Supplement to: A glacial systems model configured for large ensemble analysis of Antarctic deglaciation

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1. Supplementary figures and tables

Figures include: parameter sensitivity plots for the basal sliding coefficient and tidewater calving parametrization, temperature and precipitation fields used for the climate forcing, glacial indices used in the model, and some additional ensemble parameter sensitivities. Tables present the data used to tune and validate the SSM model.

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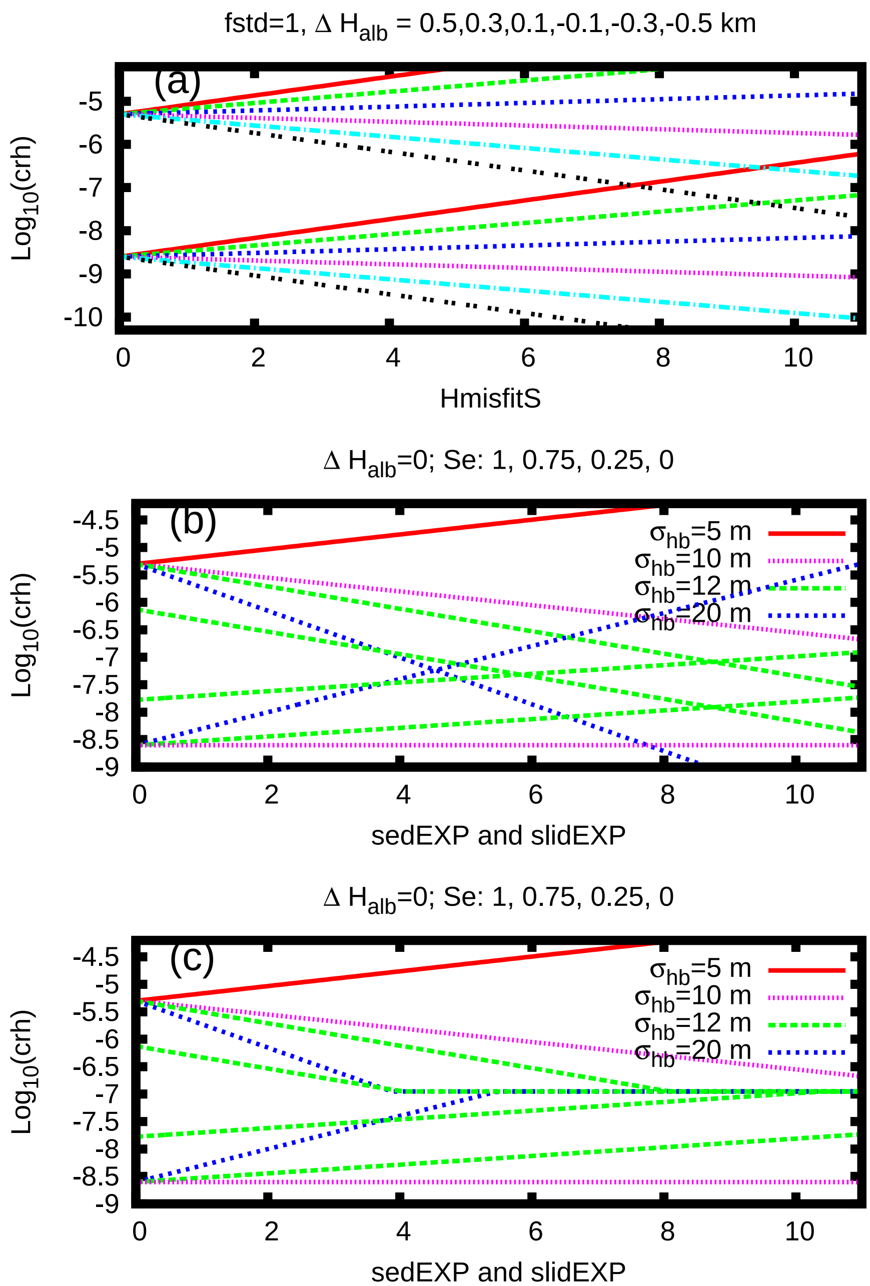

Figure 1: Parametric sensitivity of basal sliding coefficient to: a) **HmisfitS**, and for b) and c) to the sediment presence variable (Se), **sedEXP** and **slidEXP**. Plot (b) shows the case with inactive Γ_{bnd} as implemented for the results presented. Plot (c) is with $\Gamma_{bnd} = (\mathbf{slidsedC}/\mathbf{slidhardC})^{(0.5-Se)}$ which sets crh to the geometric mean of **slidsedC** and **slidhardC**. The **slidsedC** and **slidhardC** values for baseline run nn2679 are used. The descending values of crh for **slidEXP**$= 0$ correspond to the descending values of Se.

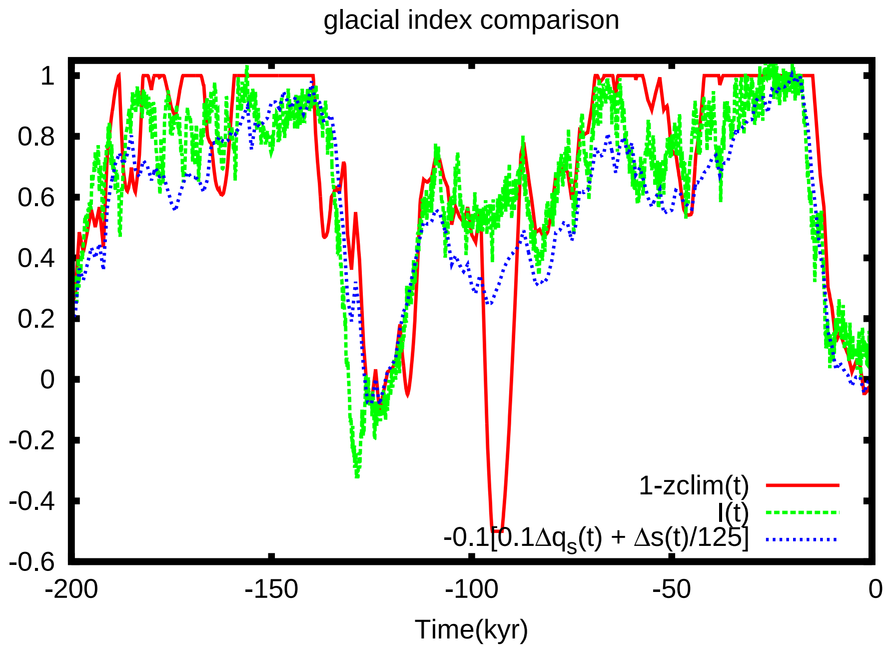

Figure 2: Comparison of three glacial climate indices used in the parametrizations. $zclim(t)$ is an SST interglacial index used for thin ice calving (eq. 24 in main text) and ice-shelf front melt (eq. 28) . $I(t)$ is the glacial index for temperature forcing Tf_3 (eq. 9) and precipitation forcing Pf_3 (eq. 16). The remaining index is $-0.1\times$ the time dependence for Tf_1 (eq. 5).

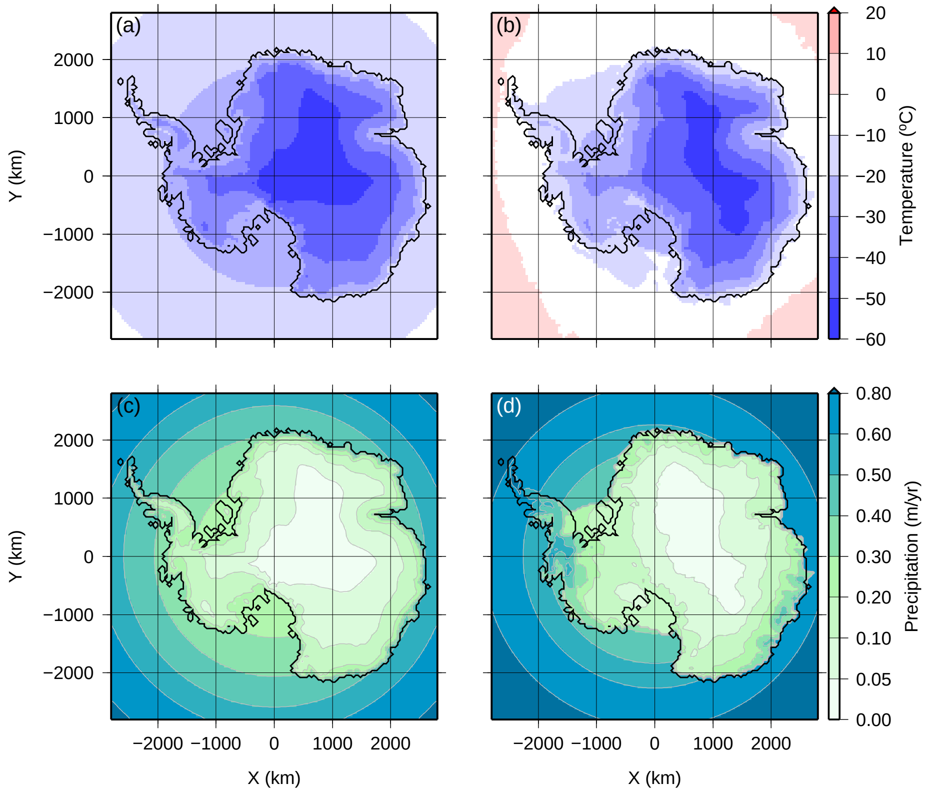

Figure 3: Present day climate forcing fields for (a) $Tf1$, (b) $Tf2$, (c) $Pf1$, and (d) $Pf2$.

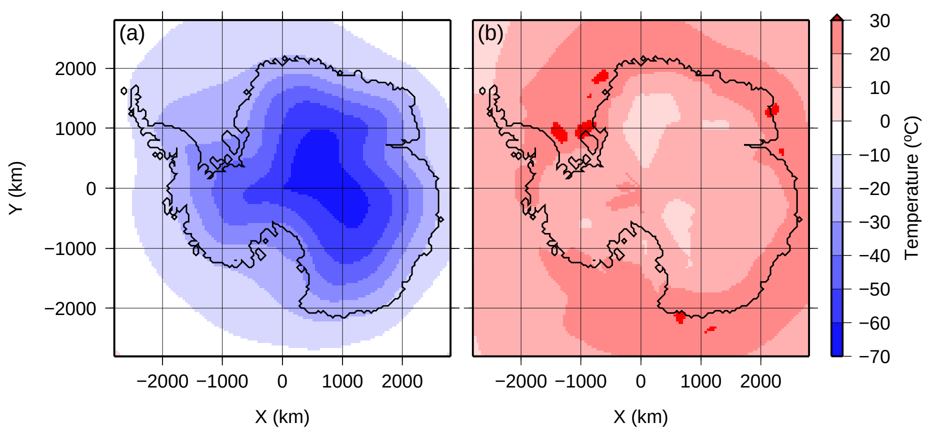

Figure 4: LGM temperature forcing fields, (a) shows $Tave_{LGM}$ and (b) the associated EOF, $Teof_{LGM}$.

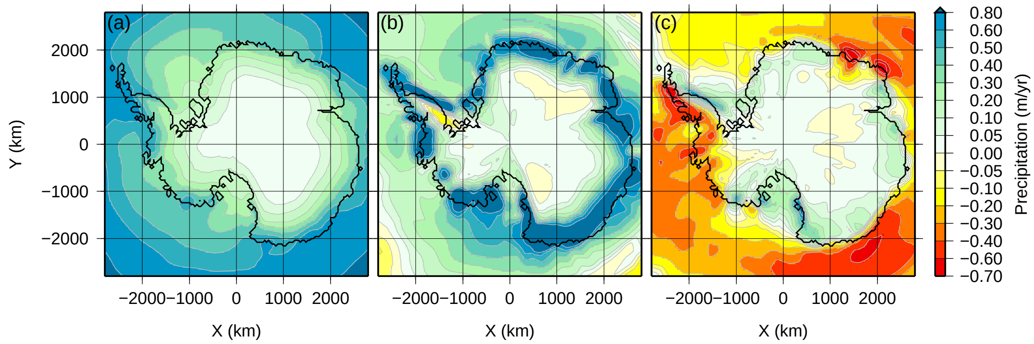

Figure 5: LGM precipitation forcing fields, (a) shows $Pave_{LGM}$, (b) shows the associated EOF $Peof1_{LGM}$, and (c) $Peof2_{LGM}$.

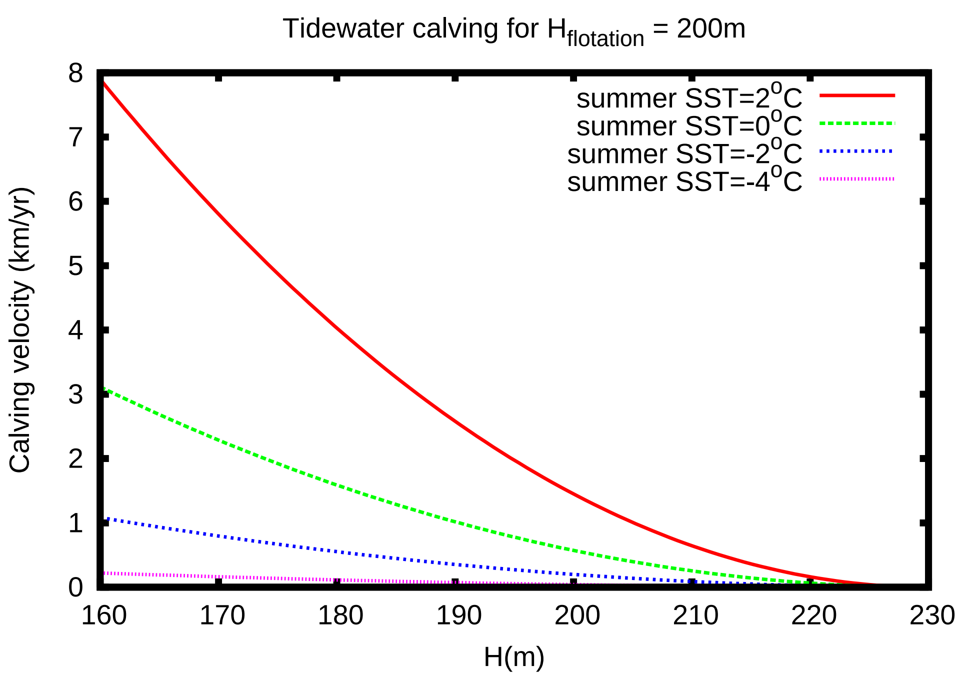

Figure 6: Tidewater calving parametrization response to ice thickness (H) and summer sea surface temperature. The response shown is with the baseline nn2679 **calvmaxV** calving velocity scale ensemble parameter value. For the given flotation thickness, calving velocity values are constant beyond the plotted limits for H.

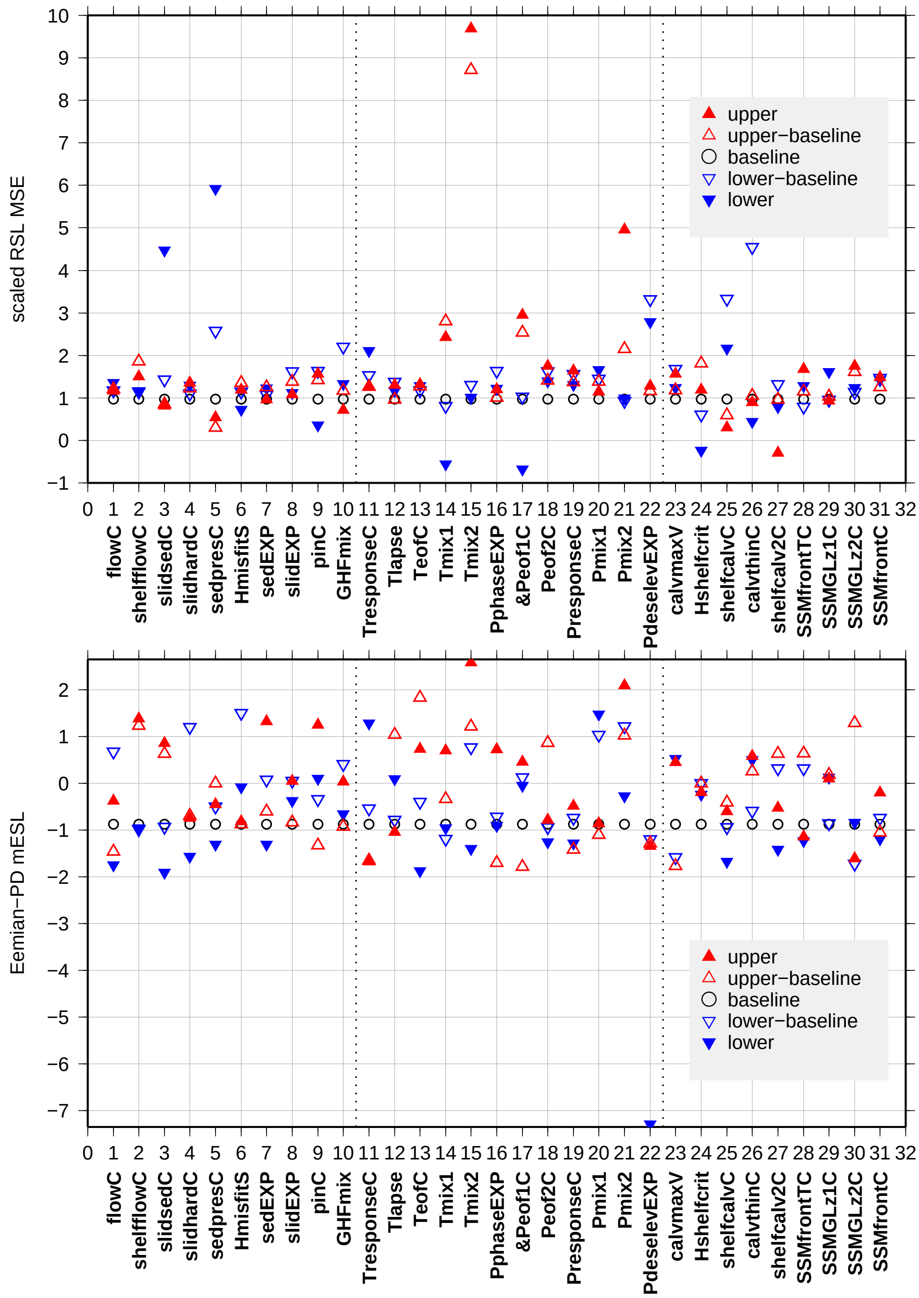

Figure 7: Sensitivity results for scaled (and weighted) RSL mean squared error (MSE, upper) and 120 ka - present-day ice volume (mESL, lower). Refer to Briggs and Tarasov (2013) for details on data-point weighting.

Table 1: Table of thickness (H) and melt rates for the AMY ice shelf. The data was extracted from Fig. 4 and Fig. 6 in Wen et al. (2007).

(a)

Distance from grounding line (km)	H (m)	Melt rate ($\mathrm{m\ yr^{-1}}$)
0	1600	-1
25	1540	-4.5
50	1400	-4.5
75	1220	-2.5
100	1200	-0.65
125	1150	-0.45
150	1020	-0.7
170	1010	-0.1
185	980	-0.5
210	930	-1.25
230	900	-0.75
260	860	-0.4
280	750	-0.5
310	700	0.15

(b)

Distance from grounding line (km)	H (m)	Melt rate ($\mathrm{m\ yr^{-1}}$)
325	660	0.25
350	650	-0.1
375	640	0.0
400	590	0.25
425	575	0.25
450	530	0.25
475	510	0.2
510	490	0.0
550	480	0.25
590	450	0.05
640	450	0.0
680	420	-0.05
720	400	-1.6
750	250	-6

Table 2: Table of thickness (H) and melt rates for the RON ice shelf. The data was extracted from Fig 9. and Fig. 10 in Jenkins and Doake (1991).

(a)

Distance from grounding line (km)	H (m)	Melt rate ($\mathrm{m\,yr^{-1}}$)
0	2300	-
20	-	-22.5
40	2000	-
60	-	-11
75	1640	-
90	-	-6.5
110	1300	-
130	-	-3
140	1040	-
165	-	-2.5
180	920	-
200	-	-1.5
220	840	-
235	-	-1.5
255	760	-
265	-	-1
280	720	-
300	-	-0
315	700	-

(b)

Distance from grounding line (km)	H (m)	Melt rate ($\mathrm{m\,yr^{-1}}$)
345	640	-
335	-	0.5
360	-	1
375	600	-
390	-	1.5
410	520	-
430	480	-
420	-	0.5
430	480	-
450	-	0
470	440	-
485	-	1.5
495	380	-
505	-	1.5
510	360	-
520	-	1.5
525	300	-
530	-	-2.0
540	280	-

Table 3: SSM observations as extracted from the literature.

Shelf	Reference	Type of data	Value	Method
AMY				
	Jacobs et al. (1996)	Average rate (all Jacobs et al. (1996) estimates $\pm$ 50%)	0.65 $\mathrm{m\ yr^{-1}}$	Measurement
	Jacobs et al. (1996)	Net melt	23 $\mathrm{Gt\ yr^{-1}}$	”
	Williams et al. (2001)	Total melt	5.8 $\mathrm{Gt\ yr^{-1}}$ and 18.0 $\mathrm{Gt\ yr^{-1}}$	Model
	Rignot and Jacobs (2002)	at grounding line	31.5 $\mathrm{m\ yr^{-1}}$	InSAR
	Wen et al. (2007)	Mean melt near the southern grounding line	23.0$\pm$ 3.5 $\mathrm{m\ yr^{-1}}$	In-situ and remote sensing
	Wen et al. (2007)	Freezing rates	-0.5 $\pm$ 0.1 to -1.5 $\pm$ 0.2 $\mathrm{m\ yr^{-1}}$	”
	Wen et al. (2007)	Total basal melting	50.3 $\pm$ 7.5 $\mathrm{Gt\ yr^{-1}}$	”
	Wen et al. (2007)	Total refreezing	-7.0 $\pm$ 1.1 $\mathrm{Gt\ yr^{-1}}$	”
	Wen et al. (2007)	Net basal melting	43.3$\pm$ 6.5 $\mathrm{Gt\ yr^{-1}}$	
	Yu et al. (2010)	Net basal melting	27.0 $\pm$ 7.0 $\mathrm{Gt\ yr^{-1}}$	In-situ and remote sensing
ROS				”
	Jacobs et al. (1996)	Average rate (excluding 100 km of shelf front)	0.22 $\mathrm{m\ yr^{-1}}$	Measurement
	Jacobs et al. (1996)	Net melt (excluding 100 km of shelf front)	81 $\mathrm{Gt\ yr^{-1}}$	”

Table 3: SSM observations continued.

Holland et al. (2003)	Estimated from Fig 10, max melt at GL	0.12 $\mathrm{m\ yr^{-1}}$	Model
Holland et al. (2003)	Estimated from Fig 10, average freeze cm	-0.02 $\mathrm{m\ yr^{-1}}$	”
Loose et al. (2009)	average basal melt rate of	33-50 $\mathrm{km^3/a}$	Noble gases, stable isotopes, and CFC transient tracers
Reddy et al. (2010)	average basal melt rates of (including a seasonal signal)	0.1 $\mathrm{m\ yr^{-1}}$	CFC tracers
Horgan et al. (2011)	Melt law for shelf front (40 km by 760 km)	16 $\mathrm{km^3/a}$	Remote sensing
	within the front km	2.8 $\pm$ 1.0 $\mathrm{m\ yr^{-1}}$	”

Table 3: SSM observations continued. Joughin and Padman (2003) employed two methods for the RON-FIL system, yielding two different net melt totals. The second method also enabled discrimination between RON and FIL. Both methods are quoted here. The values for grounding line melt, freeze on, and front melt are taken from Joughin and Padman (2003) Fig. 2

FIL-RON

Jacobs et al. (1996)	Average rate (excluding 100 of shelf front)	0.55 $\mathrm{m\ yr^{-1}}$	Measurement
Jacobs et al. (1996)	Net melt (excluding 100 of shelf front)	202 $\mathrm{Gt\ yr^{-1}}$	”
Grosfeld et al. (1998)	Net melt for FIL	0.35 $\mathrm{m\ yr^{-1}}$	Model
Rignot and Jacobs (2002)	at grounding line	2-14 $\mathrm{m\ yr^{-1}}$	InSAR

Table 3: SSM observations continued.

	Joughin and Padman (2003)	Total net melt rate for FIL-RON (Method 1)	83.4 $\pm$ 24.8 $\mathrm{Gt\ yr^{-1}}$	In situ and remote sensing
	Joughin and Padman (2003)	Total net melt rate for FIL-RON (Method 2)	78.7 $\mathrm{Gt\ yr^{-1}}$	In situ and remote sensing
	Joughin and Padman (2003)	RON grounding area melt	50.4 $\mathrm{Gt\ yr^{-1}}$	”
	Joughin and Padman (2003)	RON freeze-on (-55.6+(-1.1))	-56.7 $\mathrm{Gt\ yr^{-1}}$	”
	Joughin and Padman (2003)	RON front melt	55.9 $\mathrm{Gt\ yr^{-1}}$	”
	Joughin and Padman (2003)	FIL melt	20.6 $\mathrm{Gt\ yr^{-1}}$	”
	Joughin and Padman (2003)	FIL freeze-on	-16.1 $\mathrm{Gt\ yr^{-1}}$	”
	Joughin and Padman (2003)	Downstream of Foundation Ice Stream	24.8 $\mathrm{Gt\ yr^{-1}}$	”
Other shelves				
	Jacobs et al. (1996)	Total estimate - (AMY+ROS+FIL+RON)	450 $\mathrm{Gt\ yr^{-1}}$	Measurement

Table 4: Processed SSM observational data used for verification purposes.

Shelf	Melt type	Avg. melt rate (whole shelf) $\mathrm{m\,yr^{-1}}$	±	Mass loss (whole shelf) $\mathrm{Gt\,yr^{-1}}$	±	Notes	Reference
AMY	net melt	0.65	0.325	23.3	11.5		Jacobs et al. (1996)
	net melt			43.0	6.5		Wen et al. (2007)
	net melt	0.51	0.13	27.0	7.0		Yu et al. (2010)
	freeze on	-0.5 → -1.5		7.0	-1.1		Wen et al. (2007)
ROS	net melt	0.22	0.11	81	40.5		Jacobs et al. (1996)
	net melt			48.5	18.6		Loose et al. (2009)
	net melt	0.1					Reddy et al. (2010)
	grounding area	0.12				max	Holland et al. (2003)
	freeze-on	-0.02				ave	Holland et al. (2003)
	freeze-on	0 → -0.24				ave	Reddy et al. (2010)
	freeze-on	0 → -0.48				max	Reddy et al. (2010)
	shelf front	2.8	1	14.67		40 x 760 km	Horgan et al. (2011)
RON-FIL							
	net melt	0.55		202	101		Jacobs et al. (1996)
	net melt			83.4 [1]	24.8		Joughin and Padman (2003)
	net melt			78.7 [2]			Joughin and Padman (2003)
RON							
	net melt			49.6 [2,3]			Joughin and Padman (2003)
	grounding area			50.4 [2]			Joughin and Padman (2003)
	freeze on			-56.7 [2]			Joughin and Padman (2003)
	shelf front			55.9 [2]			Joughin and Padman (2003)
FIL							
	net melt	-0.35		*22.8*			Grosfeld et al. (1998)
	net melt			4.5 [2,4]			Joughin and Padman (2003)
	grounding area			20.6 [2]			Joughin and Padman (2003)
	freeze-on			-16.1 [2]			Joughin and Padman (2003)
OTHERS							
	net melt			450	225 [5]		Jacobs et al. (1996)

[1] Based on value computed from method 1 in Joughin and Padman (2003)

[2] Based on values computed from method 2, presented in Figure 2 in Joughin and Padman (2003)

[3] Summed from grounding area, freeze on, and shelf front values (See (Joughin and Padman, 2003))

[4] Summed from grounding area and freeze on values (See (Joughin and Padman, 2003))

[5] 50 % error reported for all the shelves (Jacobs et al., 1996) is repeated here.

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