

Supplement for manuscript **Increased future ice loss due to nested ice-climate feedbacks if Antarctic heatwaves intensify**

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References

Copernicus Climate Change Service: ERA5-Land post-processed daily statistics from 1950 to present, <https://doi.org/10.24381/cds.e9c9c792>, accessed: 15-09-2026, 2024.

Davison, B. J., Hogg, A. E., Gourmelen, N., Jakob, L., Wuite, J., Nagler, T., Greene, C. A., Andreasen, J., and Engdahl, M. E.: Annual mass budget of Antarctic ice shelves from 1997 to 2021, *Science Advances*, 9, eadi0186, 2023.

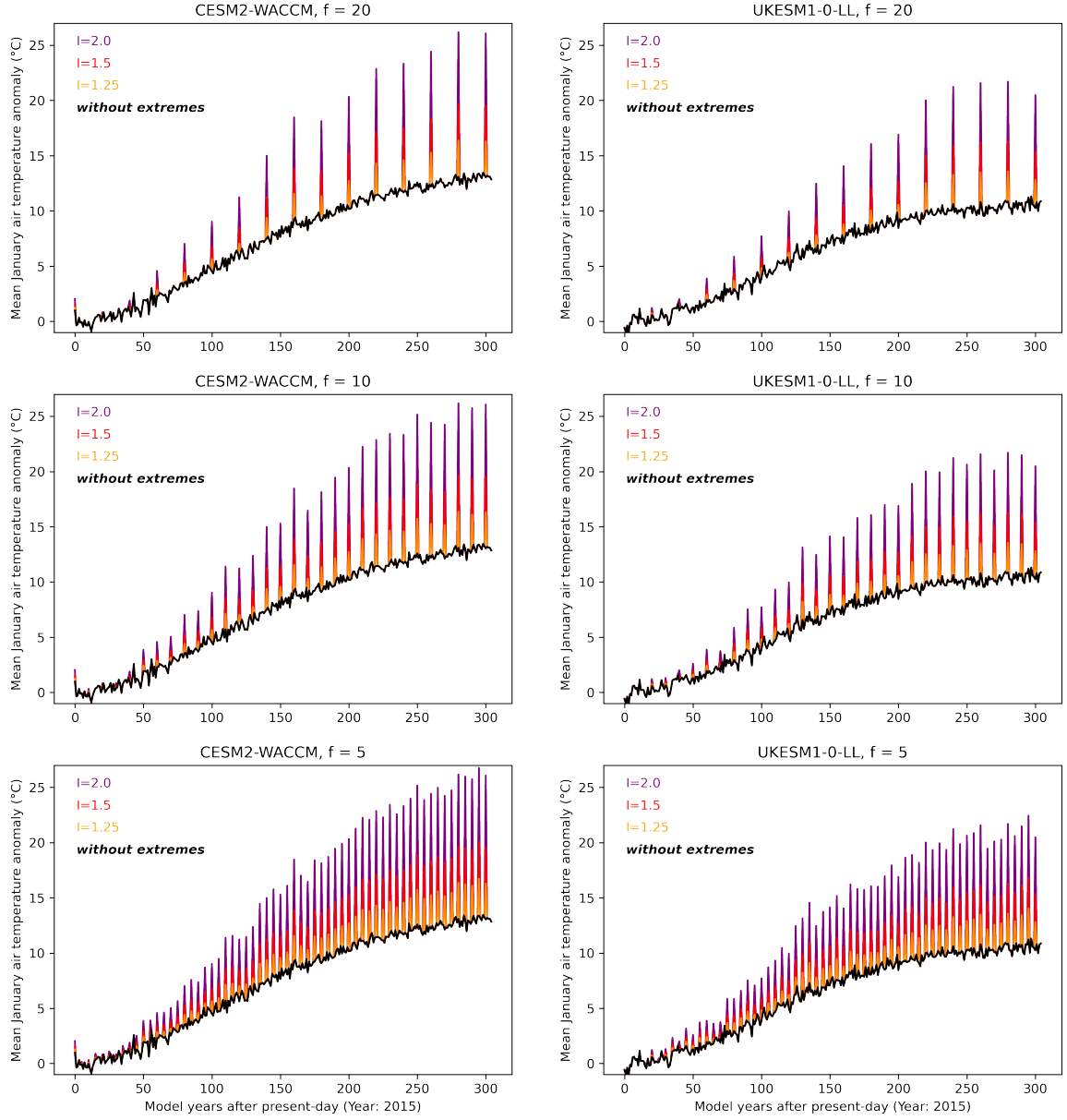


Figure S1. Strength of temperature anomalies. The heatwaves amplify the January warming anomalies by a factor of $I=1.25, 1.5, 2.0$ every $f=5, 10$ or 20 years, for the different forcing scenarios.

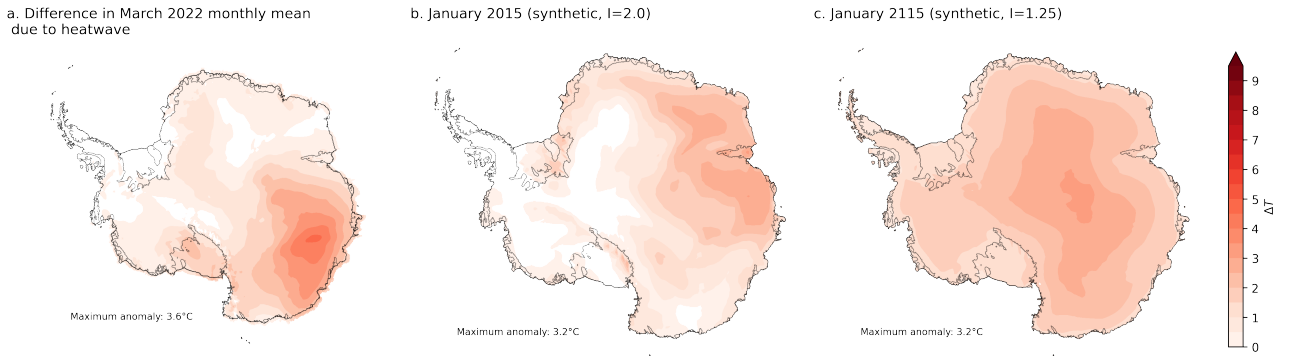


Figure S2. Comparison of heatwave strengths to observed heatwave in 2022. Shown are the deviations from the monthly mean temperature due to the (imposed) heatwave for an observed heatwave (a. using daily ERA5-Land data, obtained from the Copernicus Climate Change Service (2024)) and two synthetic heatwaves for different intensity $I=1.5$ and $I=2.0$.

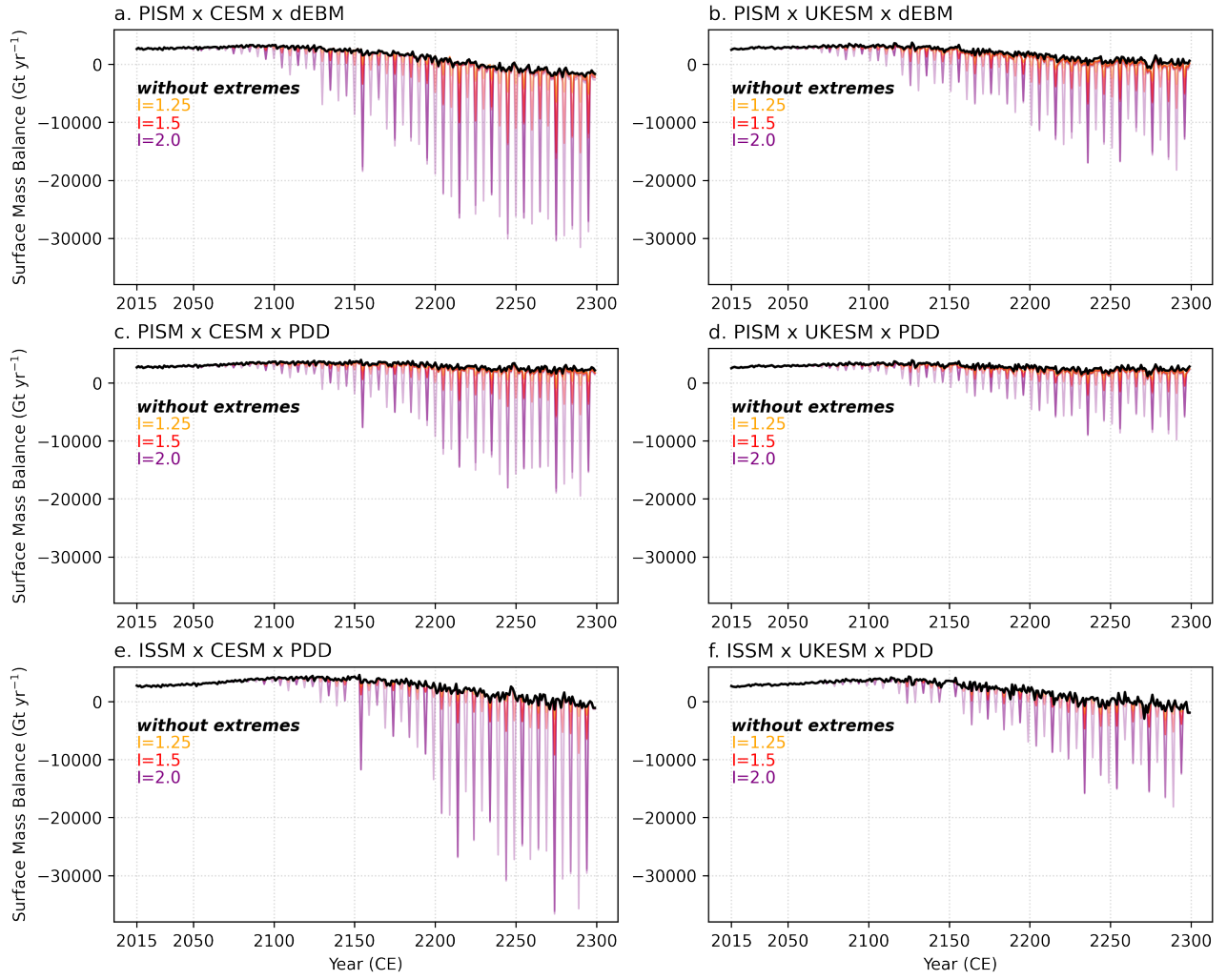
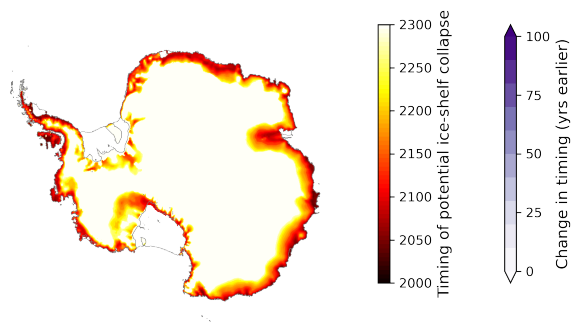
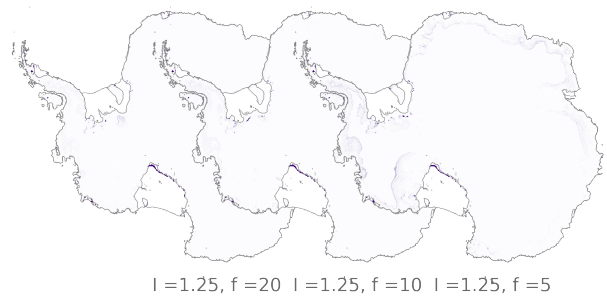


Figure S3. Simulated surface mass balance for the different PISM (a.-d.) and ISSM (e., f.) model configurations.

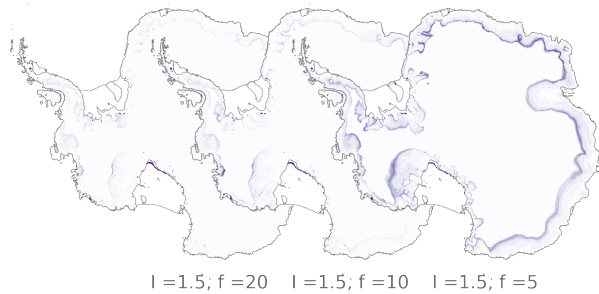
a. Timing of ice-shelf collapse (BSL)



b. Difference with extremes of intensity: $I = 1.25$



c. Difference with extremes of intensity: $I = 1.5$



d. Difference with extremes of intensity: $I = 2.0$

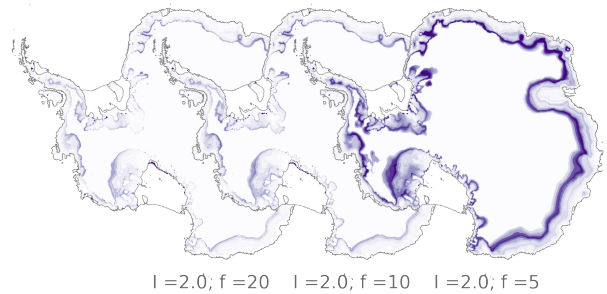


Figure S4. Change in timing of ice-shelf collapse due to extremes (if coupled/prescribed), simulated with PISM x dEBM x CESM x HYDRO-FRACT.

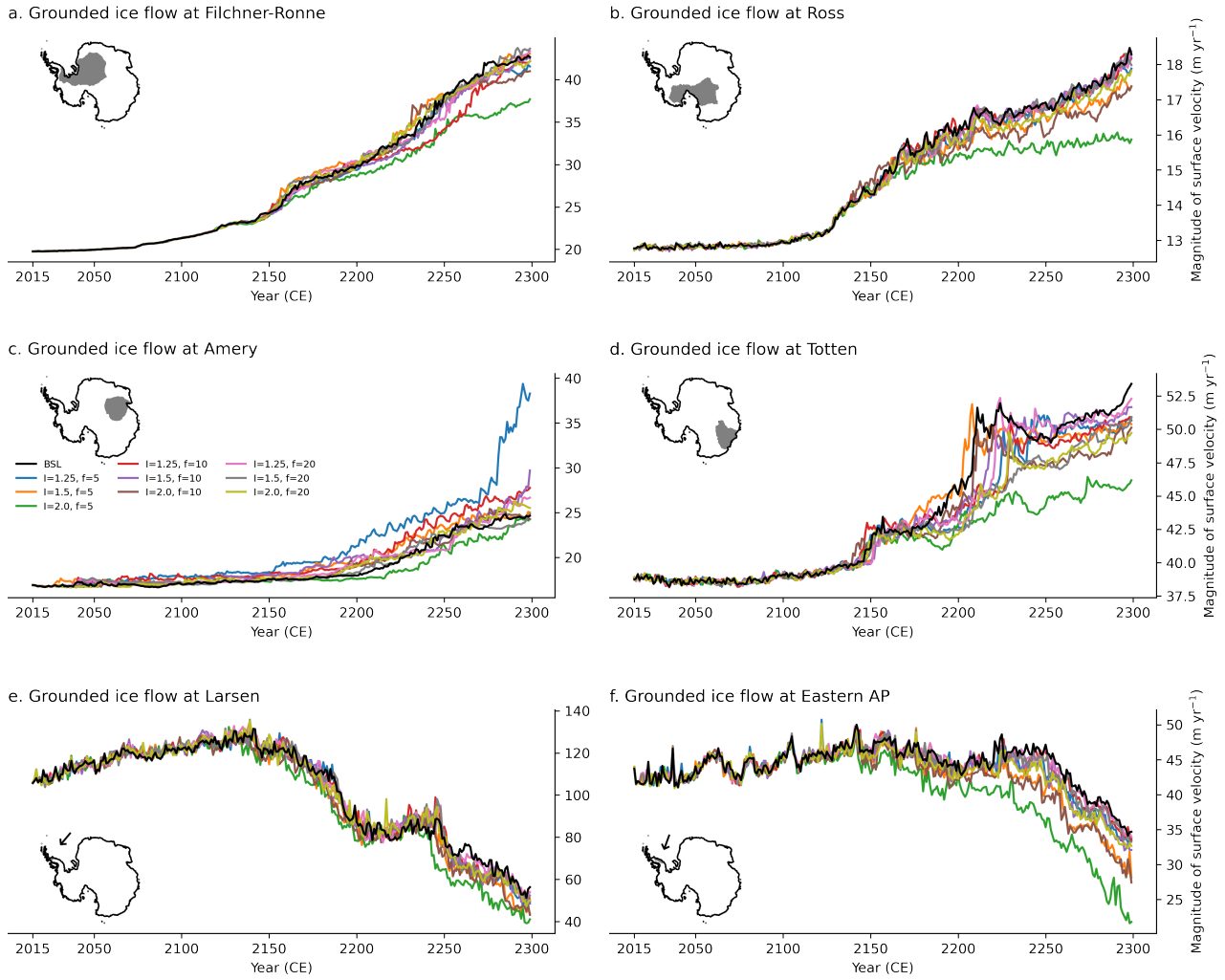


Figure S5. Grounded ice flow speed for selected Antarctic regions. Note the different scales on the y-axes.

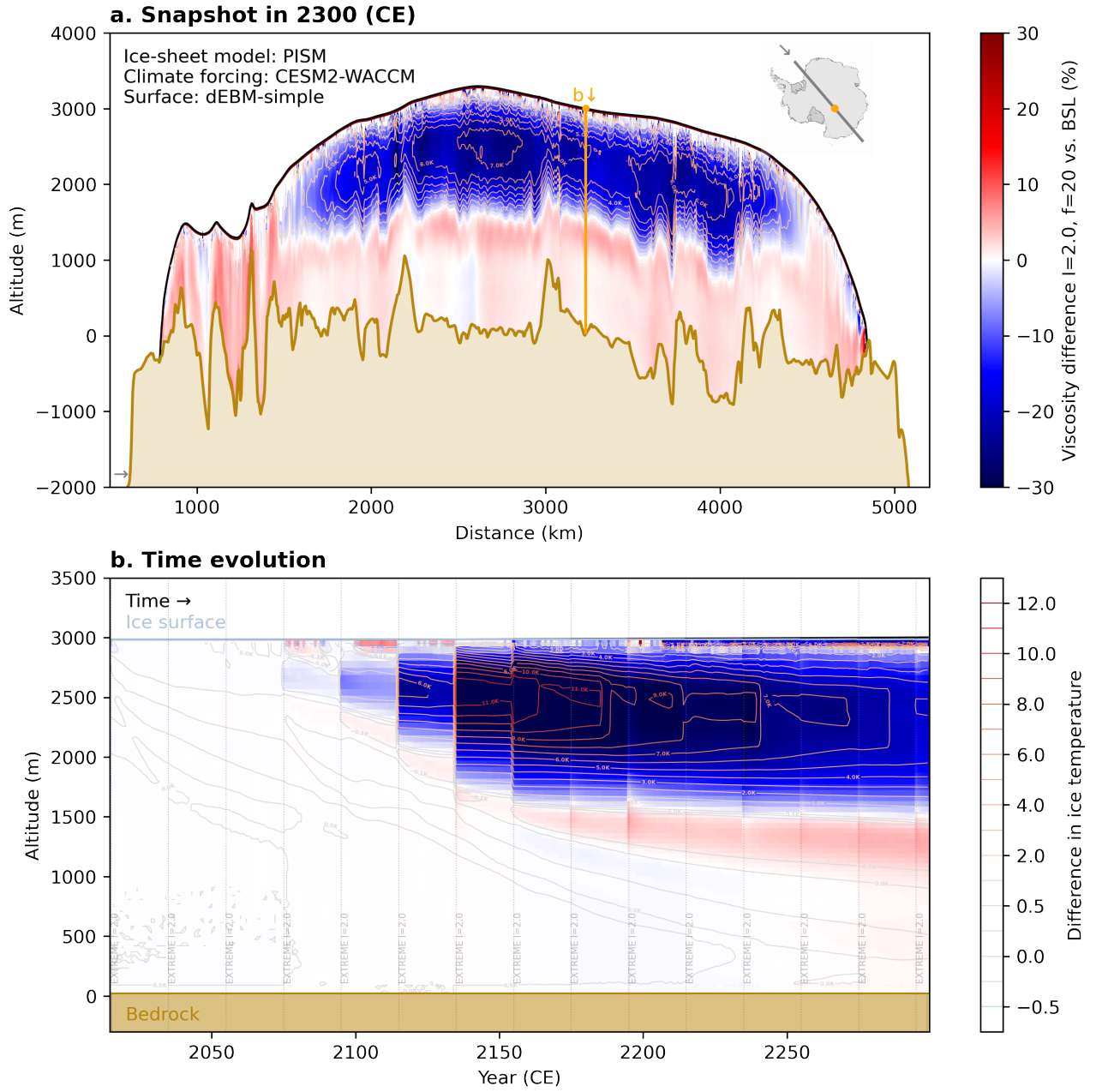


Figure S6. Viscosity differences due to extremes. Example change by 2300 (a.) and over time at one location on the ice sheet (b.) in viscosity and ice temperature for extremes scenario $I=2.0$, $f=20$ compared to the baseline evolution with PISM x dEBM x CESM.

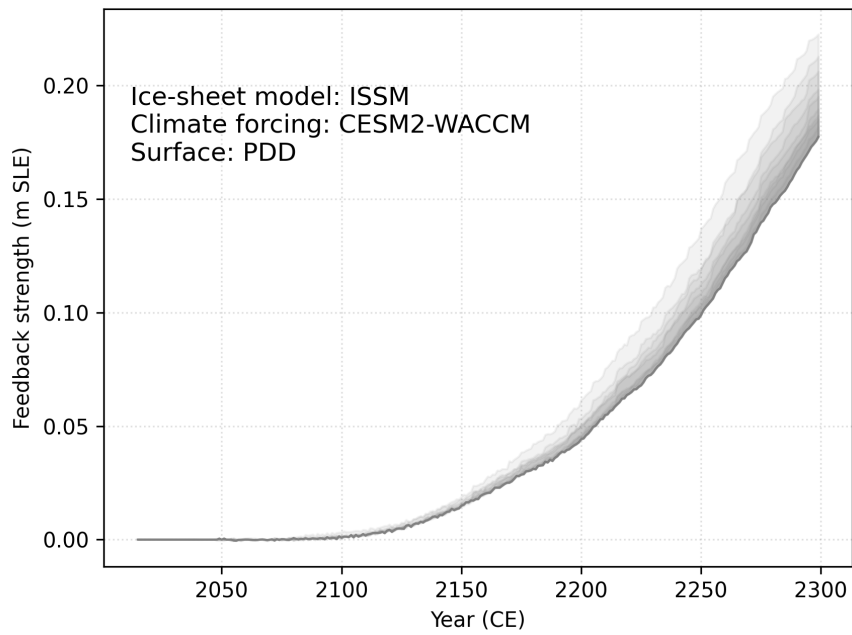


Figure S7. Strength of melt-elevation feedback from ISSM model simulations.

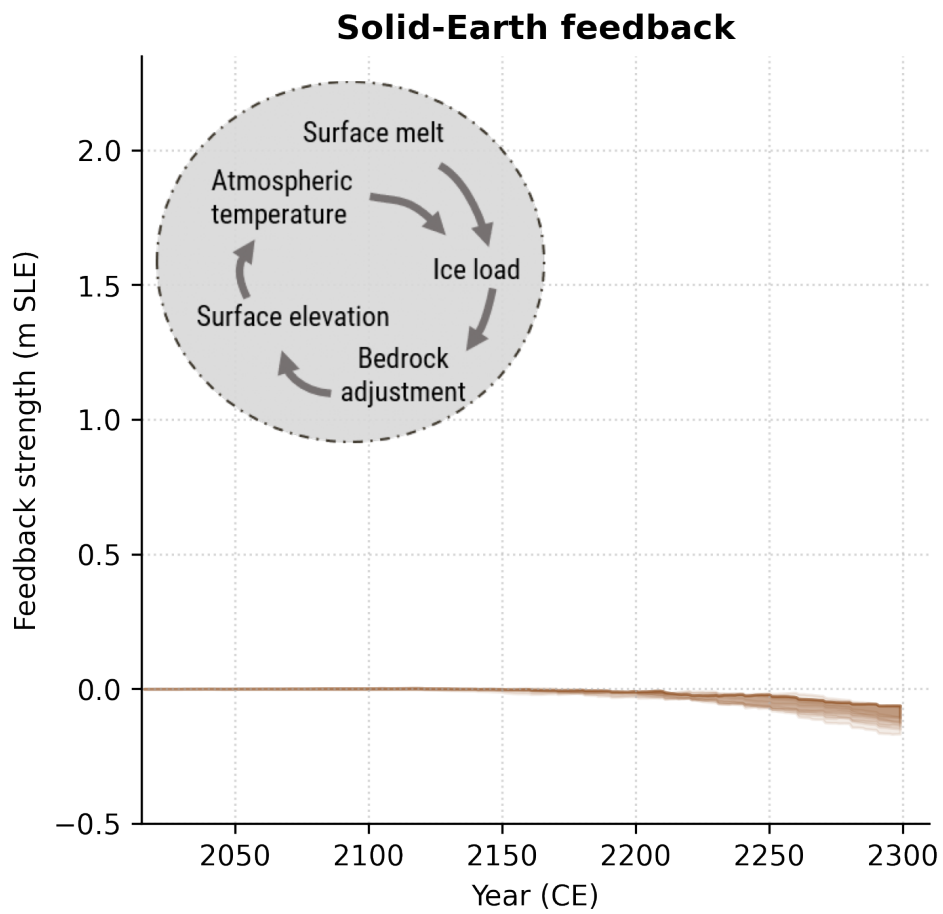


Figure S8. Strength of the Solid-Earth feedback assessed by PISM x dEBM x CESM. Plotted similarly as Fig. 4.

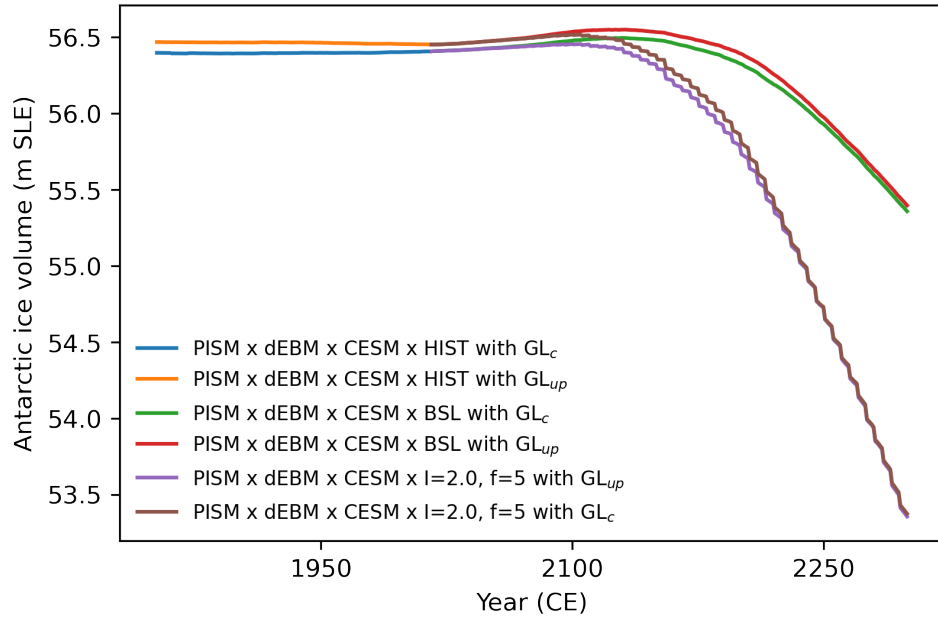


Figure S9. Test of an alternative grounding-line schemes in PISM. GL_c = centered thickness, GL_{up} = upstream. SLE = sea-level equivalent.

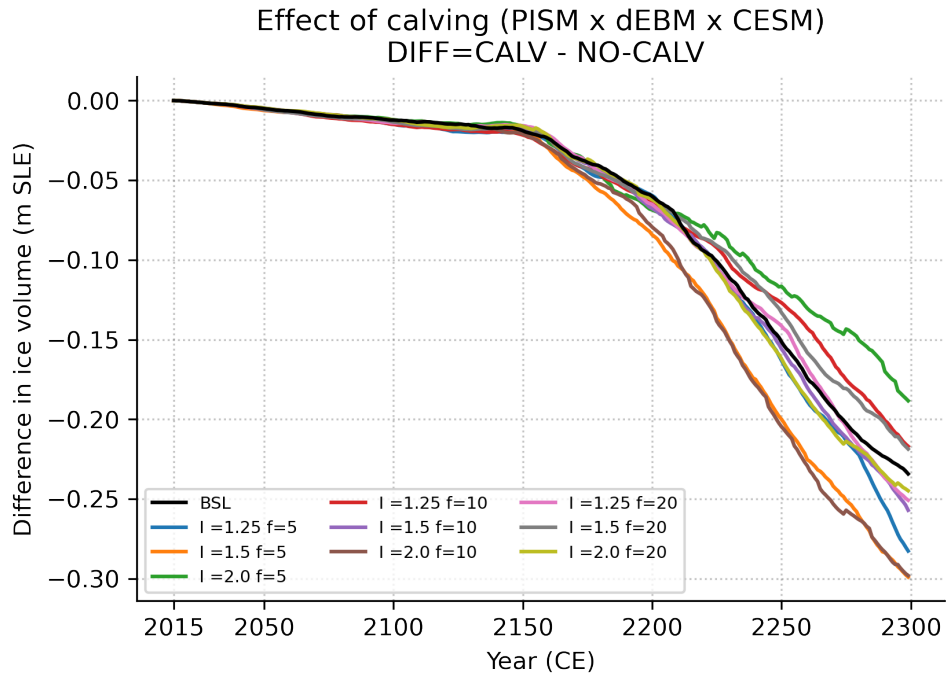


Figure S10. Influence of calving on results with PISM x dEBM x CESM (standard experiments compared to respective NO-CALV run, $DIFF = CALV - NO-CALV$.)

Table S1. Results from the ISSM basal melt rate tuning to match integrated ice-shelf melt rates from Davison et al. (2023).

Shelf region	Davison et al., 2023 range	computed melt rate	δT_{sector}
Jelbart	-13.4 - 26.4	6.5	0.25
Fimbul	-9.2 - 51.0	20.9	0.18
Nivl	-3.6 - 12.4	4.4	-0.42
Lazarev	-10.5 - 14.7	2.1	-0.55
Baudouin	-3.4 - 34.4	15.5	-0.3
Prince Harald	-26.3 - 34.7	4.2	0.6
Shirase	-27.0 - 36.8	4.9	2.0
Rayner Thyer	-6.2 - 20.0	6.9	2.0
Zubchatyy/Porter/Myers	-6.5 - 8.5	1.0	0.52
WilmaRobertDowner	-8.3 - 18.1	4.9	0.97
Edward VIII	-6.4 - 9.2	1.4	2.0
Utsikkar/Mulebreen/...	-20.6 - 24.4	1.9	2.0
Publications	-18.4 - 27.2	4.4	1.09
Sorsdal/Hovde/Flatnes/Dalk	-7.9 - 7.9	0.0	-0.58
West	-28.0 - 45.6	8.8	0.21
Helen	-14.1 - 12.5	-0.8	-2.0
Shackleton	-9.4 - 74.4	32.5	0.55
Tracy Tremenchus	-5.9 - 10.3	2.2	0.65
Conger Glenzer	-9.2 - 17.4	4.1	2.0
Moscow University	20.0 - 32.4	26.2	0.52
Voyeykov	-6.0 - 7.4	0.7	1.27
Frost	-2.6 - -1.6	-2.1	-2.0
Dibble	-6.3 - 18.3	6.0	0.74
WattBay/Zelee/...	-1.4 - -0.6	-1.0	-2.0
Mertz	-6.7 - 31.9	12.6	1.0
Ainsworth/Fisher	-0.6 - -0.4	-0.5	-2.0
Ninnis	-0.2 - 0.2	0.0	-0.48
Deakin/HornBluff	0.1 - 0.5	0.3	0.52
Cook	-19.1 - 20.7	0.8	-0.44
Andreyev/Slava	-3.2 - -1.6	-2.4	-2.0
Lauritzen	-12.3 - 12.3	0.0	-1.56
Matusevitch	-0.2 - 0.0	-0.1	-2.0
Suvorov/Gillet/...	-5.3 - 6.9	0.8	2.0
Rennick	-7.6 - 19.6	6.0	0.86
Chugunov/Barber/Gannutz	0.2 - 0.6	0.4	0.52
Lillie	-7.1 - 14.1	3.5	1.59
Arneb/Manhaul/...	-0.1 - 0.7	0.3	0.52
Tucker	0.6 - 1.0	0.8	1.11
Mariner	-10.3 - 13.7	1.7	0.87
Aviator	-7.4 - 9.4	1.0	1.96
Campbell/...	-0.2 - 0.0	-0.1	0.52
Nansen	-12.3 - 11.7	-0.3	-2.0
Drygalski	-25.6 - 33.2	3.8	1.26
Nordenskjold/Marin/...	-5.5 - 6.1	0.3	0.52
Ross East	-39.1 - 53.9	7.4	-0.22
Ross West	-79.9 - 33.9	-23.0	-0.64
Hamilton	-2.8 - 2.6	-0.1	0.52
Swinburne	-4.6 - 9.2	2.3	0.69
Nickerson	-9.2 - 21.2	6.0ex	0.71

Table S2. Table S1 continued.

Shelf region	Davison et al., 2023 range	computed melt rate	δT_{sector}
Land	-7.1 - 20.3	6.6	1.89
Hull	-3.8 - 15.8	6.0	2.0
Jackson/Perkins/...	0.1 - 0.7	0.4	0.52
Dotson/Philbin Inlet	31.5 - 71.5	51.5	0.47
Crosson	4.2 - 73.2	38.7	0.86
Thwaites	66.5 - 144.9	105.7	2.0
Pine Island	73.3 - 136.3	104.8	1.67
Walgreen Coast	-3.6 - 4.2	0.3	1.0
Cosgrove	-1.7 - 11.3	4.8	0.32
Abbot	33.5 - 90.9	62.2	0.41
Thomson	0.7 - 0.9	0.8	0.52
Stange	11.5 - 41.9	26.7	-0.33
George VI	48.6 - 104.8	76.7	-1.47
Bach	-1.2 - 16.0	7.4	-0.15
Wordie	-1.2 - 1.6	0.2	-0.25
LarsenA	0.1 - 0.1	0.1	0.52
LarsenD	-22.0 - 57.8	17.9	0.41
LarsenE	-15.0 - 17.4	1.2	0.87
LarsenF	-10.8 - 10.4	-0.2	-2.0
Ronne	-37.1 - 144.1	53.5	-0.11
Filchner	-27.3 - 43.7	8.2	-0.23
Brunt Stancomb	-18.0 - 18.0	0.0	-0.16
Riiser-Larsen	10.7 - 24.5	17.6	0.25
Quar	0.8 - 1.6	1.2	2.0
Ekstrom	-5.7 - 12.5	3.4	0.28

Table S3. Overview of simulations

	PISM	ISSM
HIST (1850-2015)	dEBM-simple, PDD	-
DRIFT (present-day continued)	dEBM-simple, PDD	PDD
BSL (2015-2300) with CESM2-WACCM	dEBM-simple, PDD	PDD
BSL (2015-2300) with UKESM1-0-LL	dEBM-simple, PDD	PDD
9 x EXTR (2015-2300) with CESM2-WACCM	dEBM-simple, PDD	PDD
9 x EXTR (2015-2300) with UKESM1-0-LL	dEBM-simple, PDD	PDD
Additional sensitivity tests with PISM and CESM2-WACCM		
BSL NO-ALB	dEBM-simple	-
BSL NO-ELV	dEBM-simple	PDD
BSL NO-BED	dEBM-simple	-
BSL NO-CALV	dEBM-simple	-
BSL HYDRO-FRACT	dEBM-simple, PDD	-
BSL NO-MASS	dEBM-simple, PDD	PDD
9 x EXTR NO-ALB	dEBM-simple	-
9 x EXTR NO-ELV	dEBM-simple	PDD
9 x EXTR NO-BED	dEBM-simple	-
9 x EXTR NO-CALV	dEBM-simple	PDD
9 x EXTR HYDRO-FRAC	dEBM-simple, PDD	-
9 x EXTR NO-MASS	dEBM-simple, PDD	PDD