

Supplementary Information for

Ocean memory amplifies Antarctica's sea-level contribution after climate overshoot

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Supplementary Methods

Inversion procedure and regularisation

We first jointly inverted the logarithmic basal-friction and ice-viscosity controls using a nonlinear Weertman sliding relation with a velocity exponent of $1/3$. Regularisation weights were selected using an L-surface analysis, giving $\lambda_\beta = 3 \times 10^5$ for basal-friction smoothing, $\lambda_\alpha = 3 \times 10^6$ for viscosity-control smoothing, and $\lambda_{\alpha,\text{prior}} = 0.02$ for the viscosity prior. This procedure differs from Zhao et al.¹, in which a linear sliding coefficient was inverted and the resulting basal stress was subsequently converted to regularised-Coulomb coefficients.

For the regularised-Coulomb configurations, we performed a separate adjoint inversion for each value of C_{max} , initialised from the selected Weertman solution. Effective pressure during these inversions was calculated using the perfect-ocean-connection approximation,

$$N = \rho_i g H + \rho_o g z_b,$$

and bounded below by $N_{\text{min}} = 0.05$ MPa for numerical stability. The area over which this bound is active was not quantified, so the bound may also influence basal resistance in regions of low effective pressure. Separate L-surface analyses were conducted for $C_{\text{max}} = 0.8, 0.5$, and 0.2 . The selected regularisation weights ($\lambda_{\beta,\text{RC}}, \lambda_{\alpha,\text{RC}}$) were $(3 \times 10^4, 5 \times 10^5)$ for both $C_{\text{max}} = 0.8$ and 0.5 , and $(1 \times 10^4, 5 \times 10^5)$ for $C_{\text{max}} = 0.2$.

Forcing preprocessing and verification

The construction of the LOW, HIGH and controlled high-forcing experiments is described in the Methods. Here we describe the checks applied during forcing preparation. Surface mass balance (SMB; `acabf`), the SMB–elevation gradient (`dacabfdz`), ocean thermal forcing (`tf`), and the practical salinity (`so`) were prepared on the grids required by Elmer/Ice before the forcing pathways were combined. For each variable, the LOW and HIGH source fields were checked for consistent spatial dimensions, coordinate ordering, temporal coverage and units.

The prescribed HIGH-to-LOW weights were applied independently to each forcing record and grid location. The resulting files were checked to confirm that weights of one and zero recovered the HIGH and LOW fields. The transition timing was confirmed to be the same for the atmospheric and ocean forcing in HIGH20, HIGH50, HIGH75 and HIGH100. Separate weights were used for the atmosphere–ocean recovery experiments. These checks verify the construction of the forcing. The recovery of the atmosphere and of the Southern Ocean is prescribed, not simulated.

The post-2100 HIGH extension was inspected for discontinuities at the transition from the SSP3–7.0 fields to the climatological-anomaly extension. Spatially integrated forcing and basin-mean ocean thermal forcing were compared immediately before and after 2100. The extension retained the evolving SSP1–2.6 background while preserving the mean 2081–2100 SSP3–7.0-minus-SSP1–2.6 contrast (Methods).

Calculation and verification of grounded ice above flotation

The Antarctic sea-level contribution was calculated from the volume of grounded ice above flotation, the integral over the grounded area of the height above flotation (HAF). An independent reconstruction from ice thickness, bed elevation and surface elevation was used to verify this field.

For grounded ice, the reconstructed HAF was calculated as

$$H_{\text{af}} = \max \left[H - \frac{\rho_o}{\rho_i} \max(z_{\text{sl}} - z_b, 0), 0 \right], \quad (1)$$

where H is ice thickness, z_b is bed elevation, z_{sl} is sea level, and $\rho_i = 917 \text{ kg m}^{-3}$ and $\rho_o = 1028 \text{ kg m}^{-3}$ are the densities of ice and seawater. HAF was set to zero for floating and ice-free elements. The reconstructed nodal values were averaged over each element and multiplied by the element area to give the grounded volume above flotation.

The cumulative sea-level contribution, ASC, was calculated as

$$\text{ASC}_e(t) = -[V_{\text{af},e}(t) - V_{\text{af},e}(2015)] \frac{\rho_i}{\rho_o A_o}, \quad (2)$$

where $V_{\text{af},e}$ is grounded volume above flotation for experiment e and $A_o = 3.625 \times 10^{14} \text{ m}^2$ is the global ocean area. Positive ASC is a loss of grounded ice above flotation, that is, a rise in global-mean sea level. The exported and reconstructed HAF were compared before the reconstructed quantities were used in the diagnostics; both are plotted for the Thwaites–Pine Island basin in Supplementary Fig. S10a.

Basin and sector integration

Basin-integrated quantities were calculated using the fixed mask of 18 IMBIE drainage basins. Each mesh element was assigned to a basin according to its horizontal location, and basin volume above flotation was calculated by summing HAF multiplied by element area. All reported whole-Antarctic ASC and Δ ASC values are sums over these 18 basins. Elements outside the basin mask were excluded, ensuring that basin, regional and continental sea-level contributions use the same spatial domain. The Antarctic Peninsula comprises basins Hp–I, I–Jpp and Jpp–J; West Antarctica comprises Ep–F, F–G, G–H, H–Hp and J–Jpp; and East Antarctica comprises A–Ap, Ap–B, B–C, C–Cp, Cp–D, D–Dp, Dp–E, E–Ep, Jpp–K and K–A. These groupings were applied consistently across experiments and model configurations.

For every sensitivity configuration c , the additional contribution was calculated against the LOW simulation with the same model configuration and climate forcing,

$$\Delta\text{ASC}_{e,c}(t) = \text{ASC}_{e,c}(t) - \text{ASC}_{\text{LOW},c}(t). \quad (3)$$

Taking the matching LOW simulation as the reference removes the differences in background evolution between configurations from the reported response.

Heterogeneous response of Antarctic drainage basins

Across the forcing pathways, Antarctica's cumulative sea-level contribution is concentrated in a small number of marine drainage basins (Supplementary Fig. S6). Under HIGH100, cumulative ASC by 2300 reaches 177 mm SLE in the Thwaites–Pine Island basin (G–H) and 166 mm SLE in the basin feeding the Ronne Ice Shelf (J–Jpp). Together, these two basins account for approximately 85.8% of the summed positive basin contributions under HIGH100. The Filchner sector (Jpp–K) contributes a further 37 mm SLE. This sector includes the Recovery catchment, the East Antarctic catchment identified as most sensitive to Weddell Sea warming². These cumulative contributions establish the importance of a geographically restricted set of basins, but do not reveal how each basin responds to overshoot duration.

The additional contribution relative to LOW, Δ ASC, varies among basins (Supplementary Fig. S7). J–Jpp shows the largest increase with high-forcing duration: by 2300, Δ ASC rises from -1.1 mm SLE under HIGH20 to $+3.0$, $+8.2$ and $+17.1$ mm SLE under HIGH50, HIGH75 and HIGH100, respectively (Supplementary Figure S9). Longer high-forcing intervals in J–Jpp produce greater cumulative grounding-line discharge and a larger grounded-area deficit relative to LOW, consistent with a dynamic contribution to the larger sea-level response (Supplementary Fig. S9). Smaller increases in Δ ASC between HIGH20 and HIGH100 occur in several East Antarctic basins, including the Aurora Basin sector (Cp–D; $+3.8$ mm SLE) and the Filchner sector (Jpp–K; $+2.7$ mm SLE). Several West Antarctic and Antarctic Peninsula basins show weak or negative responses relative to LOW. Longer high-forcing intervals therefore increase Δ ASC in some basins while producing little change or a negative response in others.

The sharpest contrast between cumulative ASC and LOW-relative Δ ASC occurs in G–H. This basin has the largest cumulative ASC under HIGH100 (Supplementary Fig. S6), yet its Δ ASC changes sign as high-forcing duration increases. It is $+1.0$ mm SLE under HIGH20 and then -2.8 , -5.3 and -5.0 mm SLE under HIGH50, HIGH75 and HIGH100, respectively. Under sustained HIGH forcing, Δ ASC becomes more negative, reaching -7.4 mm SLE. Under HIGH100, G–H contributes 177 mm SLE by 2300, compared with approximately 182 mm SLE under LOW, a difference of 3%. A negative Δ ASC does not indicate net ice gain: G–H continues to lose grounded ice under high forcing, but loses less than under LOW.

G–H mass-balance diagnostics. Basin-total SMB, ice-shelf basal melt and grounding-line flux were evaluated over the fixed G–H basin relative to LOW. Basin-total SMB includes both grounded and floating ice. Cumulative anomalies were calculated by trapezoidal integration of the annual rates. A positive SMB anomaly denotes greater net surface mass gain than under LOW, whereas positive basal-melt and grounding-line-flux anomalies denote greater ice-shelf melting and greater flux across the grounding line.

Under sustained HIGH forcing, cumulative basin-total SMB over 2015–2300 exceeds LOW by 8.70×10^3 Gt (23.3 mm SLE), while cumulative grounding-line flux is 3.47×10^3 Gt (9.3 mm SLE) greater (Supplementary Fig. S10). The difference between these two cumulative anomalies is $+5.23 \times 10^3$ Gt. Over the same period, G–H retains 2.76×10^3 Gt more grounded ice above flotation than under LOW, corresponding to Δ ASC = -7.4 mm SLE. This retention occurs despite an additional 9.27×10^3 Gt of cumulative ice-shelf basal melt and a grounded area that is 1.84×10^3 km² smaller than under LOW in 2300.

To assess the surface mass-balance contribution to the duration response, we additionally integrated SMB over the evolving grounded fraction of each mesh element in G–H. Cumulative grounded-ice SMB over 2015–2300 is 2.11×10^3 Gt greater under HIGH100 than HIGH20, equivalent to approximately 5.7 mm SLE. Applying the same initial LOW grounded footprint to both experiments gives an almost identical difference, indicating that the increase is not primarily caused by changes in grounded area. This comparison supports greater surface mass gain as a contributor to the lower sea-level contribution under HIGH100.

These diagnostics do not constitute a closed budget for grounded ice above flotation. Basin-total SMB includes accumulation over floating ice, and moving-boundary and lateral-transport terms are not explicitly accounted for. Ice-shelf basal melt affects grounded ice indirectly through changes in ice-shelf geometry and buttressing. Neither the SMB-minus-grounding-line-flux anomaly nor the grounded-SMB difference should therefore be interpreted as a complete attribution of the change in grounded ice above flotation.

Between HIGH20 and HIGH100, ΔASC decreases in G–H but increases in J–Jpp, so their responses partly offset in the whole-Antarctic total. J–Jpp has the largest positive change in ΔASC (+18.2 mm SLE), whereas G–H changes by –6.0 mm SLE, offsetting approximately 33% of the J–Jpp increase. This pattern extends beyond these two basins, with duration-dependent changes concentrated in a small subset of Antarctic drainage basins (Supplementary Fig. S8).

Sensitivity and trajectory comparisons

The sensitivity experiments evaluate three sources of uncertainty: basal sliding, ice-shelf basal-melt parameterisation and climate-model forcing. The sensitivity classes and the model configurations are listed in Supplementary Table S1 and S2.

The experiments form a deterministic sensitivity ensemble, not a probabilistic projection. The 5th-percentile, median and 95th-percentile labels refer to the basal-melt calibration coefficients and not to confidence intervals on the simulated sea-level contribution. Lines join the 20-, 50-, 75- and 100-year experiments in the figures as a visual guide.

To compare post-recovery evolution over a common interval, similarity to the SSP534-over experiment (OVER534; Methods) was assessed using the root-mean-square difference (RMSD) between annual whole-Antarctic ΔASC trajectories from 2125 to 2300. The start year 2125 is the first year after the recovery transition is complete in the longest controlled experiment, HIGH100; the same interval was used for HIGH20, HIGH50, HIGH75 and HIGH100.

$$\text{RMSD}_e = \left[\frac{1}{N} \sum_{i=1}^N (\Delta\text{ASC}_e(t_i) - \Delta\text{ASC}_{\text{OVER534}}(t_i))^2 \right]^{1/2}. \quad (4)$$

The years t_i are the N output years of OVER534 between 2125 and 2300. The idealised trajectories were linearly interpolated to the OVER534 output years where necessary. Annual values were unsmoothed and equally weighted. The comparison measures the similarity of the sea-level trajectories, not of the climate-forcing pathways.

Supplementary Figures

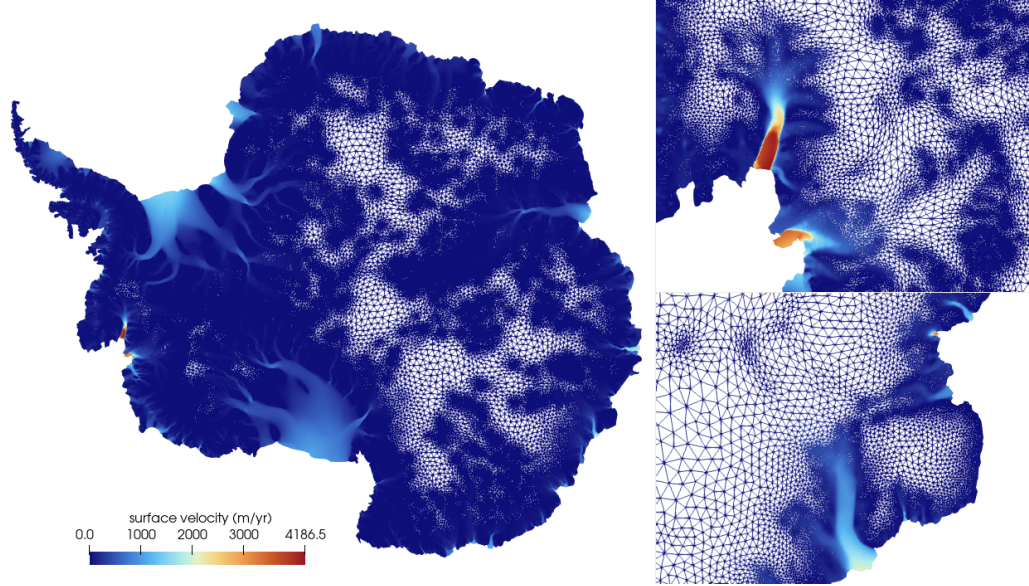


Figure S1. Computational mesh of the Antarctic Ice Sheet. Insets: the mesh in the Pine Island–Thwaites Glacier sector of West Antarctica (top right) and the Totten Glacier sector of East Antarctica (top left). Resolution is about 1 km in fast-flowing ice and near the grounding line and about 25 km in the interior (Methods).

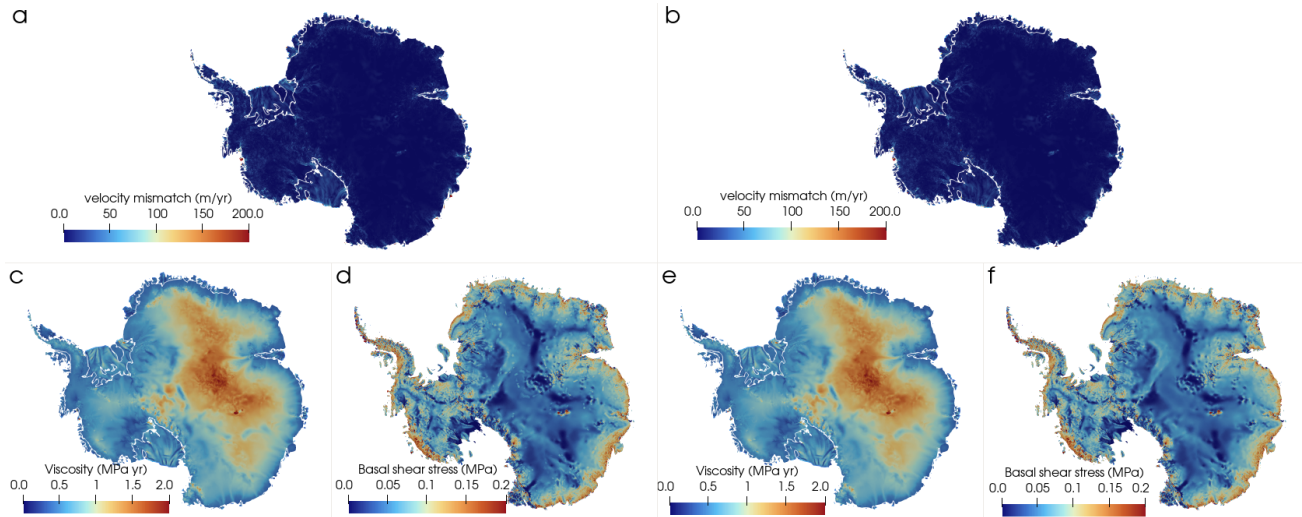


Figure S2. Inversion results for the power-law and regularised-Coulomb sliding relations. **a,c,d**, Power-law inversion; **b,e,f**, regularised-Coulomb inversion. **a,b**, Magnitude of the horizontal surface-velocity residual between the simulation and observations (m yr^{-1}). **c,e**, Inferred SSA mean viscosity (MPa yr). **d,f**, Inferred basal shear-stress magnitude (MPa); **d** shows τ_w for the power-law relation, and **f** shows τ_{RC} for the regularised-Coulomb relation.

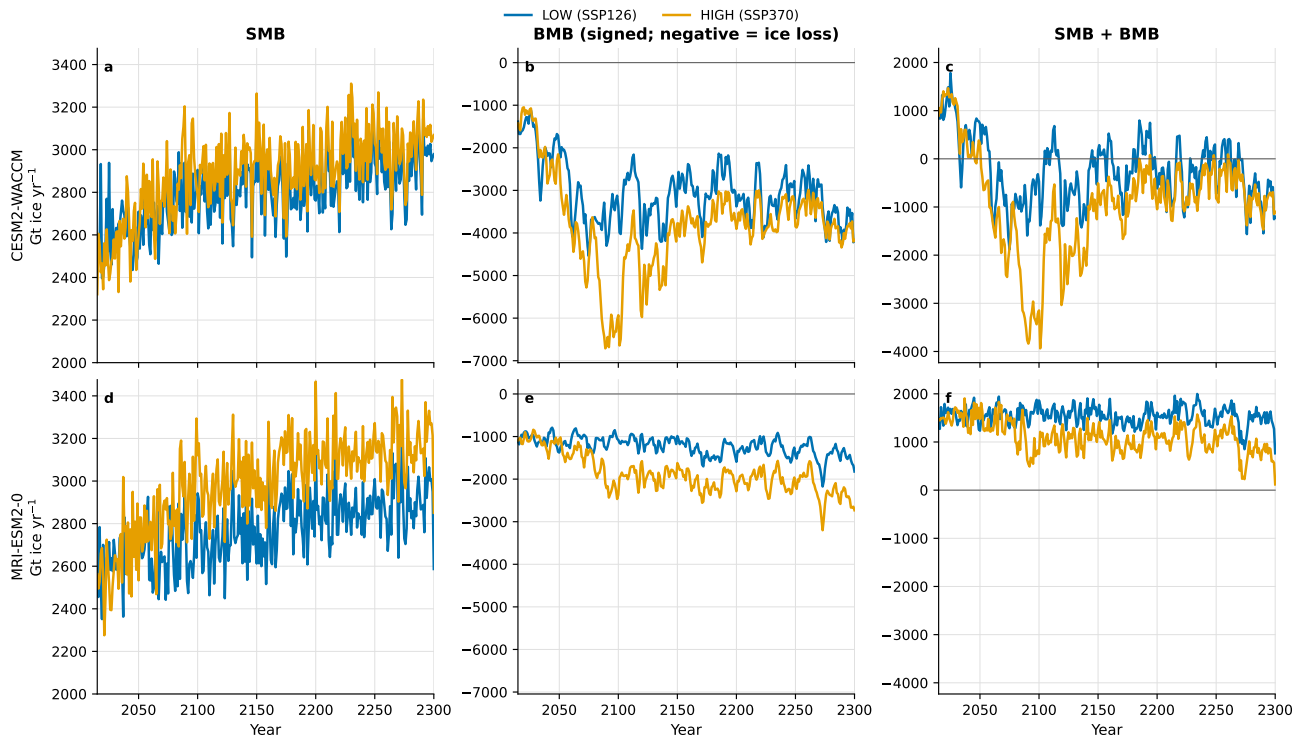


Figure S3. Antarctic surface and basal mass-balance components for the reference configuration (m005). Time series of Antarctic-integrated surface mass balance (SMB; a,d), floating-ice basal mass balance (BMB; b,e), and their sum (SMB+BMB; c,f) from 2015 to 2300, expressed in Gt ice yr^{-1} . The upper row shows simulations forced by CESM2-WACCM, and the lower row shows simulations forced by MRI-ESM2-0. Blue and orange curves denote SSP1-2.6 and SSP3-7.0, respectively. BMB is shown using a signed convention, with negative values indicating ice loss through basal melting. SMB+BMB represents the combined surface and floating-ice basal mass-balance contribution; ice discharge and calving are not included.

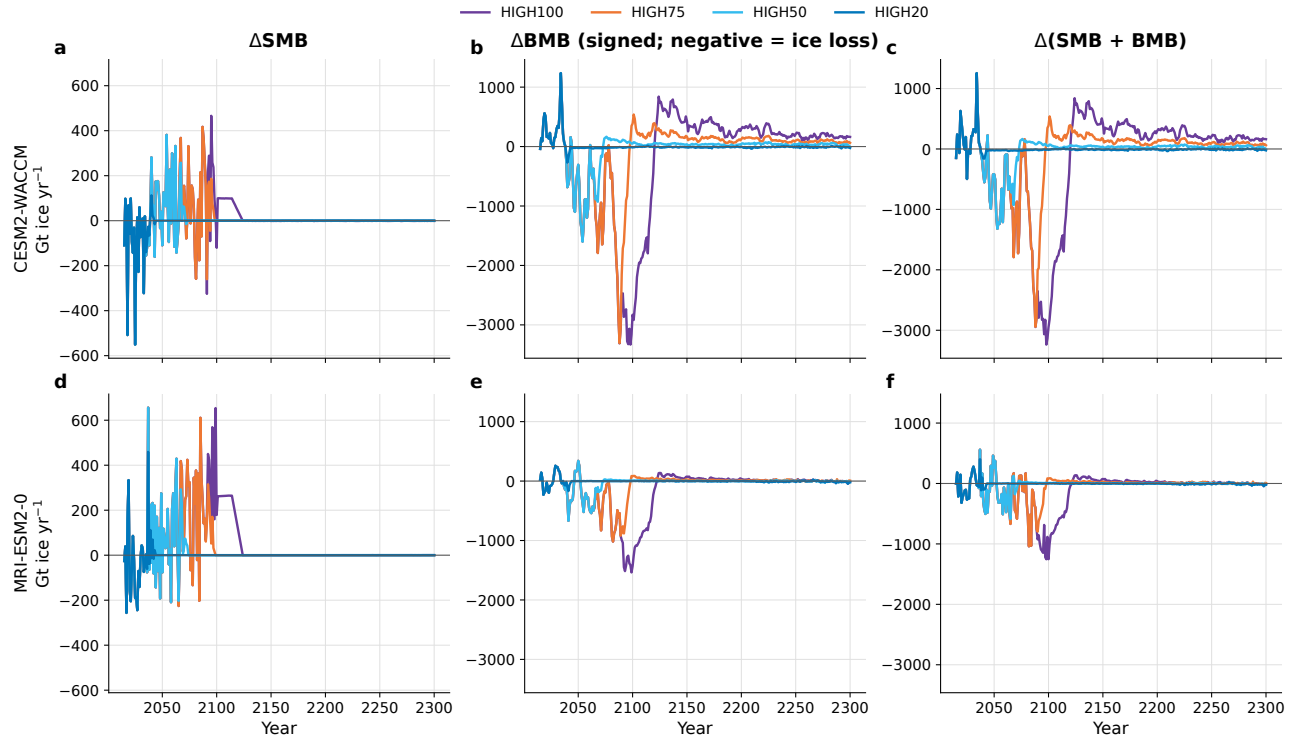


Figure S4. Surface and basal mass-balance anomalies under high-forcing experiments. **a–c**, Whole-Antarctic anomalies in surface mass balance (ΔSMB), signed basal mass balance (ΔBMB) and their sum, for forcing derived from CESM2-WACCM. **d–f**, The same for forcing derived from MRI-ESM2-0. Results are shown for HIGH20, HIGH50, HIGH75 and HIGH100, each relative to the matching LOW experiment in Gt yr^{-1} . Positive ΔSMB is more accumulation; negative ΔBMB is more basal melting. Under both climate models the sum is dominated by basal mass balance during the high-forcing period, and the sum is larger under CESM2-WACCM than under MRI-ESM2-0. The sum is the applied mass-balance forcing, not a closed mass budget.

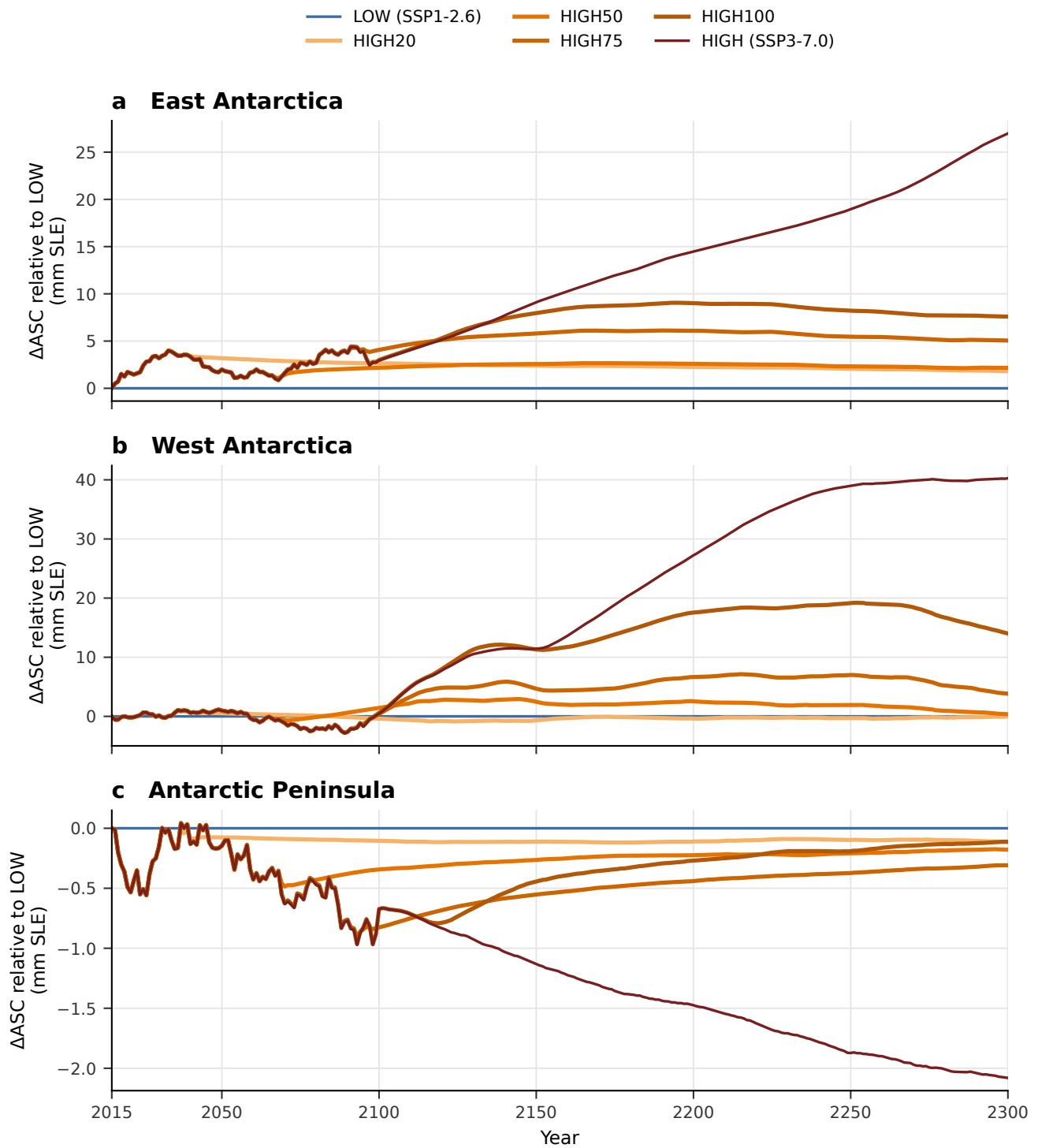
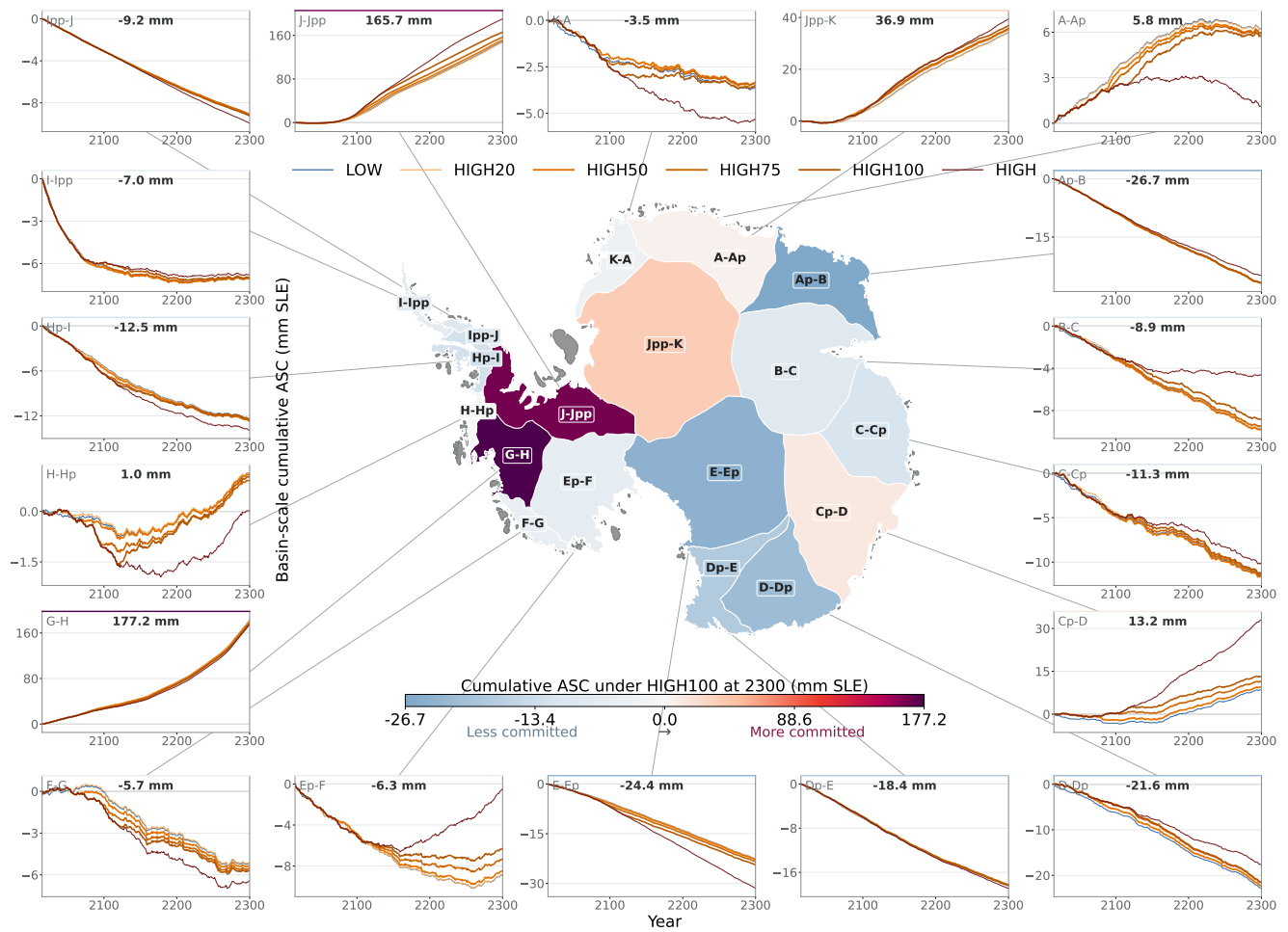


Figure S5. Regional Antarctic sea-level contributions relative to sustained low forcing. Annual Δ ASC for (a) East Antarctica, (b) West Antarctica and (c) the Antarctic Peninsula under LOW, HIGH20, HIGH50, HIGH75, HIGH100 and sustained HIGH forcing from 2015 to 2300. Each trajectory is the regional sea-level contribution minus that of the corresponding region under LOW; LOW is therefore zero throughout. Positive values indicate a greater contribution than LOW, and negative values indicate a smaller contribution, not necessarily net ice gain. Values are in millimetres of global mean sea-level equivalent (SLE).



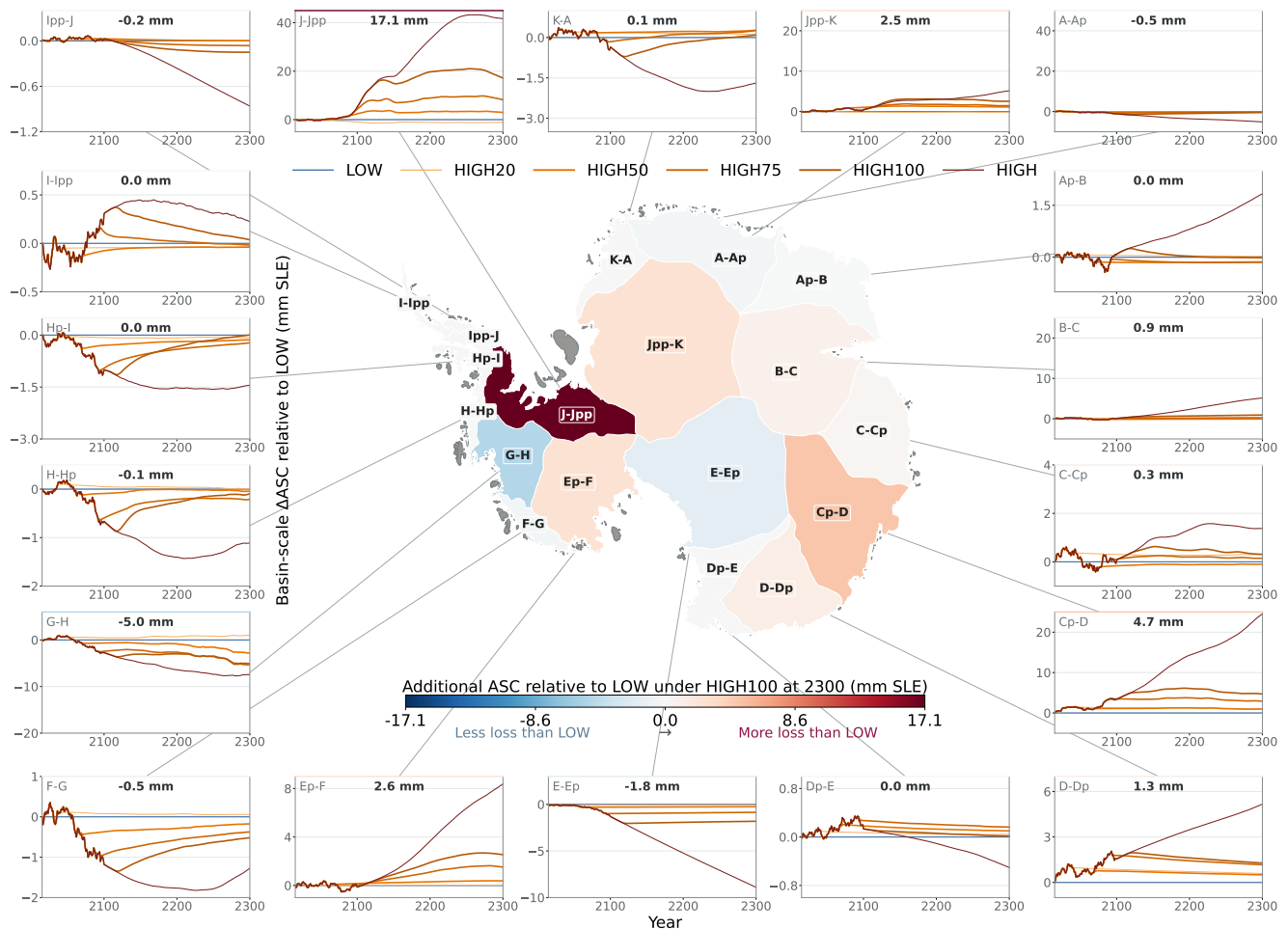


Figure S7. Spatially contrasting responses of Antarctic drainage basins to climate overshoot. The central map shows Antarctica's additional sea-level contribution relative to LOW, $\Delta\text{ASC} = \text{ASC}_{\text{experiment}} - \text{ASC}_{\text{LOW}}$, in each drainage basin under HIGH100 in 2300. Surrounding panels show basin-scale ΔASC from 2100 to 2300 under LOW, HIGH20, HIGH50, HIGH75, HIGH100 and sustained HIGH forcing. Values above the panels report HIGH100 ΔASC in 2300. Positive values indicate greater grounded-ice loss than under LOW; negative values indicate less loss than under LOW, not necessarily net ice gain. Basin IDs follow the 18-basin Ice Sheet Mass Balance Inter-comparison Exercise (IMBIE) drainage-basin mask used throughout the study³.

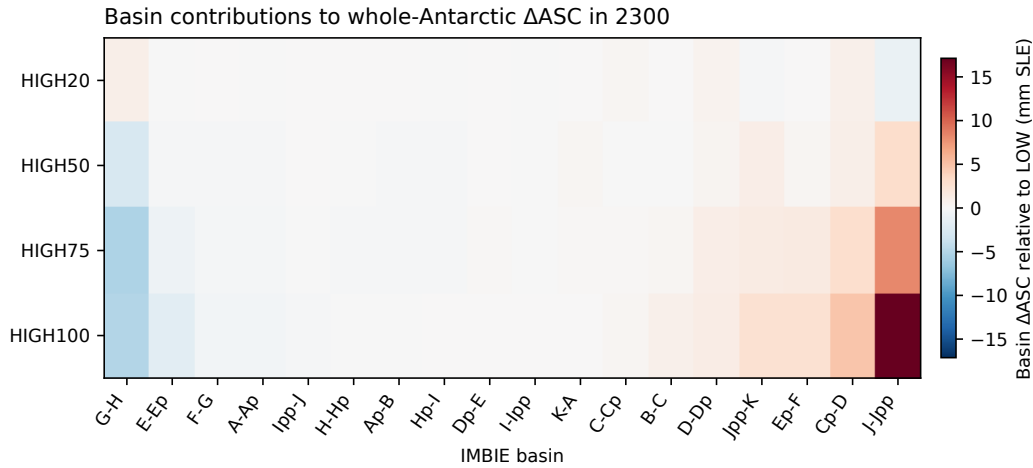


Figure S8. Basin contributions to Antarctic’s sea-level contribution across overshoot durations. Contributions from the 18 IMBIE basins to whole-Antarctic Δ ASC in 2300 for HIGH20, HIGH50, HIGH75 and HIGH100, each calculated relative to the matching LOW simulation. Basins are ordered by contribution under HIGH100. The increase in whole-Antarctic contribution with overshoot duration is spatially heterogeneous. A growing positive contribution from basin J-Jpp dominates, partly offset by a negative contribution from basin G-H. Values in mm SLE.

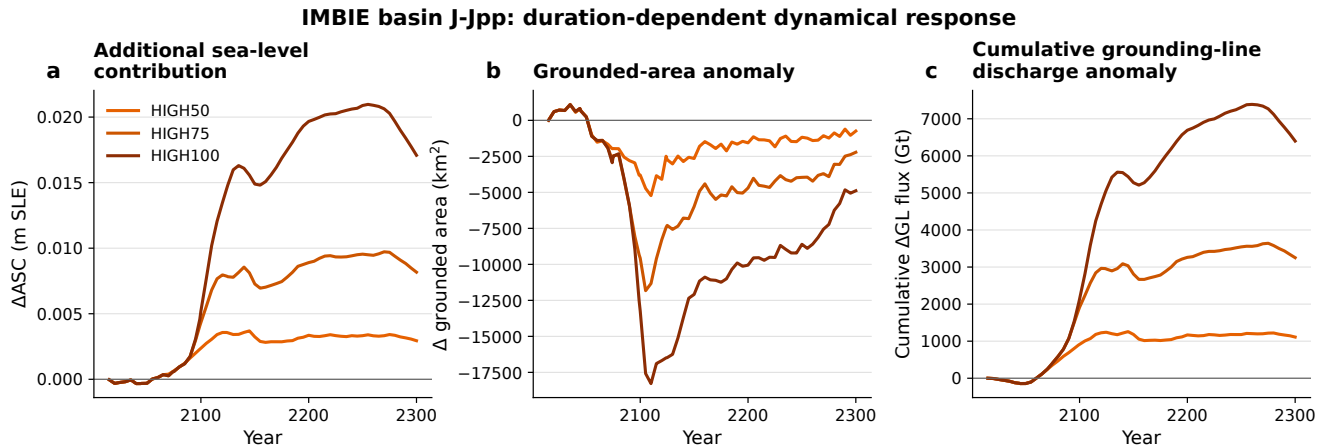


Figure S9. Duration-dependent response of the Ronne drainage basin (J-Jpp). **a**, Additional sea-level contribution (Δ ASC) under HIGH50, HIGH75 and HIGH100, calculated from grounded ice volume above flotation. **b**, Grounded-area anomaly. **c**, Cumulative grounding-line discharge anomaly. All anomalies are relative to LOW. Positive values in **a** and **c** are additional sea-level contribution and greater cumulative discharge; negative values in **b** indicate a smaller grounded area than under LOW. By 2300, Δ ASC reaches 2.94, 8.17 and 17.09 mm SLE under HIGH50, HIGH75 and HIGH100, with grounded-area deficits of 743, 2215 and 4888 km² and cumulative discharge anomalies of 1111, 3252 and 6399 Gt. These diagnostics support a dynamic contribution to the larger sea-level response under longer high-forcing intervals. The anomalies decline late in the simulation, which means the difference from LOW narrows; the decline does not show that ice regrows or that the grounding line readvances.

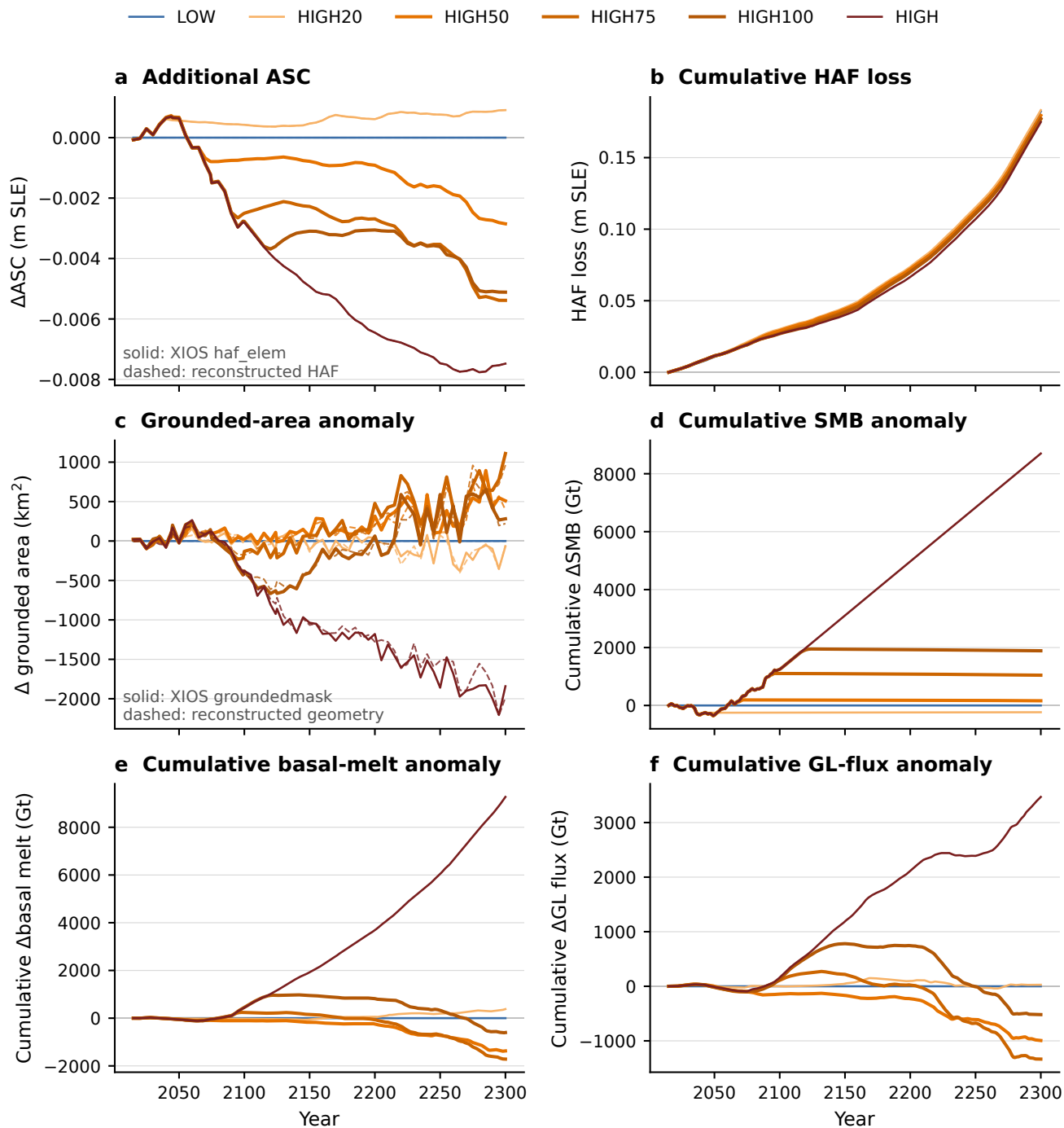


Figure S10. Mass-budget diagnostics for the Thwaites–Pine Island basin (G–H). **a**, Antarctica’s additional sea-level contribution relative to LOW (ΔASC), calculated from the modelled height above flotation (HAF; solid lines) and a reconstruction from ice thickness, surface elevation and bed elevation (dashed lines). **b**, Cumulative HAF loss relative to the common initial state. **c**, Grounded-area anomaly relative to LOW, calculated from the modelled grounded mask (solid lines) and the reconstructed flotation condition (dashed lines). **d–f**, Cumulative anomalies relative to LOW in surface mass balance (SMB), ice-shelf basal melt and grounding-line flux. Positive SMB anomalies are more accumulation; positive basal-melt and grounding-line-flux anomalies are more mass loss. Under sustained HIGH forcing, the larger cumulative SMB offsets part of the larger discharge and melt, so less ice above flotation is lost than under LOW by 2300. SMB minus grounding-line flux is not a closed mass budget (Supplementary Methods).

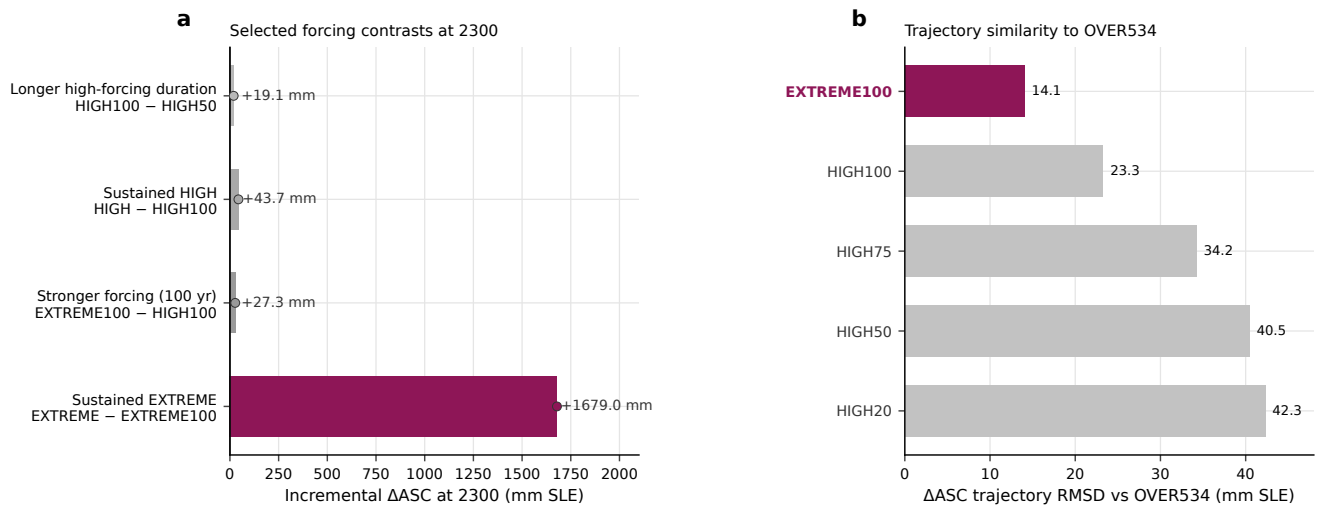


Figure S11. Selected forcing contrasts and trajectory similarity to OVER534. **a**, Incremental additional Antarctic sea-level contribution (Δ ASC) at 2300 associated with extending SSP3-7.0-derived high forcing from 50 to 100 years (HIGH100–HIGH50), sustaining HIGH beyond 100 years (HIGH–HIGH100), increasing forcing magnitude at a fixed 100-year duration (EXTREME100–HIGH100), and sustaining EXTREME beyond 100 years (EXTREME–EXTREME100). These contrasts use different reference experiments and do not establish a general ranking of duration and magnitude effects. **b**, Root-mean-square difference (RMSD) between the annual LOW-relative Δ ASC trajectories of OVER534 and the five idealised overshoot experiments over 2125–2300, after all idealised experiments have completed their transitions towards LOW. EXTREME100 has the lowest RMSD within this comparison period. RMSD describes similarity in the net sea-level response, rather than agreement in forcing history or individual process contributions. All quantities are expressed in millimetres of sea-level equivalent (mm SLE).

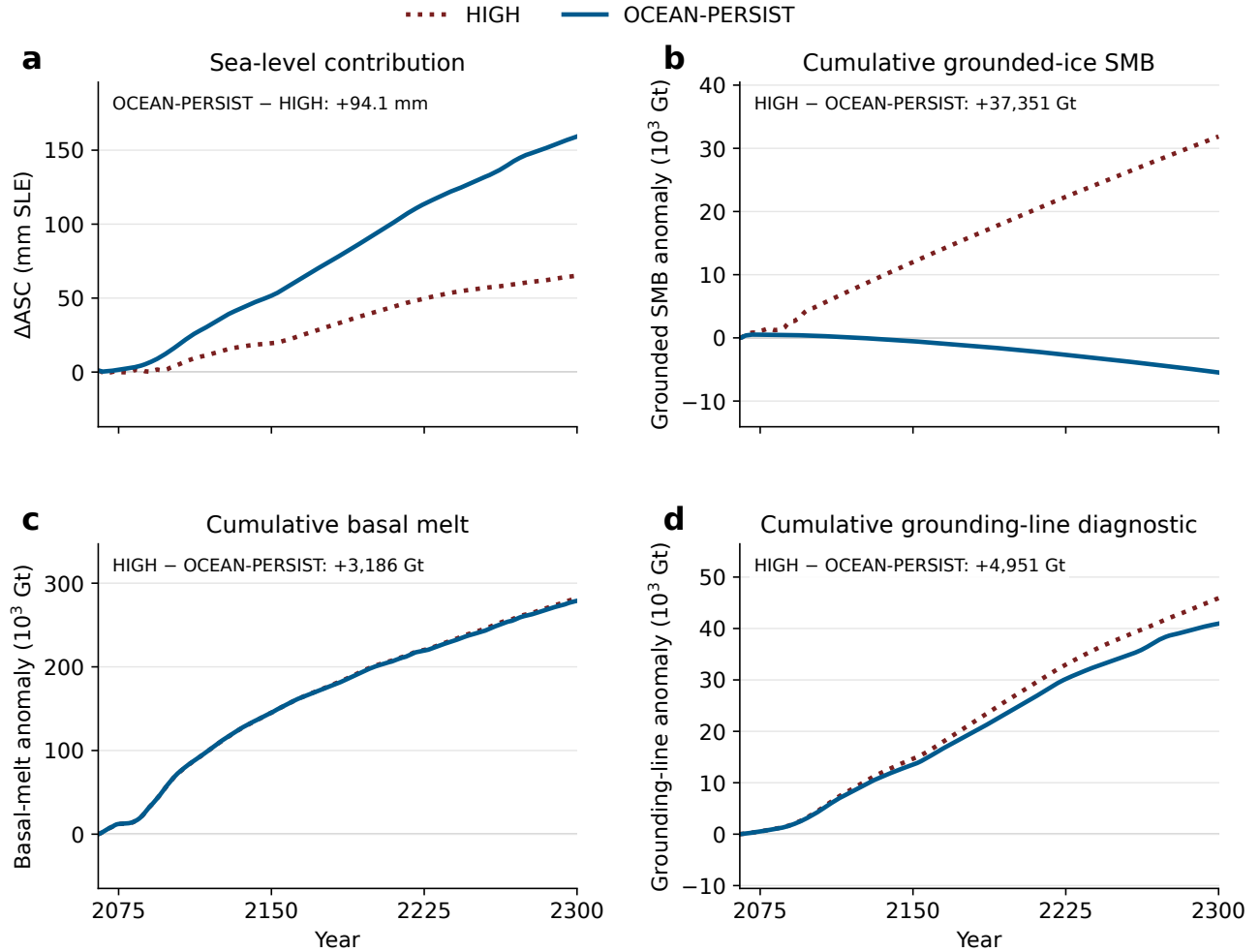


Figure S12. Atmospheric modulation under persistent high ocean forcing. HIGH and OCEAN-PERSIST retain the same prescribed high ocean forcing but differ in atmospheric forcing after 2065. **a**, Antarctic sea-level contribution relative to LOW (ΔASC). **b–d**, Cumulative anomalies relative to LOW in grounded-ice surface mass balance (**b**), ice-shelf basal melt (**c**) and the exported grounding-line-flux diagnostic (**d**), integrated from 2065 to 2300. Grounded-ice surface mass balance is calculated over the evolving grounded area in each simulation. Positive basal-melt anomalies indicate additional melting. Annotations show the difference between experiments at 2300; the subtraction order is given in each panel. These flux diagnostics do not form a closed budget for changes in grounded ice above flotation.

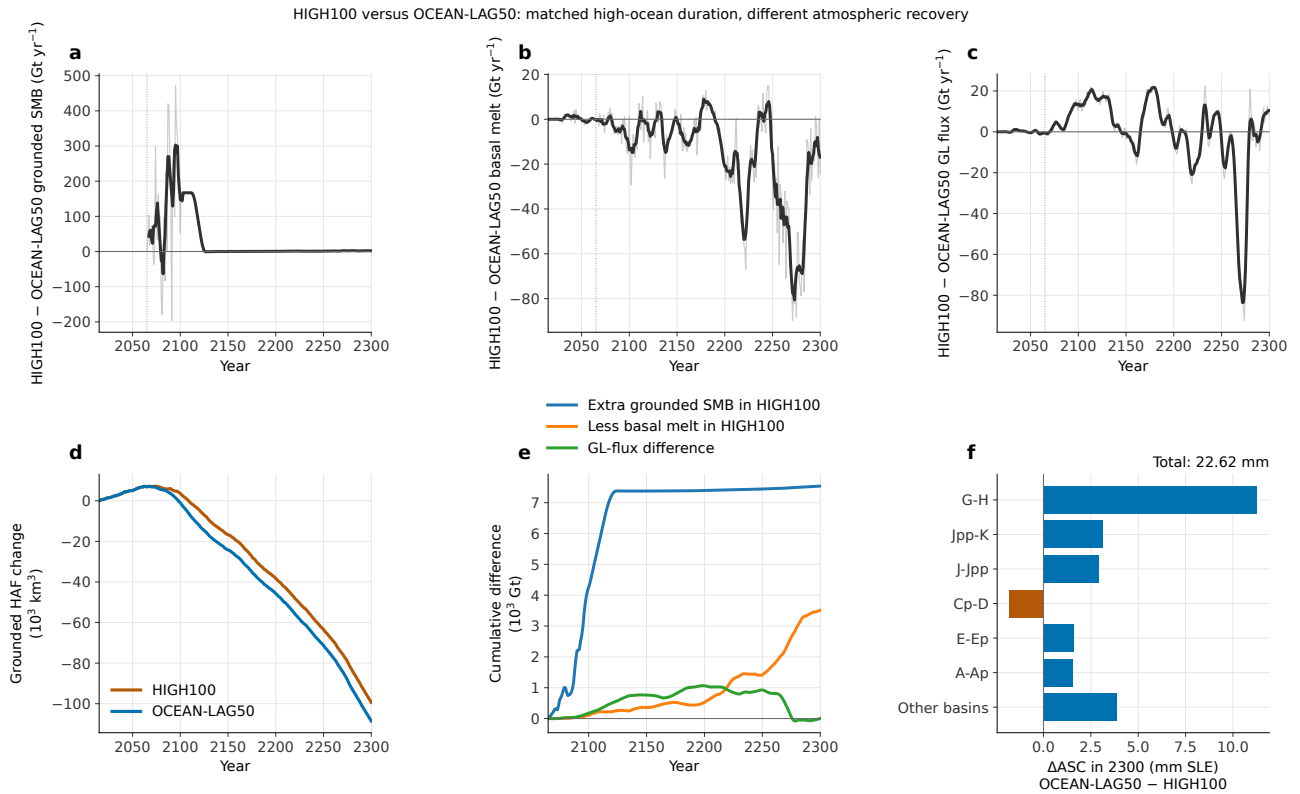


Figure S13. Grounded-ice accumulation and the sea-level response under matched ocean forcing. HIGH100 and OCEAN-LAG50 prescribe the same ocean-forcing pathway but differ in atmospheric recovery after 2065. (a–c) Annual HIGH100-minus-OCEAN-LAG50 differences in grounded-ice surface mass balance (SMB), ice-shelf basal melt and the exported grounding-line-flux diagnostic. Grey curves show annual values; black curves show five-year running means. (d) Grounded height-above-flotation volume change since 2015. (e) Cumulative differences from 2065, integrated from annual values. SMB is integrated over each experiment’s evolving grounded footprint, with triangular-element weights given by the mean nodal value of $(\text{groundedmask} + 1)/2$. Basal melt and grounding-line diagnostics retain their original full-domain integration. The diagnostics do not constitute a closed sea-level budget. (f) Basin contributions to the OCEAN-LAG50-minus-HIGH100 difference in ΔASC at 2300. Dotted lines mark 2065. Fluxes are in Gt yr^{-1} , cumulative differences in 10^3 Gt , HAF volume change in 10^3 km^3 , and sea-level contribution in mm SLE.

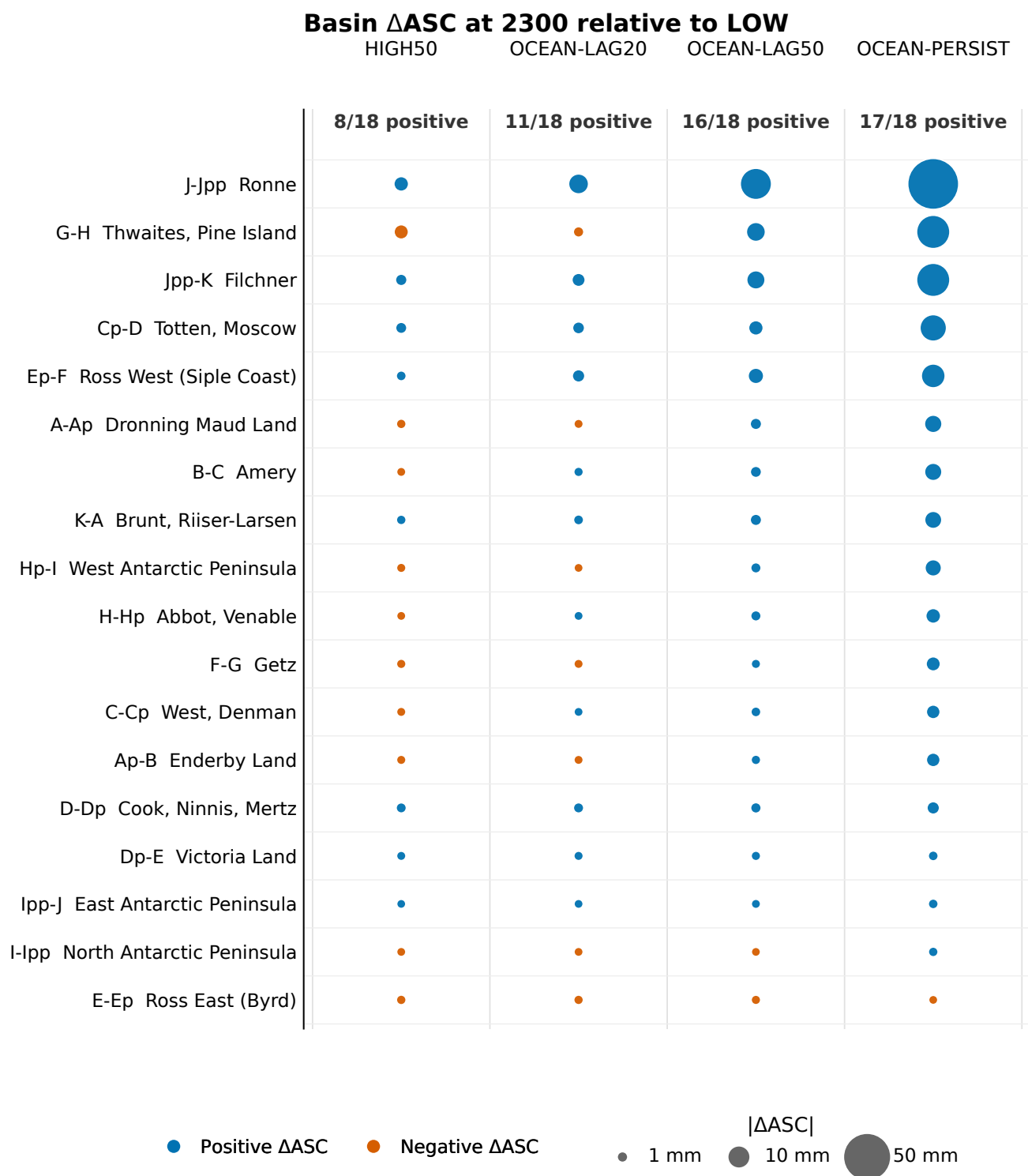


Figure S14. Basin-scale sea-level response to ocean-recovery timing. Basin Δ ASC at 2300 relative to LOW under HIGH50, OCEAN-LAG20, OCEAN-LAG50 and OCEAN-PERSIST. Blue and orange circles denote positive and negative Δ ASC, respectively, and circle size indicates its absolute magnitude. Reference circle sizes show 1, 10 and 50 mm SLE. Basins are ordered by decreasing Δ ASC under OCEAN-PERSIST. Values above the columns give the number of the 18 basins with positive Δ ASC under each experiment.

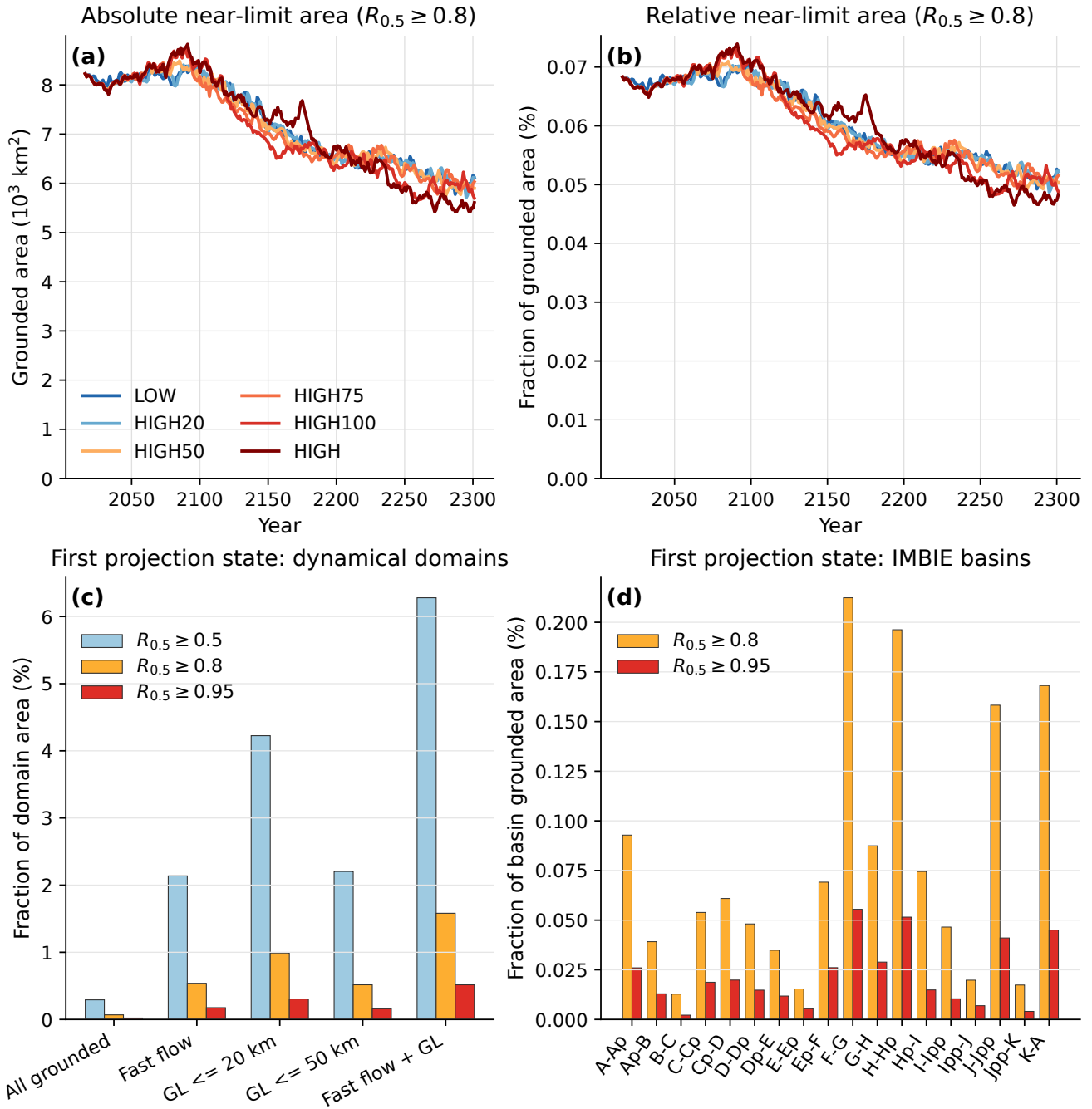


Figure S15. Spatial concentration and temporal evolution of basal traction close to the regularised-Coulomb limit in the reference RC05 simulations ($C_{\max} = 0.5$). The traction ratio is $R_{0.5} = \tau_b / (0.5N)$, where τ_b is basal traction and N is effective pressure. **a**, Grounded-ice area for which $R_{0.5} \geq 0.8$ under LOW, HIGH20, HIGH50, HIGH75, HIGH100 and sustained-HIGH forcing. The near-limit area peaks in the late twenty-first century and then declines under all forcing pathways, including sustained HIGH forcing. **b**, The same area expressed as a percentage of the grounded-ice area at the same time. **c**, Fractions of the grounded area at the common 2015 initial state within five dynamical domains exceeding $R_{0.5}$ thresholds of 0.5, 0.8 and 0.95. Fast flow is $\geq 100 \text{ m a}^{-1}$; “Fast flow + GL” is fast-flowing grounded ice within 20 km of the grounding line. **d**, Fractions of the grounded area within each IMBIE basin at the same state exceeding $R_{0.5}$ thresholds of 0.8 and 0.95. Fractions in **c** and **d** are normalised by the grounded area of the same domain or basin. The near-limit area is small and shrinking, so the increase of sea-level contribution with overshoot duration does not come from a spread of near-limit traction across the continent. $R_{0.5}$ measures closeness to the traction cap, not the transition parameter χ (Methods), so these areas are called near-limit rather than Coulomb-dominated.

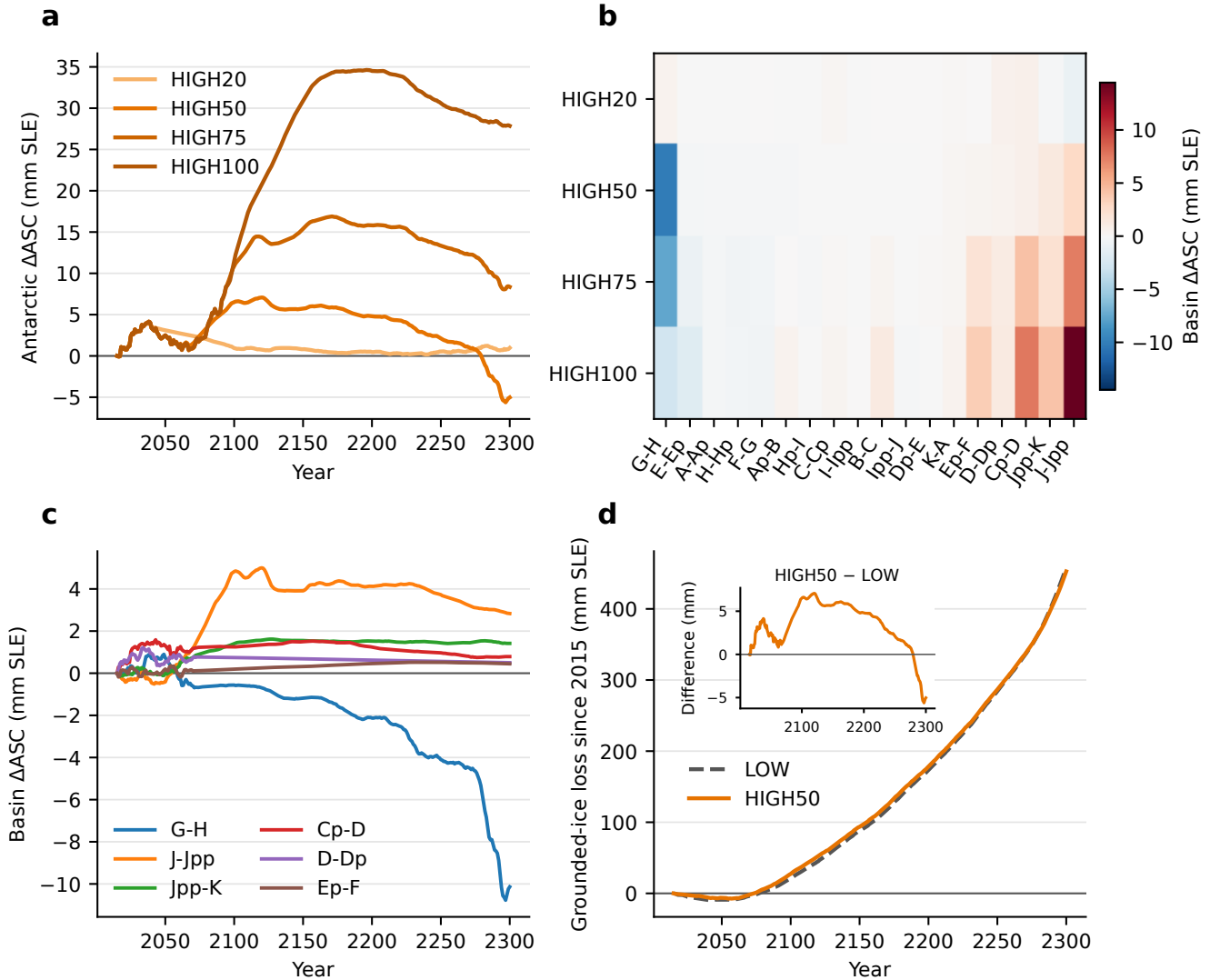


Figure S16. Basin origin of the negative m008 HIGH50 response ($K = 7.75 \times 10^{-5}$; Fig. 5c). **a**, Whole-Antarctic's sea-level contribution (Δ ASC) relative to the matching LOW simulation for m008 under HIGH20, HIGH50, HIGH75 and HIGH100 forcing. **b**, Contributions from the 18 IMBIE basins to Δ ASC in 2300, ordered by contribution under HIGH50. **c**, Time series of the six largest basin contributions to the HIGH50 response in 2300. **d**, Cumulative grounded-ice loss since 2015 under LOW and HIGH50 forcing; inset, the HIGH50-minus-LOW difference. The negative whole-Antarctic HIGH50 response in 2300 (-5 mm SLE) is dominated by smaller grounded-ice loss in basin G-H (-10 mm SLE), which outweighs the positive contributions from the remaining basins. The non-monotonic duration response of m008 is confined to one basin; it is not a continent-wide reversal.

Supplementary Tables

Table S1. Sensitivity experiments for the three sources of modelling uncertainty. The full forcing suite (LOW, HIGH20, HIGH50, HIGH75, HIGH100 and HIGH) was run for each configuration.

Sensitivity	Configurations	Experiments
Basal sliding	Power-law sliding and regularised Coulomb sliding with $C_{\max} = 0.8$ (RC08), $C_{\max} = 0.5$ (RC05) and $C_{\max} = 0.2$ (RC02). RC05 is the reference configuration.	LOW, HIGH20, HIGH50, HIGH75, HIGH100 and HIGH.
Ice-shelf basal melt	ISMIP7 local quadratic formulation with the calibrated 5th-percentile, median and 95th-percentile parameter sets, and an ISMIP6-compatible quadratic formulation as a structural sensitivity. The median ISMIP7 calibration is the reference configuration.	LOW, HIGH20, HIGH50, HIGH75, HIGH100 and HIGH.
Climate forcing	CESM2-WACCM forcing (reference) and MRI-ESM2-0 forcing, with the same ice-sheet model settings.	LOW, HIGH20, HIGH50, HIGH75, HIGH100 and HIGH.

Δ ASC is calculated relative to the LOW simulation with the same configuration (Supplementary Methods).

Table S2. Ice-sheet model configurations used in the sensitivity experiments. The reference configuration is m005. Each forcing experiment is compared with the LOW simulation with the same model configuration. The climate-forcing sensitivity uses the m005 physics with MRI-ESM2-0 forcing, and Δ ASC for that run is calculated relative to the MRI-ESM2-0 LOW simulation.

Member	Sliding relation	$C_{\max}$	Basal-melt formulation	Basal-melt coefficient
m002	Power law	–	ISMIP7 local quadratic	$K_{50} = 4.75 \times 10^{-5}$
m003	Regularised Coulomb	0.8	ISMIP7 local quadratic	$K_{50} = 4.75 \times 10^{-5}$
m005	Regularised Coulomb	0.5	ISMIP7 local quadratic	$K_{50} = 4.75 \times 10^{-5}$
m006	Regularised Coulomb	0.2	ISMIP7 local quadratic	$K_{50} = 4.75 \times 10^{-5}$
m007	Regularised Coulomb	0.5	ISMIP7 local quadratic	$K_{05} = 2.50 \times 10^{-5}$
m008	Regularised Coulomb	0.5	ISMIP7 local quadratic	$K_{95} = 7.75 \times 10^{-5}$
m009	Regularised Coulomb	0.5	ISMIP6 local quadratic	$\gamma_{0,50} = 11075.45 \text{ myr}^{-1}$
m010	Regularised Coulomb	0.5	ISMIP6 local quadratic	$\gamma_{0,05} = 7710 \text{ myr}^{-1}$
m011	Regularised Coulomb	0.5	ISMIP6 local quadratic	$\gamma_{0,95} = 15300 \text{ myr}^{-1}$

Table S3. Climate-forcing variables in the controlled experiments. The HIGH-to-LOW transitions are defined in the Methods.

Variable	Physical quantity	Temporal resolution	Model use
acabf	Downscaled surface mass balance	Monthly	Primary SMB forcing
dacabfdz	SMB–elevation gradient	Annual	Correction for evolving surface elevation
tf	Ocean thermal forcing	Annual	Online calculation of ice-shelf basal melt
so	Practical salinity	Annual	Local-quadratic basal-melt calculation

Table S4. Antarctic’s sea-level contribution in 2300. ASC is the cumulative Antarctic sea-level contribution relative to the common 2015 initial state, and Δ ASC is the additional contribution relative to LOW. EAIS, WAIS and AP are the signed contributions to Δ ASC of the East Antarctic Ice Sheet, the West Antarctic Ice Sheet and the Antarctic Peninsula. Values in mm SLE.

Experiment	ASC	Δ ASC	EAIS	WAIS	AP
LOW	222.9	0.0	0.0	0.0	0.0
HIGH20	224.6	1.7	1.8	0.0	−0.1
HIGH50	225.3	2.3	2.2	0.4	−0.2
HIGH75	231.5	8.6	5.1	3.8	−0.3
HIGH100	244.4	21.5	7.6	14.0	−0.1
HIGH	288.1	65.2	27.0	40.3	−2.1

Table S5. Basin diagnostics of the HIGH20 response relative to LOW at 2300. Positive Δ ASC is a larger loss of grounded ice above flotation under HIGH20. Negative Δ SMB is less cumulative surface accumulation than under LOW; positive Δ basal melt is more cumulative basal melting. The five basins were selected from the basin-resolved HIGH20 response at 2300: C–Cp, Cp–D and D–Dp provide the principal positive EAIS contributions, whereas G–H and J–Jpp provide the dominant opposing contributions in WAIS. The diagnostics support attribution to a process; they are not a closed basin mass budget.

Basin	Sector	Δ ASC (mm SLE)	Cumulative Δ SMB (Gt)	Cumulative Δ basal melt (Gt)	Δ grounded area (km ²)
C–Cp	EAIS	0.297	-177	-40	29
Cp–D	EAIS	0.910	-611	29	24
D–Dp	EAIS	0.589	-387	-4	-36
G–H	WAIS	0.983	-233	381	-67
J–Jpp	WAIS	-1.114	-47	-856	146

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