAR CMIP5	SWD	Wm^{-2}	-20.7 (± 2.0)	-2.5 (± 0.3)
MAR CMIP6	SWD	Wm^{-2}	-14.2 (± 1.8)	2.1 (± 0.5)

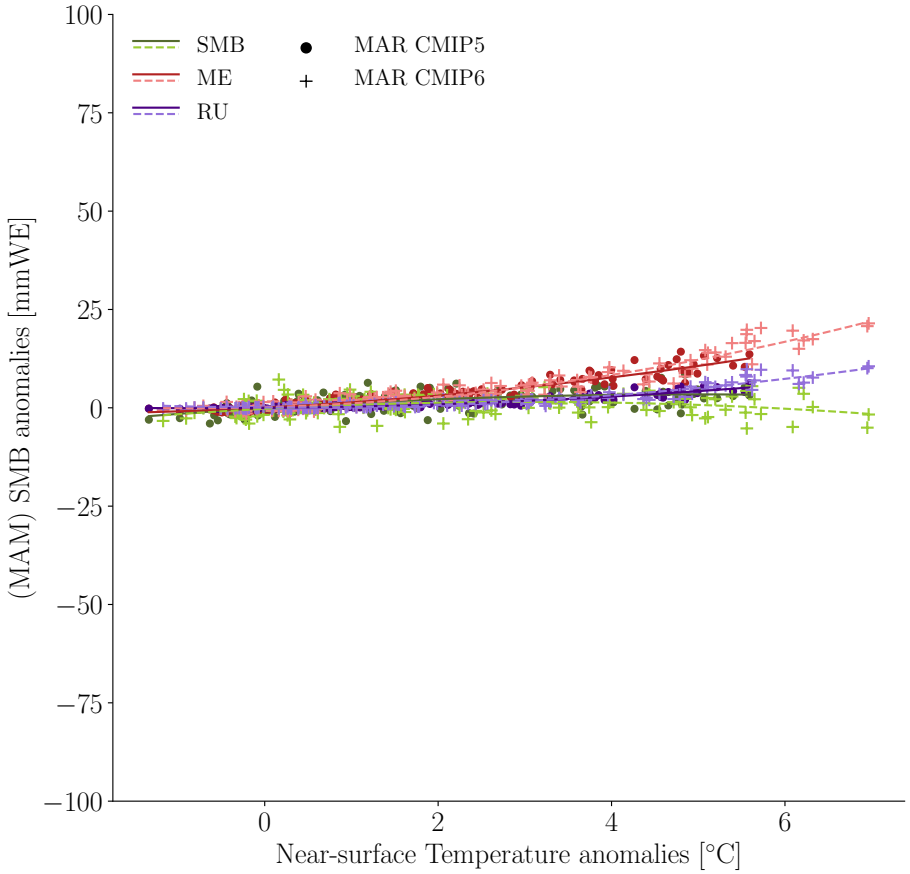
T 1: MAR CMIP5 and MAR CMIP6 projected anomalies of climate variables for a given temperature increase, associated units, and ± one standard deviation given in brackets. The standard deviation is calculated for a 20 year interval prior the selected warming. Temperature increase of + 5.4°C + 6.7°C is selected for summer (JJA) and autumn (SON) respectively, representing the close to end temperature for the MAR CMIP5 projections where it deviates the most from MAR CMIP6.

Forcing Field	JJA	SON
ACCESS1.3	(2078 – 2097)	(2069 – 2080)
CSIRO-Mk3-6-0	(2081 – 2100)	(2078 – 2097)
HadGEM2-ES	(2056 – 2075)	(2042 – 2061)
IPSL-CM5A-MR	(2056 – 2075)	(2045 – 2064)
MIROC5	(2060 – 2079)	(2057 – 2076)
NorESM1-M	(2069 – 2080)	(2065 – 2084)
CESM2	(2045 – 2064)	(2052 – 2071)
CNRM-CM6-1	(2060 – 2079)	(2056 – 2075)
CNRM-ESM2-1	(2062 – 2081)	(2059 – 2078)
MRI-ESM2-0	(2066 – 2085)	(2051 – 2070)
UKESM1-0-LL	(2030 – 2049)	(2032 – 2051)

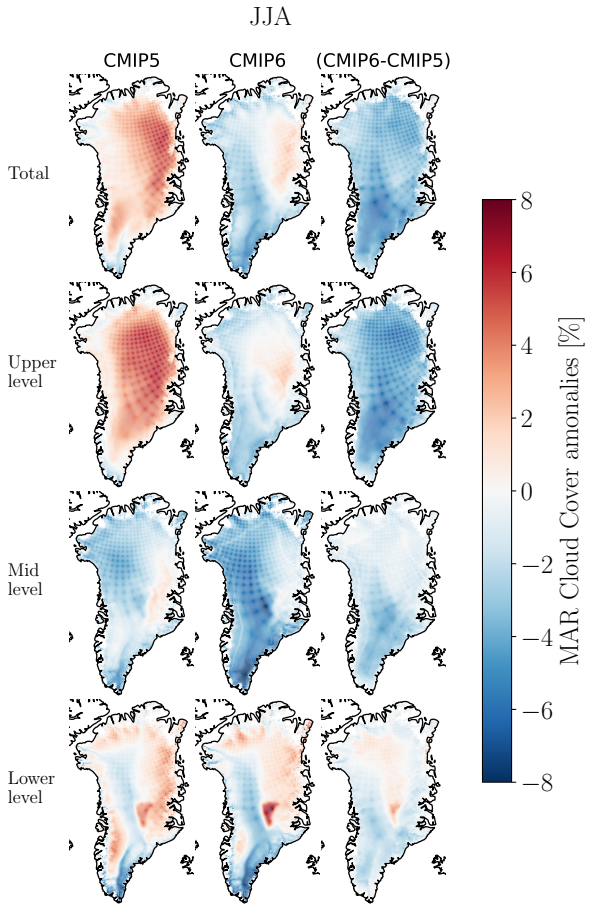
T 2: Twenty-year warming period of $\sim 4°$C near-surface temperature, spatially averaged over the Greenland ice sheet for summer (JJA) and autumn (SON), from individual MAR simulations of CMIP5 models (top six models) and CMIP6 (bottom five models). All anomalies are related to the thirty-years averaged reference period (1961-1990).



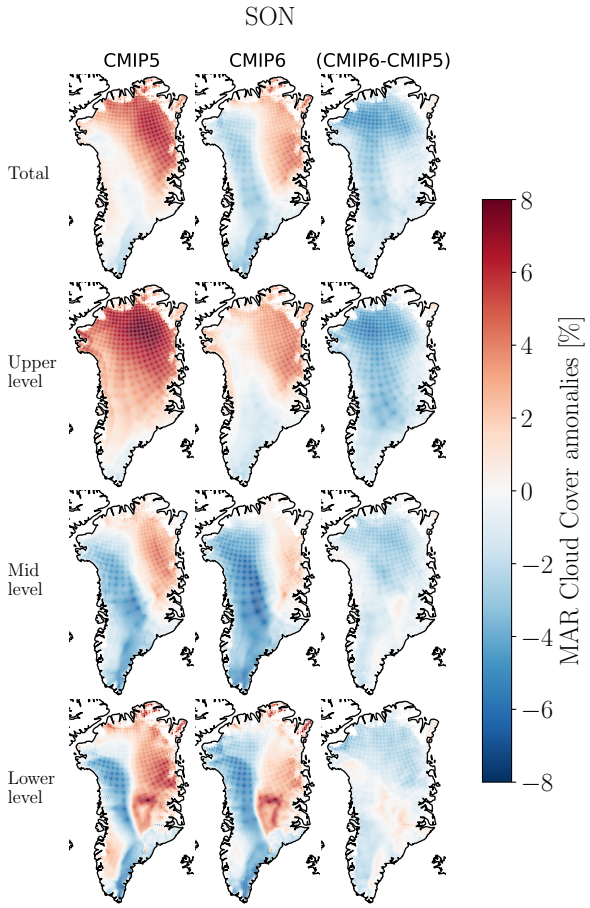
S 1: Seasonal SMB, melt and runoff anomalies [mmWE] over the GrIS according to near-surface temperature anomalies [°C]. Winter (DJF) SMB-, melt- (ME), and runoff anomalies (RU) [mmWE] over the GrIS as a function of annual near-surface temperature anomalies [°SC] from MAR CMIP5 (dots) and MAR CMIP6 (crosses), with regression drawn in solid lines for MAR CMIP5 and scattered lines for MAR CMIP6. All anomalies are related to the thirty-years averaged reference period (1961–1990)



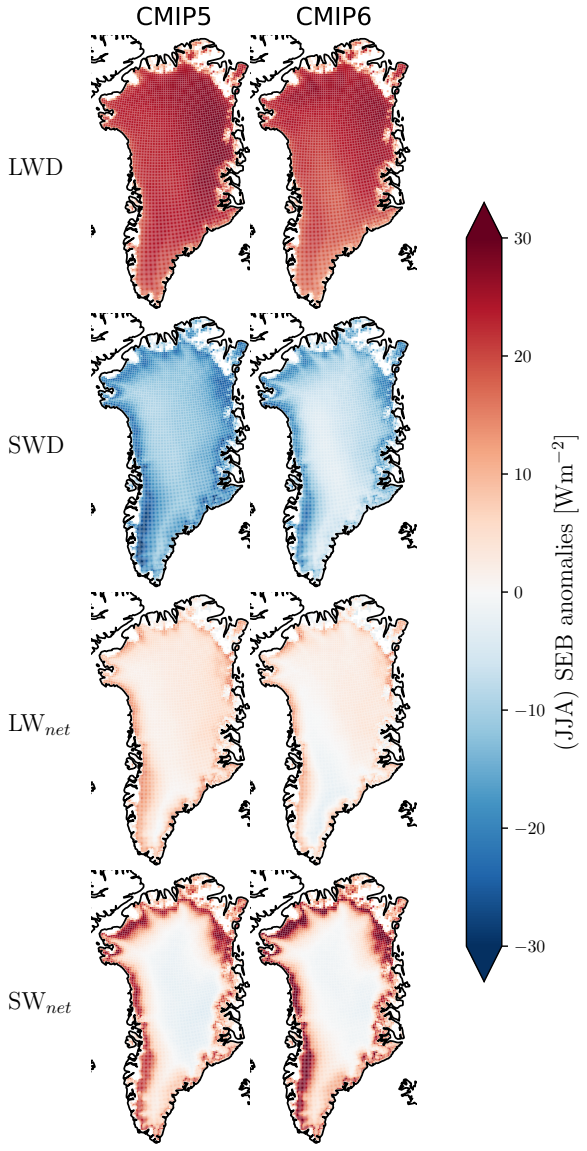
S 2: Seasonal SMB, melt and runoff anomalies [mmWE] over the GrIS according to near-surface temperature anomalies [°C]. Spring (MAM) SMB, melt (ME), and runoff anomalies (RU) [mmWE] over the GrIS as a function of annual near-surface temperature anomalies [°C] from MAR CMIP5 (dots) and MAR CMIP6 (crosses), with regression drawn in solid lines for MAR CMIP5 and scattered lines for MAR CMIP6. All anomalies are related to the thirty-years averaged reference period (1961–1990).



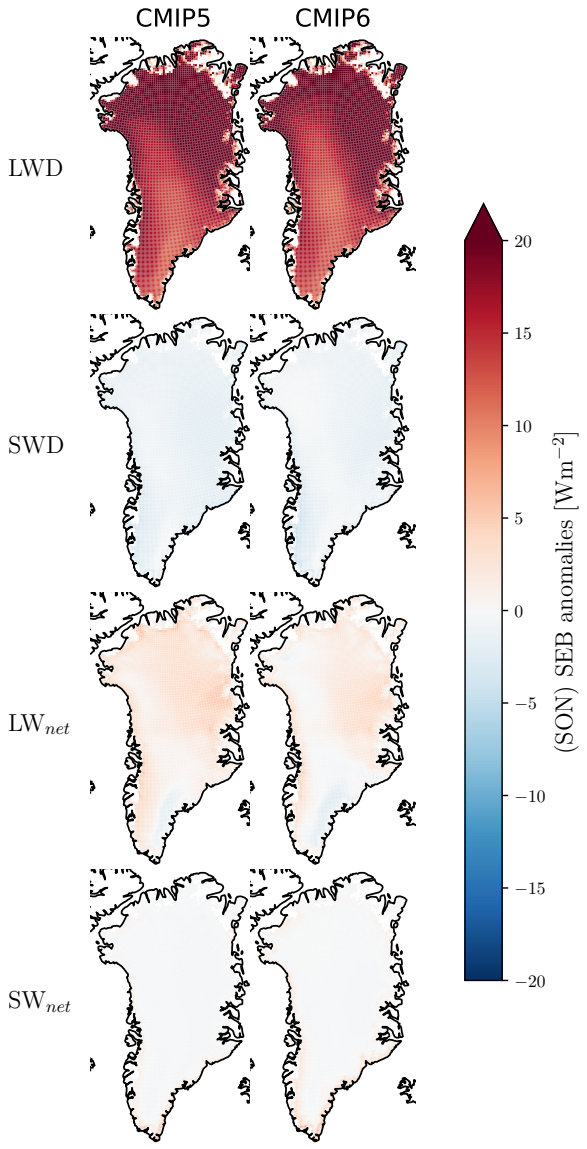
S 3: Spatial projection of Cloud cover anomalies [%] for MAR CMIP5 and MAR CMIP6 simulations (+ 4 °C ± 10 years) for summer (JJA). Twenty-year average (4 °C ± 10 years) of the cloud cover [%] over the GrIS) for summer (JJA). The four rows from top-down indicate the total, upper level (< 44000 Pa), mid level (⩽ 68000 Pa, ⩾ 44000 Pa), and lower level cloud cover (> 68000 Pa). The three columns from left to right indicate the cloud cover anomalies for MAR CMIP5, for MAR CMIP6, and for the difference between the two (CMIP6-CMIP5). For MAR CMIP5 and MAR CMIP6 a positive value (red) indicates an increase in cloud cover, and a negative value (blue) a reduction in cloud cover compared to the reference period. For the difference (CMIP6-CMIP5) a positive value (red) indicates more positive cloud cover anomaly, and negative values (blue) indicate a more negative cloud cover anomaly in MAR CMIP6 compared to MAR CMIP5.



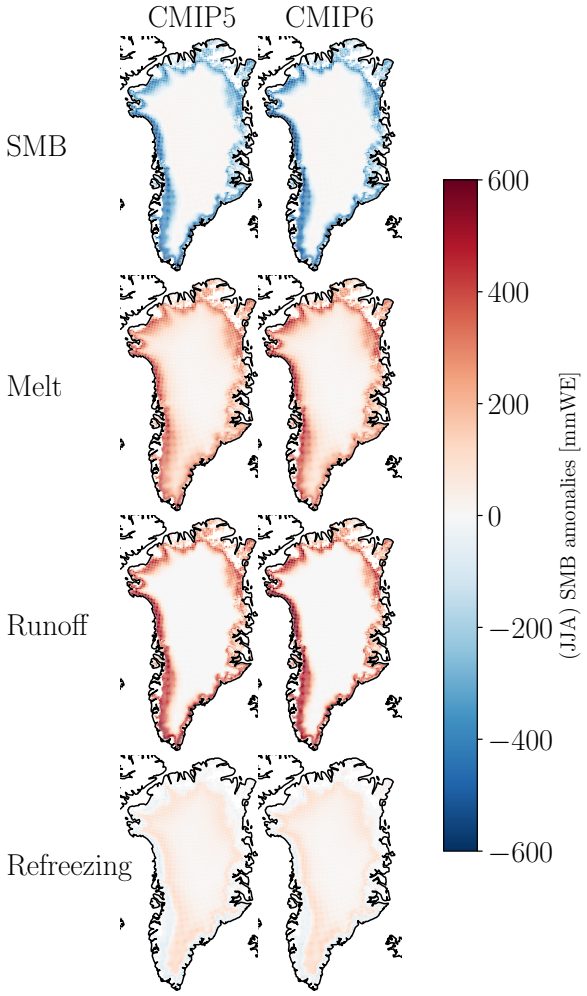
S 4: Spatial projection of Cloud cover anomalies [%] for MAR CMIP5 and MAR CMIP6 simulations (+ 4 °C ± 10 years) for autumn (SON). Twenty-year average (4 °C ± 10 years) of the cloud cover [%] over the GrIS) for autumn (SON). The four rows from top-down indicate the total, upper level, mid level, and lower level cloud cover. The three columns from left to right indicate the cloud cover anomalies for MAR CMIP5, for MAR CMIP6, and for the difference between the two (CMIP6-CMIP5). For MAR CMIP5 and MAR CMIP6 a positive value (red) indicates an increase in cloud cover, and a negative value (blue) a reduction in cloud cover compared to the reference period. For the difference (CMIP6-CMIP5) a positive value (red) indicates more positive cloud cover anomaly, and negative values (blue) indicate a more negative cloud cover anomaly in MAR CMIP6 compared to MAR CMIP5.



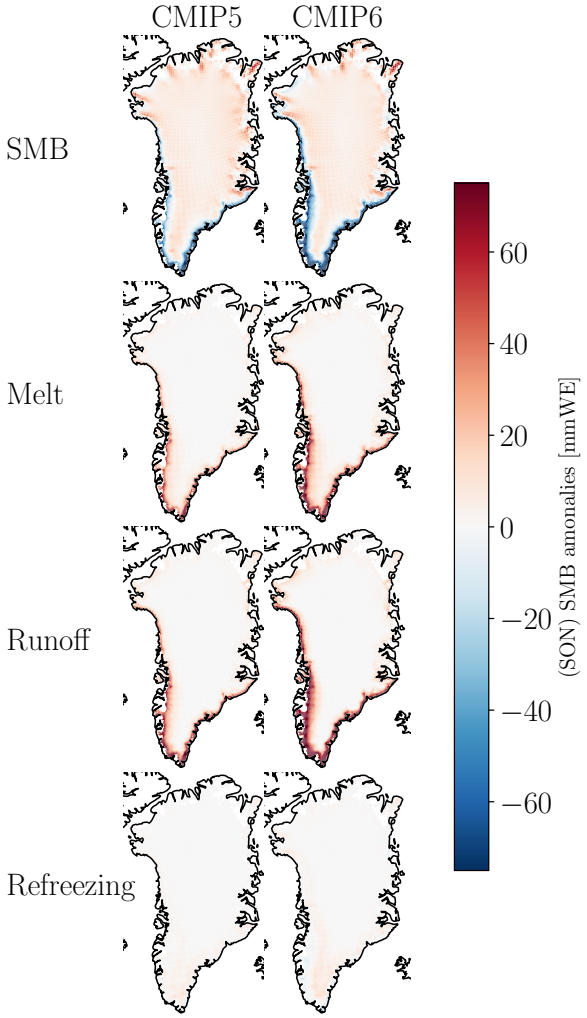
S 5: Spatial projection of selected SEB components anomaly for MAR CMIP5 and MAR CMIP6 simulations (+ 4°C ± 10 years) for summer (JJA). Twenty-year average (+ 4°C ± 10 years) anomalies of LWD, SWD, LW$_{net}$ and SW$_{net}$ [Wm^{-2}], of MAR CMIP5 (left) and MAR CMIP6 (right). Anomalies are related to the reference period (1961–1990). Positive value (red) indicates an incrFease in the energy flux reaching the surface, and a negative value (blue) a decrease, compared to the reference period (1961–1990).



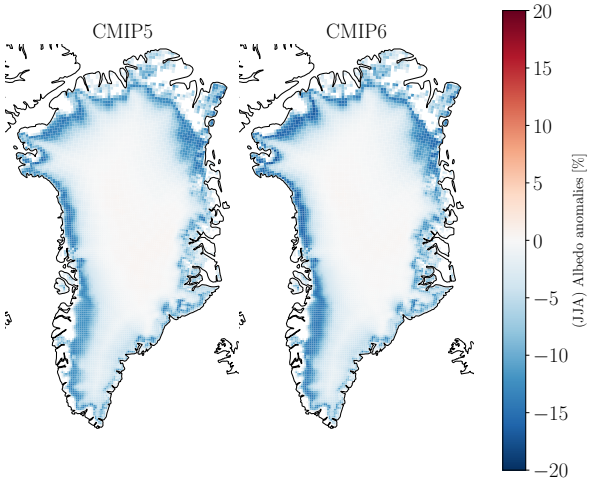
S 6: Spatial projection of selected SEB components anomaly for MAR CMIP5 and MAR CMIP6 simulations (+ 4°C ± 10 years) for autumn (SON). Twenty-year average (+ 4°C ± 10 years) anomalies of LWD, SWD, LW$_{net}$ and SW$_{net}$ [Wm^{-2}], of MAR CMIP5 (left) and MAR CMIP6 (right). Anomalies are related to the reference period (1961–1990). Positive value (red) indicates an increase in the energy flux reaching the surface, and a negative value (blue) a decrease, compared to the reference period (1961–1990).



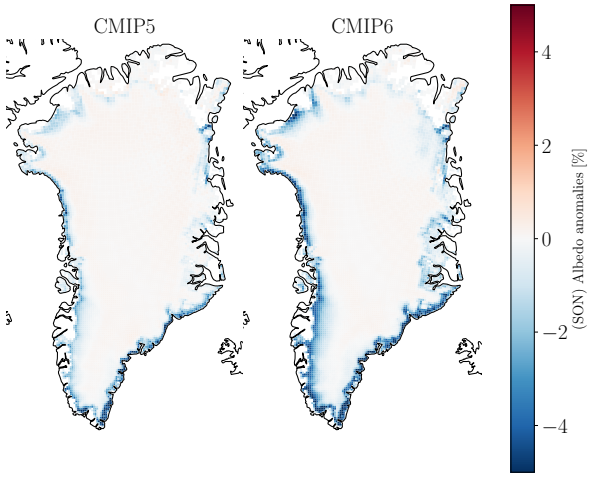
S 7: Spatial projection of selected SMB components anomaly for MAR CMIP5 and MAR CMIP6 simulations (+ 4°C ± 10 years) for summer (JJA). Twenty-year average (+ 4°C ± 10 years) anomalies of melt, runoff, refreezing and the total SMB [mmWE], of MAR CMIP5 (left) and MAR CMIP6 (right). Anomalies are related to the reference period (1961–1990). Positive value (red) indicates an increase in the surface mass balance components, and a negative value (blue) a decrease, compared to the reference period (1961–1990).



S 8: Spatial projection of selected SMB components anomaly for MAR CMIP5 and MAR CMIP6 simulations (+ 4°C ± 10 years) for autumn (SON). Twenty-year average (+ 4°C ± 10 years) anomalies of melt, runoff, refreezing and the total SMB [mmWE], of MAR CMIP5 (left) and MAR CMIP6 (right). Anomalies are related to the reference period (1961–1990). Positive value (red) indicates an increase in the surface mass balance components, and a negative value (blue) a decrease, compared to the reference period (1961–1990)



S 9: Spatial projection of albedo anomaly [%]for MAR CMIP5 and MAR CMIP6 simulations (+4° ± 10 years) for summer (JJA). Twenty-year average (+4° ± 10 years) of albedo [%] over the GrIS for summer (JJA). Anomalies are related to the reference period (1961–1990). Positive value (red) indicates an increase in the albedo, and a negative value (blue) a decrease, compared to the reference period (1961–1990).



S 10: Spatial projection of albedo anomaly [%]for MAR CMIP5 and MAR CMIP6 simulations (+4° ± 10 years) for autumn (SON). Twenty-year average (+4° ± 10 years) of albedo [%] over the GrIS for autumn (SON). Anomalies are related to the reference period (1961–1990). Positive value (red) indicates an increase in the albedo, and a negative value (blue) a decrease, compared to the reference period (1961–1990).