Supplement of The Cryosphere, 17, 4267–4288, 2023
https://doi.org/10.5194/tc-17-4267-2023-supplement

The Cryosphere
Open Access

Supplement of

Sensitivity of the MAR regional climate model snowpack to the parameterization of the assimilation of satellite-derived wet-snow masks on the Antarctic Peninsula

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Supplementary : 2020-2021 melt season

Figure S 1. Evolution of backscattering coefficient σ_0 (in blue) and brightness temperature (orange) over the Larsen C ice shelf (top, 67.54°S 63.90°W) and the Wilkins coast (bottom, 68.08°S 65.86°W) over the 2019-2020 melt season. In a place where no melting is observed (top), σ_0 and the brightness temperature show almost no changes. On the contrary, in areas subject to melt (bottom), we can observe a decrease of σ_0 and an increase in the observed brightness temperature.

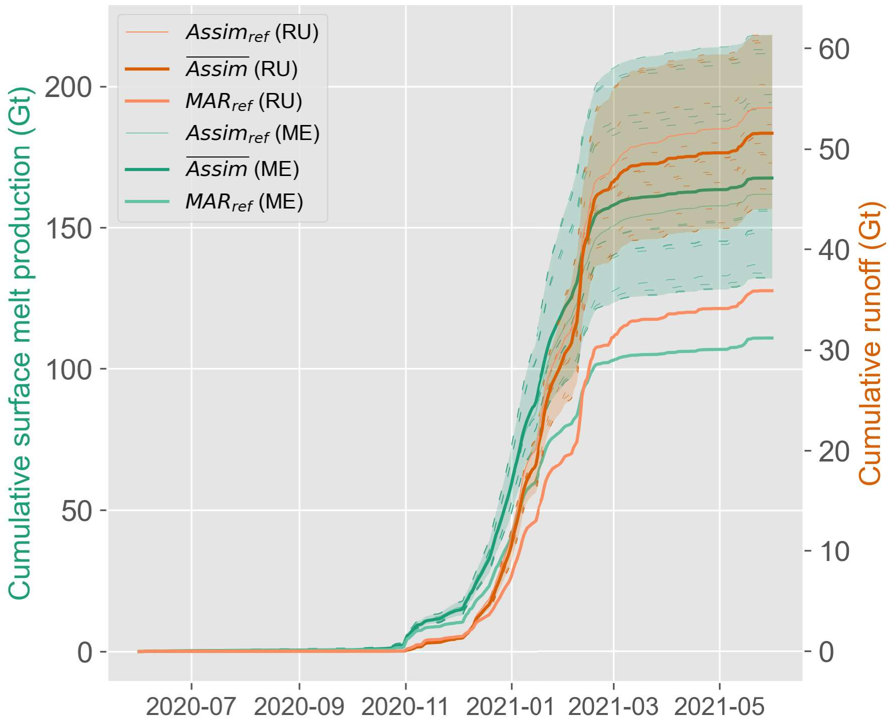

Figure S 2. Comparison between the cumulative surface meltwater production (Gt) in green and the cumulative runoff (Gt) in orange over the whole MAR domain (excluding ocean areas) for the 2020-2021 melt season as modeled by MAR without assimilation and with data assimilation. Shaded areas represent the range of the assimilations. While the increase in Gt is larger for meltwater production, the relative increase is similar for meltwater production and runoff.

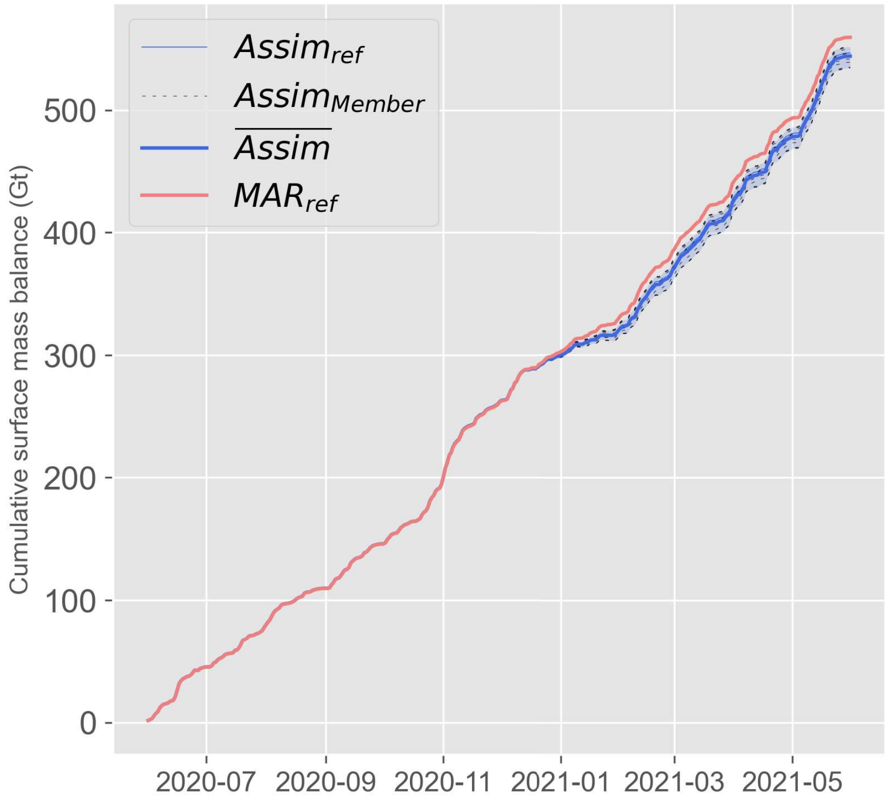

Figure S 3. Cumulative surface mass balance (Gt) over the entire MAR domain (excluding ocean areas) for the 2020-2021 melt season as modeled by MAR without assimilation (MAR_{ref} in red), with data assimilation ($Assim_{member}$ in dashed lines), and their averaged value ($\overline{Assim}$ in blue). Shaded areas represent the range of the assimilations. Despite the increase in surface melt production, the surface mass balance does not significantly decrease.

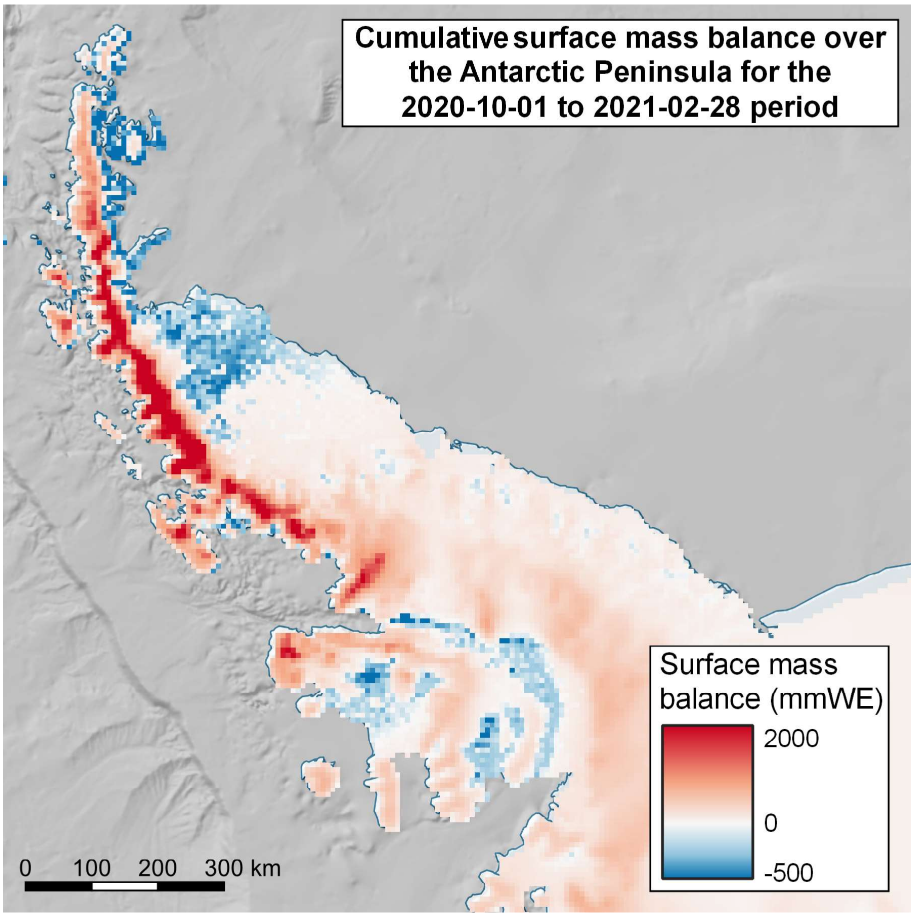

Figure S 4. Cumulative SMB (mmWE) from 2020-10-01 to 2021-02-28 over the AP as modeled by $Assim_{ref}$. Larsen C is outlined in purple, George VI in green, and Wilkins in red. The southern ice shelves and the northernmost coastlines are experiencing a negative SMB in contrast with the rest of the AP. Larsen C is divided in two regimes. Its northern part is experiencing a negative SMB while the southern part is positive.

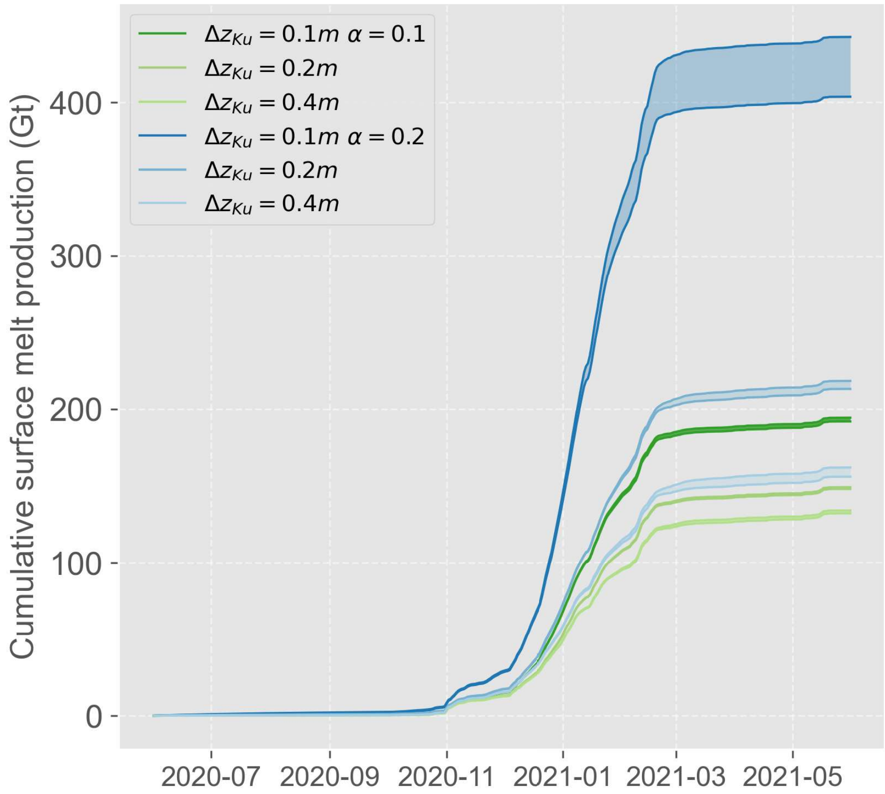

Figure S 5. Cumulative surface melt production (Gt) over the entire MAR domain for the 2020-2021 melt season as modeled by the different assimilation experiments. The assimilations are grouped by their α and Ku-band Δ_z thresholds. Shaded areas represent the range of the assimilation of the groups. Groups of assimilations with Ku-band $\Delta_z = 0.1$ m produce more melt than the group of assimilations with the sameα but different Δ_z.

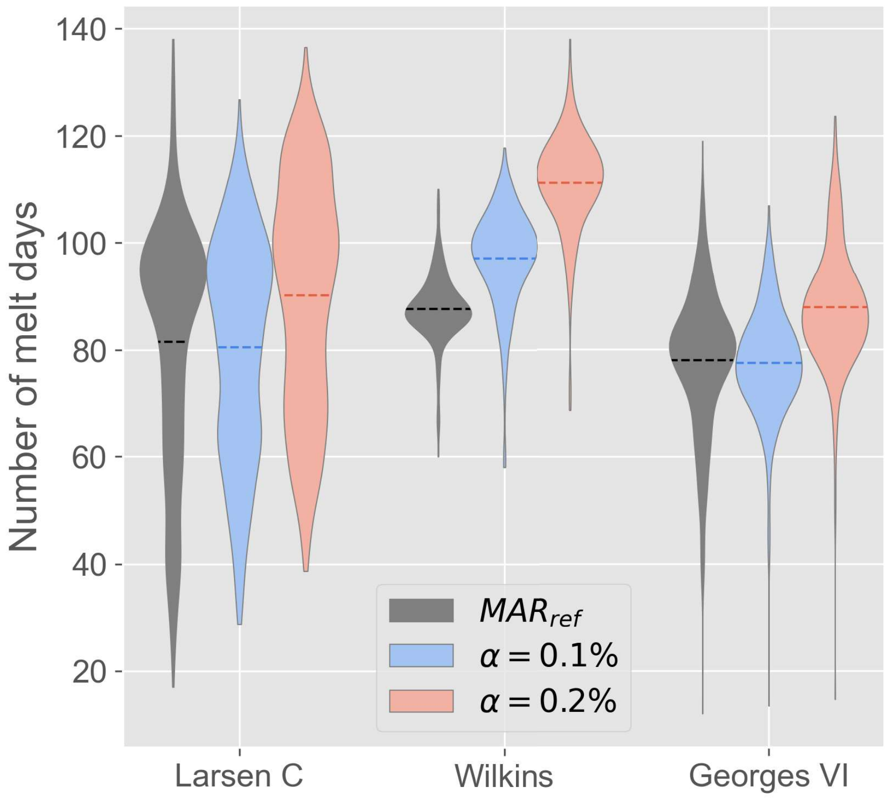

Figure S 6. Distribution of the number of melt days for the 2020-2021 melt season as modeled by MAR_{ref} and the assimilations grouped by the specified α threshold values for the three studied ice shelves. Dashed lines represent the mean value of the distribution. On the three ice shelves, assimilations with α = 0.2 $\%$ produce more melt days than MAR_{ref} and the other assimilations. Assimilations with α = 0.2 $\%$ exhibit an increase in the mean number of melt days relative to MAR_{ref} over the Larsen C ice shelf of 15 days, 8 days on the Wilkins ice shelf, and 9 days on the Georges VI ice shelf.

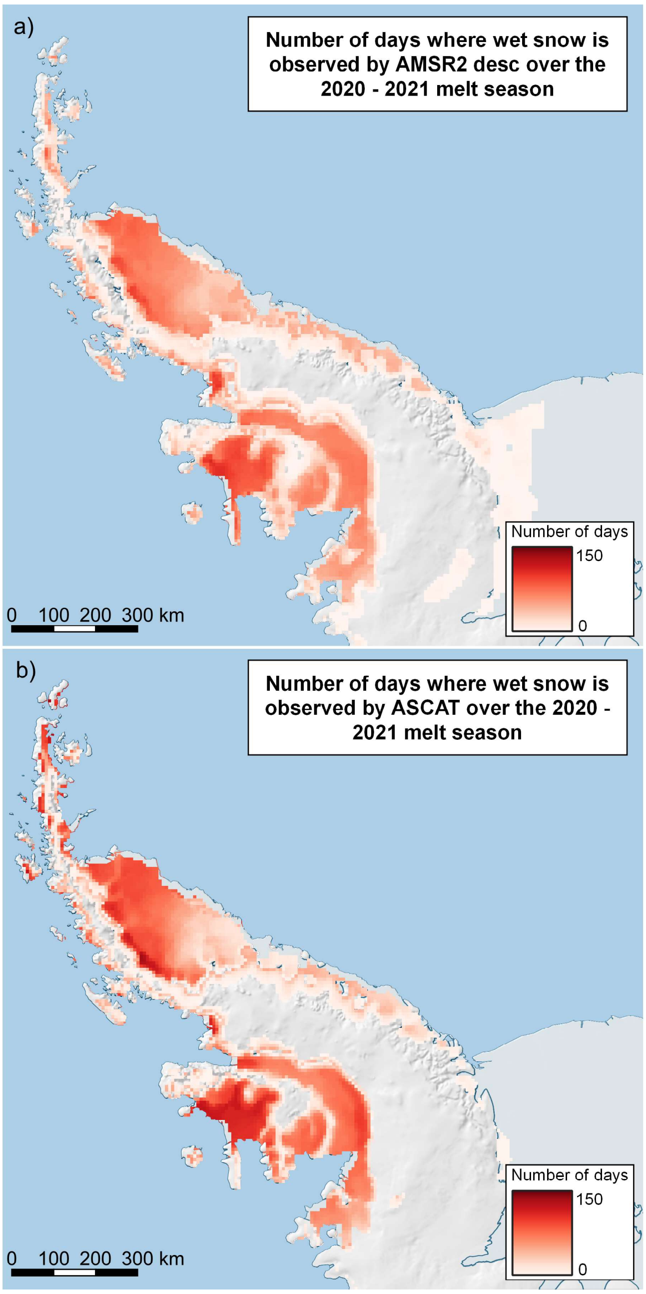

Figure S 7. (a) Number of days with wet snow observed by AMSR2 ascending on the AP for the 2020-2021 melt season. (b) Number of days with wet snow observed by ASCAT on the Antarctic Peninsula for the 2020-2021 melt season. ASCAT observes more wet snow than AMSR2 over the ice shelves but less melt on average at higher altitudes and in areas of steep terrain.

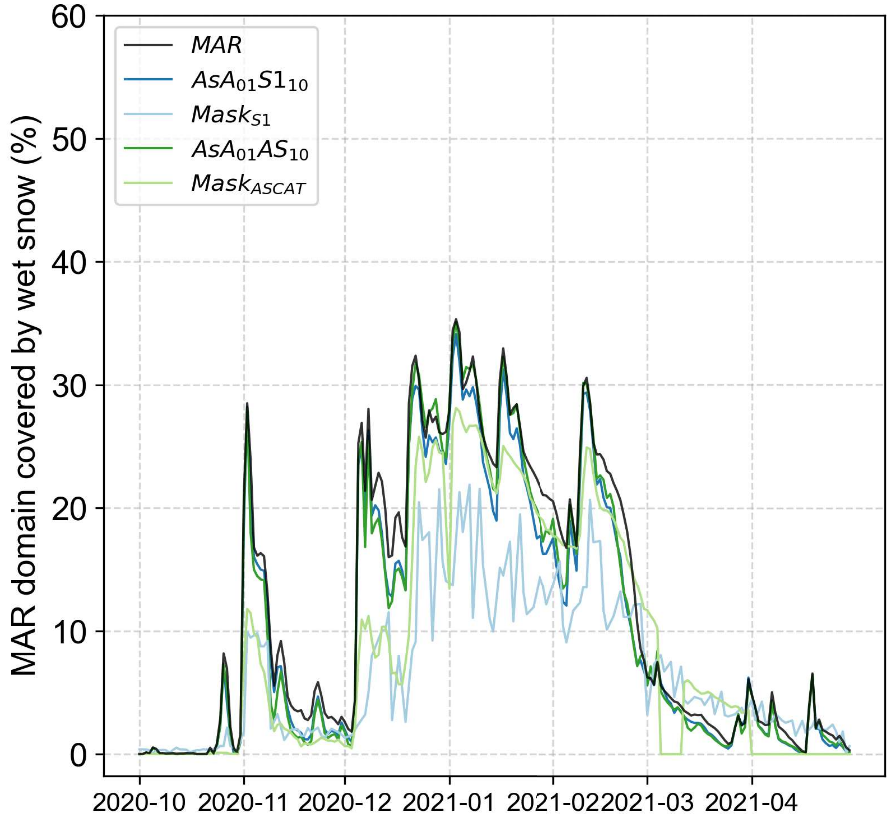

Figure S 8. Evolution of the wet-snow extent over the entire MAR domain (including grounded ice and ice shelves) during the 2020-2021 melt season as modeled by MAR_{ref}, the assimilation of S1 alone ($AsA_{01}S1_{10}$), the assimilation of ASCAT alone ($AsA_{01}AS_{10}$), and the wet-snow masks from S1, and ASCAT. The S1 wet-snow mask has a lower extent as the AP is not covered entirely every day by S1 images.

Table S 1. Difference (in $\mathrm{Gt\,yr^{-1}}$ and $\%$) in surface meltwater production (ME), runoff (RU), refreezing (RZ), surface mass balance (SMB), snowpack liquid water content (LWC), and snowpack density (ρ) between MAR_{ref} and the mean value of the assimilations ($\overline{Assim}$) for 2020-2021 for the entire MAR spatial extent (including grounded ice and ice shelves). Variables are accumulated annually and over summer (November through April) except for snowpack density and the liquid water content which are averaged over the periods. LWC and ρ are the average within the first meter of the snowpack while the other variables are the total for the entire snowpack.

	Annual					Summer				
	MAR_{ref}	$Assim_{ref}$	$\overline{Assim}$	Range	% Difference	MAR_{ref}	$Assim_{ref}$	$\overline{Assim}$	Range	% Difference
ME ($\mathrm{Gt\,yr^{-1}}$)	111	149	168	132 - 218	51.1	109	147	165	130 - 215	51.1
RU ($\mathrm{Gt\,yr^{-1}}$)	36	49	52	44 - 61	43.7	36	49	51	44 - 61	43.8
RZ ($\mathrm{Gt\,yr^{-1}}$)	99	124	140	112 - 182	42.4	94	120	134	108 - 173	42.8
SMB ($\mathrm{Gt\,yr^{-1}}$)	559	546	544	534 - 551	-2.7	365	352	349	340 - 357	-4.2
LWC_{1m} ($\mathrm{g\,kg^{-1}}$)	13	10	11	8 - 15	-19.5	23	17	18	14 - 25	-19.7
ρ_{1m} ($\mathrm{kg\,m^{-3}}$)	413	427	428	425 - 431	3.6	424	440	441	437 - 446	4.0

Table S 2. Difference (in $\mathrm{Gt\,yr^{-1}}$ and %) in surface melt production (ME), runoff (RU), refreezing (RZ), surface mass balance (SMB), snowpack liquid water content (LWC), and snowpack density (ρ) between MAR_{ref} and the mean value of the assimilations ($\overline{Assim}$) over the three highlighted ice shelves in 2020-2021 using the regions shown in Fig. 1. Variables are accumulated annually and over summer (November through April) except for snowpack density and the liquid water content, which are averages over the specified periods. LWC and ρ are given as the average of the snowpack first meter while the other variables are totals for the entire modeled snowpack.

	Annual					Summer				
Larsen C	MAR_{ref}	$Assim_{ref}$	$\overline{Assim}$	Range	Difference (%)	MAR_{ref}	$Assim_{ref}$	$\overline{Assim}$	Range	Difference (%)
ME ($\mathrm{Gt\,yr^{-1}}$)	30	41	47	35 - 63	54.8	30	40	46	34 - 62	55.2
RU ($\mathrm{Gt\,yr^{-1}}$)	6	9	11	8 - 13	88.6	6	9	11	8 - 13	88.6
RZ ($\mathrm{Gt\,yr^{-1}}$)	26	33	37	26 - 54	43.6	25	32	36	26 - 52	42.4
SMB ($\mathrm{Gt\,yr^{-1}}$)	20	16	14	12 - 17	-26.3	11	8	6	4 - 8	-45.9
$LWC_{1\mathrm{m}}$ ($\mathrm{g\,kg^{-1}}$)	3.0	2.6	2.7	2.1 - 3.6	-12.3	5.2	4.4	4.6	3.5 - 6.1	-12.2
$\rho_{1\mathrm{m}}$ ($\mathrm{kg\,m^{-3}}$)	531	569	574	562 - 589	8.1	574	610	615	604 - 630	7.1
Wilkins										
ME ($\mathrm{Gt\,yr^{-1}}$)	6	9	10	7 - 15	75.1	6	9	10	7 - 15	76.2
RU ($\mathrm{Gt\,yr^{-1}}$)	1	4	4	2 - 7	186.9	1	4	4	2 - 7	186.9
RZ ($\mathrm{Gt\,yr^{-1}}$)	5	6	7	6 - 10	31.4	5	6	7	6 - 10	35.8
SMB ($\mathrm{Gt\,yr^{-1}}$)	6	4	3	0 - 5	-46.6	3	1	0	-2 - 2	-91.8
$LWC_{1\mathrm{m}}$ ($\mathrm{g\,kg^{-1}}$)	0.9	0.8	0.8	0.7 - 0.9	-17.1	1.6	1.3	1.3	1.2 - 1.5	-17.2
$\rho_{1\mathrm{m}}$ ($\mathrm{kg\,m^{-3}}$)	537	590	589	573 - 605	9.7	571	637	640	621 - 657	12.0
Georges VI										
ME ($\mathrm{Gt\,yr^{-1}}$)	10	13	15	11 - 21	51.3	10	13	15	11 - 20	51.0
RU ($\mathrm{Gt\,yr^{-1}}$)	2	3	3	3 - 6	86.9	2	3	3	3 - 6	86.9
RZ ($\mathrm{Gt\,yr^{-1}}$)	10	11	13	10 - 18	38.2	9	11	13	10 - 17	36.4
SMB ($\mathrm{Gt\,yr^{-1}}$)	11	10	10	7 - 10	-15.0	6	4	4	2 - 5	-29.8
$LWC_{1\mathrm{m}}$ ($\mathrm{g\,kg^{-1}}$)	1.5	1.3	1.3	1.1 - 1.6	-9.8	2.6	2.2	2.3	2.0 - 2.7	-9.8
$\rho_{1\mathrm{m}}$ ($\mathrm{kg\,m^{-3}}$)	529	563	556	553 - 563	5.2	566	602	596	591 - 602	5.2

Table S 3. The melt season length (first to last melt day) and number of melt days modeled for MAR_{ref} and the average for assimilation simulations grouped by α-value over the three highlighted ice shelves in Fig. 1 for 2020-2021. A melt day over an ice shelf is a day where more than 10 $\%$ of the ice shelf is experiencing melt.

Larsen C	Melt season length (days)	Number of melt days modeled
MAR_{ref}	209	113
α = 0.1 $\%$	208	116
α = 0.2 $\%$	209	127
Wilkins	**Melt season length (days)**	**Number of melt days modeled**
MAR_{ref}	200	99
α = 0.1 $\%$	201	119
α = 0.2 $\%$	207	132
GeorgesVI	**Melt season length (days)**	**Number of melt days modeled**
MAR_{ref}	200	98
α = 0.1 $\%$	200	95
α = 0.2 $\%$	200	113