Cryosphere Dossier III. Previously: I. Nepal Flash Flood Disaster: A Grim Warning as the World's Ice Melts (August 2026) and II. The Mountain Has a Name (September 2026).

Global Ice Melt Crisis: Vanishing Glaciers, Rising Seas and the Choice Still Open

Earth's ice is retreating faster than at any time in the instrumental record, and on some measures faster than in two thousand years. Part of that loss is already paid for. Much of it is still being decided. Here is the ledger, the road, and the levers.

K.J. Parker · Moss Vale, NSW · 1 October 2026 · c. 5,400 words

I. Two valleys

On the morning of 26 August 2026, a mass of ice and rock broke away high in the Langtang Himal and fell more than a thousand metres into the headwaters of the Lhende Khola. Seismometers read the impact as an earthquake. It was not one. The debris dammed the river, the dam failed, and the surge ran down the Bhote Koshi and the Trishuli into the heart of Nepal.[1] By 8 September the national disaster authority had confirmed more than 1,350 deaths, with over five thousand people still unaccounted for.[2] The figures remain provisional. The grief does not.

Fifteen months earlier, in Switzerland's Lötschental, geologists watched the mountain above the Birch Glacier begin shedding rock onto the ice. On 19 May 2025 the roughly 300 residents of Blatten were ordered out within hours.[3] Nine days later the glacier gave way and buried most of the village. One man was reported missing. Everyone else was somewhere else.[4]

The physics in both valleys was the same: warming ice, weakened rock, gravity. What differed was lead time, instrumentation, and the chain of decisions that turned a measurement into a family on the move. Not every collapse gives nine days' notice, and Rasuwa may have given almost none. But the distance between those two valleys is this dossier in miniature. The ice is leaving. What we do still decides how much it takes with it.

The first two Cryosphere Dossiers stayed in the valley. "Nepal Flash Flood Disaster: A Grim Warning as the World's Ice Melts" was written in the first forty-eight hours; "The Mountain Has a Name" sorted the evidence a month on and named the Langtang hypothesis. This one climbs out of the valley to look at the planet's ice as a whole, and asks three questions in order. Where does it stand, measured honestly against the past? Where is the road we are on taking it? And what, at every scale, can still be done?

II. The ledger

Start with the mountain glaciers. They are the fastest readers of the climate and the closest to people.

In the 2025 hydrological year the world's glaciers, excluding the Greenland and Antarctic ice sheets, lost 408 ± 132 gigatonnes of ice and added 1.1 ± 0.4 millimetres to global sea level. Since 1975 the running total is 9,583 ± 1,211 gigatonnes, or 26.4 ± 3.3 millimetres of sea-level rise, and six of the highest-loss years on record fall within the past seven.[5] Annual losses that stayed below 100 gigatonnes between 1976 and 1995 averaged roughly 390 gigatonnes a year across 2016–2025.[6]

An independent reconciliation reached the same shape by a different route. The GlaMBIE community, combining field and satellite methods, found that glaciers lost 273 ± 16 gigatonnes a year from 2000 to 2023, with the rate rising 36 ± 10 per cent between the first and second halves of the period. About 5 per cent of the world's glacier ice has gone since 2000; in Central Europe, 39 per cent. Glacier loss now exceeds Greenland's by about 18 per cent and is more than double Antarctica's.[7]

No region is exempt. The 2024 hydrological year was the third running in which all 19 of the world's glacier regions lost mass.[8] In the Hindu Kush Himalaya, the water tower above Rasuwa, ICIMOD reported in March 2026 that ice-loss rates have doubled since 2000, and that only seven of the 38 field-monitored glaciers it reviewed meet the World Glacier Monitoring Service benchmark standard.[9] We are measuring the world's most consequential mountain ice with a very thin thread.

The ice sheets carry larger numbers and a longer fuse. The newest IMBIE reconciliation, published on 16 September 2026, extends the satellite record back to 1972 for Greenland and 1979 for Antarctica. Between 1979 and 2023 the two sheets lost 11.3 trillion tonnes of ice and raised the sea 3.14 centimetres: 1.81 from Greenland, 1.33 from Antarctica. Greenland's losses rose from about 60 gigatonnes a year in the 1980s to 264 in the 2010s; Antarctica's from about 48 to 202. Some 84 per cent of the combined loss came from outlet glaciers speeding up and discharging ice into a warming ocean, not from surface melt.[10]

The same study records something a dossier must not hide. Between 2020 and 2023 ice-sheet losses slowed, helped by heavy snowfall over East Antarctica and a run of mild Greenland summers; the authors are clear that this is short-term variability, not reversal.[11] Greenland lost about 129 gigatonnes in 2025, below its 2003–2024 average of 219: still a loss, still a trend.[12] Reporting the dip is not reassurance. It is accuracy, and accuracy is what makes the rest of the ledger believable.

Sea ice tells different stories at the two poles. In the Arctic, the 2026 winter peak of 14.29 million square kilometres statistically tied 2025 for the lowest in the 48-year satellite record.[13] The September minimum, 4.60 million square kilometres on 12 September, ranked eleventh-lowest on NSIDC's index, 1.63 million square kilometres below the 1981–2010 average. All twenty of the lowest minima have occurred since 2007.[14] September extent has been comparatively flat for several years: a plateau, not a recovery.

Antarctic sea ice is noisier and less well understood. It fell to a record-low minimum of 1.79 million square kilometres in February 2023, then returned to a near-average, sixteenth-lowest minimum in February 2026 as winds pushed ice outward in the Weddell Sea.[15] The 2026 maximum had not been confirmed at the time of writing.

On land, the frozen ground is warming. Northern Hemisphere spring snow cover has declined since 1978, with high confidence that the decline reaches back to 1950.[16] Northern permafrost soils hold at least 1.4 to 1.6 trillion tonnes of carbon, and in 2024 deep permafrost temperatures reached record highs at nine of twenty long-term Alaskan sites. The 2024 Arctic Report Card found that the tundra region, once wildfire emissions are counted, has shifted from long-term carbon sink to source.[17]

Exhibit 1 · The cryosphere ledger, each component against its own benchmark

Latest measured state, the benchmark the literature supports, and how far that benchmark reaches

Component	Latest measure	Benchmark	Reach
Mountain glaciers	2025: −408 ± 132 Gt. Since 1975: −9,583 ± 1,211 Gt (26.4 mm sea level).	Synchronous global retreat since the 1950s unprecedented in ≥2,000 years (medium confidence).	Millennia
Greenland Ice Sheet	1979–2023: +1.81 cm sea level. ~264 Gt/yr in the 2010s; ~129 Gt in 2025.	Close to balance in the 1970s; net loss every decade since.	Instrumental
Antarctic Ice Sheet	1979–2023: +1.33 cm sea level. ~202 Gt/yr in the 2010s.	Loss driven by ocean-forced glacier acceleration; East Antarctic snowfall offsets vary.	Instrumental
Arctic sea ice	Sept 2026 min 4.60 M km² (11th lowest). 2026 max tied record low.	Late-summer area smallest in ≥1,000 years (medium confidence).	Millennia
Antarctic sea ice	Record-low min 1.79 M km² (2023); 2026 min near average.	Satellite era only; high natural variability.	Too short to rank
N. Hemisphere snow	Spring snow cover declining since 1978.	Decline extends back to 1950 (high confidence).	Instrumental
Permafrost	Record deep temperatures at 9 of 20 Alaskan sites (2024). Holds 1.4–1.6 trillion t carbon.	No global palaeo-benchmark; tundra now a net carbon source incl. fires.	Too short to rank

● Unusual against a millennial palaeo-record (IPCC AR6) ● Record or trend within the instrumental era

◌ Record too short, or variability too high, to rank against the deep past

CAVEAT

Each component is measured over a different period and baseline, so rows are not directly comparable. “Reach” reports how far back the literature itself supports a comparison; it is not a severity score. Uncertainties are as published. Antarctic sea-ice maximum for 2026 was unconfirmed at publication; Arctic ranks differ between NSIDC and OSI SAF indices.

Sources: WGMS Network (2026); Otosaka et al. (2026, IMBIE); NOAA Arctic Report Cards 2024–25; NSIDC/NASA (2026); IPCC AR6 WGI (2021).

Exhibit 1. Where the ice stands. Sources: WGMS; IMBIE; NOAA; NSIDC/NASA; IPCC AR6.

III. What the benchmarks say

A record set within a 48-year satellite archive is one thing. The harder question is whether the present is unusual against centuries and millennia. Here the language must follow the literature exactly, because “unprecedented” is the most abused word in climate writing.

The IPCC’s Sixth Assessment is specific. The near-synchronous retreat of almost all the world’s glaciers since the 1950s is unprecedented in at least 2,000 years (medium confidence). Late-summer Arctic sea-ice area is smaller than at any time in at least 1,000 years (medium confidence), and its 2011–2020 annual average was the lowest since at least 1850 (high confidence). Global mean sea level has risen faster since 1900 than in any preceding century of at least the past 3,000 years (high confidence).[18]

Equally important is what cannot be claimed. Antarctic sea ice has no comparable millennial reconstruction, so its recent lows are remarkable within the satellite era and no further. Permafrost has no clean global palaeo-benchmark. The ice sheets' Holocene stability is inferred rather than measured year by year; what the new IMBIE record does show is that Greenland was close to balance as recently as the 1970s.[19]

The deep past offers one benchmark worth carrying. About 125,000 years ago, in the Last Interglacial, global temperatures were roughly 0.5–1.5 °C above pre-industrial and sea level stood some 5–10 metres higher than today.[20] That is not a forecast for this century. It is a statement of where ice sheets settle, given time, at temperatures close to ours.

IV. The road we are on

Not the worst case and not the best: the road.

Human-induced warming reached 1.37 °C above pre-industrial in 2025 and is rising at about 0.27 °C a decade. The remaining carbon budget for an even chance of holding 1.5 °C was about 130 billion tonnes of CO_2 at the start of 2026, roughly three years of current emissions.[21] UNEP's 2025 assessment puts the world on course for about 2.8 °C this century under current policies, and 2.3–2.5 °C if every national pledge is delivered in full.[22]

On that road, glaciers are the most predictable component, because their loss scales almost linearly with temperature. Rounce and colleagues projected losses by 2100 of 26 ± 6 per cent of glacier mass at 1.5 °C and 41 ± 11 per cent at 4 °C, with 49 to 83 per cent of the world's glaciers disappearing outright.[23] Zekollari and colleagues ran eight models forward until the ice came to rest with the climate. At 2.7 °C, the paper's current-policy benchmark, only 24 per cent of today's glacier mass survives; at 1.5 °C, 53 per cent does. Each additional tenth of a degree costs roughly 2 per cent of the world's glacier ice.[24]

For the water glaciers release, the arithmetic turns cruel with time. Melt first swells rivers; then, once the ice is too small to sustain it, flow declines. Huss and Hock found that about 45 per cent of 56 large glacierised basins, home to nearly a third of humanity, had already passed this "peak water".[25] Most Hindu Kush Himalaya basins are expected to peak around mid-century, and the region's glaciers could lose up to 80 per cent of their volume by 2100 on high emissions.[26]

Sea level is the long tail. For 2100 the IPCC's likely range runs from 0.28–0.55 metres under very low emissions to 0.63–1.01 metres under very high, relative to 1995–2014. Over two millennia the roads diverge sharply: about 2–3 metres if warming is held to 1.5 °C, 2–6 metres at 2 °C.[27] Greenland alone, out of balance with the climate it already has, has committed at least 27 centimetres whatever comes next.[28] IMBIE's authors note that high-end estimates for 2150 rise by a factor of 2.6 once ice-sheet instability is included, which is why the ice sheets remain the largest single uncertainty in every projection.[29]

Who stands in the way? Around 670 million people live in high mountain regions and around 680 million in the low-lying coastal zone, a number projected to pass one billion by 2050.[30] The Arctic, meanwhile, is projected to be practically free of sea ice in September at least once before 2050 under every scenario the IPCC assessed.[31]

V. What the ice holds up: the living world

Ice is not only a quantity. It is a surface, a habitat and a regulator, and its loss travels outward through everything those roles support.

The mirror

Snow and sea ice reflect most of the sunlight that reaches them; open ocean absorbs most of it. As the white surface shrinks, the planet darkens and warms faster, which shrinks the white surface further. Satellite measurements show the Arctic's planetary albedo falling from 0.52 to 0.48 between 1979 and 2011, adding 6.4 ± 0.9 watts per square metre of solar energy to the region. Averaged over the globe, that darkening equalled a quarter of the direct forcing from rising CO_2 over the same period.[32] The same team estimated that losing Arctic sea ice through the whole sunlit season would add heating equivalent to about a trillion tonnes of CO_2 emissions, bringing global warming forward by some 25 years.[33]

The Antarctic now counts too. A 2024 reconstruction found that global sea ice has lost 13–15 per cent of its planetary cooling effect since the early 1980s, and that Antarctic changes since 2016 have strengthened the warming feedback from sea-ice loss by about 40 per cent.[34]

There is a lever inside this mirror. Because summer sea ice tracks temperature rather than tipping, the reflectivity it provides would return if warming were reversed. Of all the amplifiers in this dossier, it is the one that runs backwards.

Life on the ice

The emperor penguin is the clearest case. It raises its chicks on sea ice that must hold until they fledge; when the ice breaks out early, the colony's year is lost. Satellite counts across the Antarctic Peninsula and the Weddell and Bellingshausen seas, home to about a third of the species, show a 22 per cent decline between 2009 and 2023, faster than models had projected even under high warming.[35] On 9 April 2026 the IUCN listed the emperor penguin as Endangered.[36]

In the Arctic, the polar bear hunts seals from the ice and fasts when it is gone. Modelling how long bears can fast against projected ice-free days, Molnár and colleagues found that thresholds for cub recruitment and adult survival may already have been crossed in some subpopulations, and that under high emissions all but a few high-Arctic subpopulations would be jeopardised by 2100. Moderate mitigation prolongs their persistence, though probably not for every subpopulation.[37]

Beneath both sits Antarctic krill, the small crustacean that feeds whales, seals, penguins, fish and seabirds, and whose young shelter and feed beneath winter sea ice. In its main population centre in the south-west Atlantic, krill has contracted toward the continent, its centre of distribution shifting about 440 kilometres south over four decades as fewer juveniles enter the population.[38] Trends in total abundance remain debated; the authors themselves describe the evidence as scarce and conflicting. The direction of travel is not in doubt.

Birds carry the signal across hemispheres. Red knots breeding in the high Arctic produce smaller, shorter-billed young in summers of early snowmelt, probably through poor early nutrition. On their West African wintering

grounds those short-billed birds cannot reach deeply buried shellfish, and they survive less well.[39] A warming tundra kills a bird on a tropical mudflat half a world away.

Mountain rivers lose their specialists. In the European Alps, cold-water invertebrates such as stoneflies and midges depend on glacial meltwater; as that influence fades their refuges move upslope, and today's protected areas cover those future refuges poorly.[40] Yet retreating ice also exposes new ground. By 2100 glacier loss could open 149,000 to 339,000 square kilometres of new land, freshwater and marine ecosystems, an area between the size of Nepal and of Finland, and less than half of today's glacier area lies inside protected areas.[41] That is a lever, plainly stated: the ecosystems of the next century can be protected before they exist.

Cascades

The ice's systems are coupled, and the couplings are where risk compounds. Four matter most.

Sea ice to food web. Less winter ice means fewer krill recruits, and fewer krill means hungrier penguins, seals and whales: a chain already measured at its first links. *Permafrost to fire to carbon.* Thawing ground and longer fire seasons have turned the tundra region from a carbon sink into a source, feeding the warming that thaws it.[42] *Greenland to the Atlantic.* Meltwater freshens the North Atlantic; the IPCC judges it very likely that the Atlantic Meridional Overturning Circulation weakens this century, with medium confidence that it will not collapse abruptly before 2100.[43] *Glaciers to rivers to people.* As meltwater peaks and then declines, the ecology downstream, and the farms, cities and turbines that rely on it, lose their dry-season buffer.

None of these cascades is new to science. What is new is that several are now observed rather than merely modelled.

Exhibit 6 · How ice loss travels: six cascades and their levers

Each row follows one chain from the ice outward; ↺ marks a loop that feeds warming back

The ice	First effect	Downstream		Lever
Arctic and Antarctic sea ice	→ Darker ocean absorbs more sunlight	→ **More warming**	↺	***Reversible: ice returns if warming falls***
Antarctic sea ice	→ Fewer krill recruits; range contracts south	→ Penguins, seals, whales, seabirds go hungry		***Precautionary krill fishery; limit warming***
Permafrost	→ Thaw, fire, carbon release	→ **More warming; roads and buildings fail**	↺	***Limit warming; build for thaw***
Greenland Ice Sheet	→ North Atlantic freshens	→ Overturning circulation very likely weakens		***Limit warming; keep monitoring***
Mountain glaciers	→ Peak water, then decline; outburst floods	→ Farms, cities, hydropower, river treaties		***Shared data, storage, early warning***
Ice sheets and glaciers	→ Sea-level rise	→ Coasts, deltas, atolls, statehood		***Defences; statehood-continuity law***

CAVEAT

The links differ in strength of evidence. Albedo loss, permafrost carbon release and sea-level rise are measured; the krill chain is observed regionally while total krill abundance is contested; AMOC weakening is a very likely projection, not an observed collapse. Levers are illustrative of documented responses, not a complete list.

Sources: Pistone et al. (2014, 2019); Duspayev et al. (2024); Atkinson et al. (2019); Fretwell et al. (2025); NOAA Arctic Report Card 2024; IPCC AR6 WGI (2021); Huss and Hock (2018); Kulp and Strauss (2019).

Exhibit 6. The cascades and their levers. Sources: Pistone et al.; Duspayev et al.; Atkinson et al.; Fretwell et al.; NOAA; IPCC AR6.

VI. What the ice holds up: the human world

The water towers

In the Hindu Kush Himalaya alone, glaciers and snow feed rivers that serve some 240 million people in the mountains and 1.65 billion downstream.[44] For them, peak water is not an abstraction but a timetable for when the dry-season river begins to fail. The hazards arrive first and the scarcity later; Rasuwa was the hazard. In the Arctic the ground itself gives way, and the cost falls first on remote and Indigenous communities, often with little outside help.[45]

The low land

Sea-level rise is the ice's most universal consequence and its least equal. Improved elevation data show that about 110 million people already live on land below the high-tide line, held back by defences. By 2050, land now home to roughly 300 million people could fall below the annual flood level, and about a billion people live within ten metres

of high tide. Six Asian countries, China, Bangladesh, India, Vietnam, Indonesia and Thailand, hold most of that exposure.[46]

For atoll nations the question is existential in the literal sense. Tuvalu's roughly 10,600 people live on islands whose highest point is about six metres above the sea. Under the Falepili Union, in force since August 2024, Australia committed to recognise Tuvalu's continuing statehood whatever the sea does and opened 280 residence places a year; some 8,750 Tuvaluans, more than four in five, entered the first ballot.[47] In July 2025 the International Court of Justice's advisory opinion on climate obligations recorded strong support among states for the continuity of statehood of nations affected by sea-level rise.[48] International law is moving to keep nations whole even where their land may not be. The lever here is legal, and it is already being pulled.

The bill

The economics run in two directions, and the second matters more. Without adaptation, coastal flooding in 2100 could reach 0.2–4.6 per cent of the world's population every year and cost 0.3–9.3 per cent of global GDP annually, under 25–123 centimetres of sea-level rise. Dikes would cost US$12–71 billion a year by 2100, far less than the damage they avoid, and end-of-century flood losses turn out to depend more on the protection strategy chosen than on the climate scenario.[49]

In the far north the bill arrives through the ground. One circumpolar assessment put permafrost-thaw damage to Arctic infrastructure at about US$276 billion under a high-emissions scenario, affecting 44 per cent of roads and 17 per cent of buildings.[50] A 2025 study estimated US$37–51 billion in damage to Alaska's roads and buildings by mid-century, about double earlier estimates.[51] Mountain economies built on hydropower, irrigation and tourism face the same arithmetic on a slower clock.

The honest summary: the damage curve rises with every centimetre and every tenth of a degree, but protection is far cheaper than loss, and the spending is a choice.

The map redrawn

Ice has always been a border as well as a landscape. As it retreats it rearranges access, and access rearranges power.

In the Arctic, Russia's Northern Sea Route logged 103 transit voyages in 2025, including a record 15 container-ship transits. The route remains seasonal and small, but it can be up to 40 per cent shorter than conventional Europe–Asia passages.[52] Greenland, astride the emerging sea lanes and holding rare earths and other critical minerals, has become a focus of great-power competition, sharpened by the US president's campaign to bring the island under American control.[53]

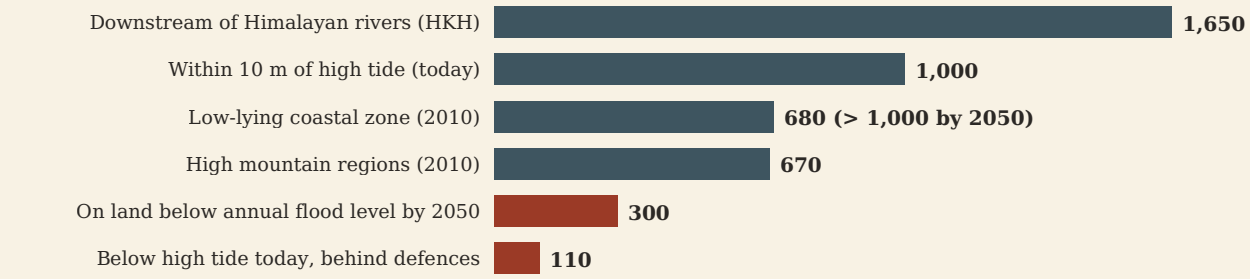
In High Asia the stakes are water. India placed the 1960 Indus Waters Treaty in abeyance in April 2025 after a terrorist attack, citing Pakistan's support for cross-border terrorism. The dispute is political rather than glacial, but it unfolds in a basin whose glacier-fed flows the treaty's drafters never had to account for.[54] Three months later China began building a 60,000-megawatt hydropower project at Medog on the Yarlung Tsangpo, about 30 kilometres upstream of India, on the river that becomes the Brahmaputra. India and China have no treaty on that river, only an expert-level mechanism for sharing data.[55] As meltwater peaks and declines, control of upstream storage becomes leverage.

None of this is fate. The Indus treaty had survived wars and nuclear standoffs before 2025.[56] The Antarctic Treaty has held a whole continent for science and peace since 1959. And Rasuwa showed that a flood from one country's glacier is another country's disaster, which makes cross-border warning a security interest rather than a courtesy. The geopolitics of melting ice reward those who share data and punish those who hoard it.

Exhibit 7 · Who stands in the path, and what the bill looks like

Exposure measures overlap and use different years; costs come from different models and do not add up

A. People living where ice loss reaches them (millions)



B. The bill, and the cheaper alternative

Coastal flood losses in 2100 without adaptation	**0.3–9.3% of world GDP a year**
Coastal protection with dikes in 2100	**US$12–71 billion a year**
Arctic infrastructure damage from thaw (high emissions)	**about US$276 billion**
Alaska roads and buildings, to mid-century	**US$37–51 billion**
Loss and damage fund pledges to mid-2026	**about US$0.82 billion**

CAVEAT

Populations are from separate studies (IPCC SROCC; ICIMOD; Kulp and Strauss) and overlap; they are not cumulative. Coastal loss and protection figures come from one global model (Hinkel et al.) under 25–123 cm of sea-level rise; the Arctic infrastructure figure is for a high-emissions pathway. The lesson the numbers support is directional: protection costs far less than the damage it avoids.

Sources: IPCC SROCC (2019); Wester et al. (2023); Kulp and Strauss (2019); Hinkel et al. (2014); Streletskiy et al. (2023); Manos et al. (2025); FRLD Board (2026).

Exhibit 7. Exposure and cost. Sources: IPCC SROCC; Wester et al.; Kulp and Strauss; Hinkel et al.; Streletskiy et al.; Manos et al.; FRLD.

VII. Committed and choosable

This is the distinction on which honest writing about ice depends, so it is worth making slowly.

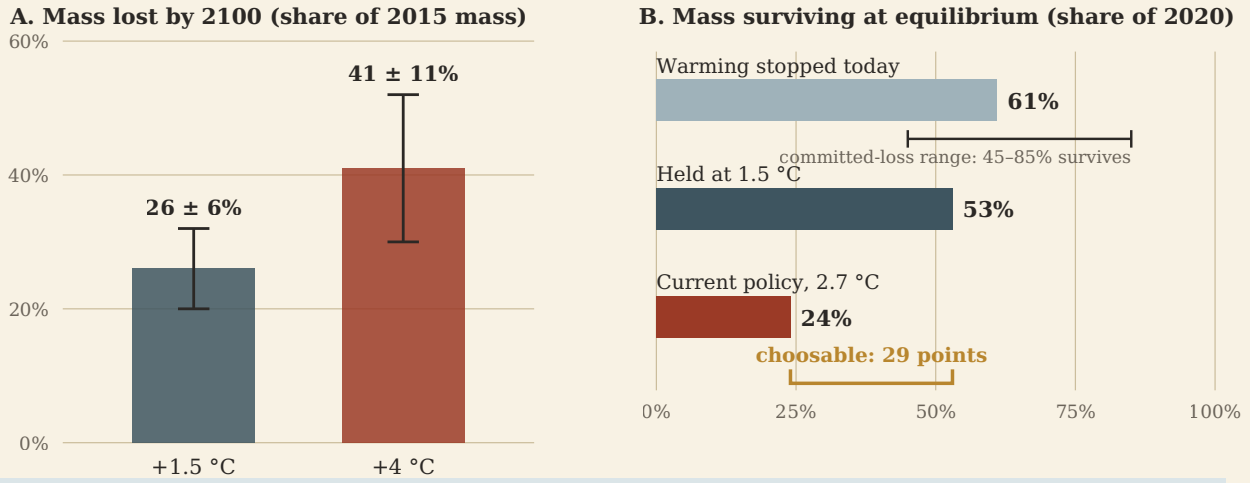
Committed loss is ice already sentenced by warming that has happened. Zekollari's team estimates that even if global temperature froze at today's level, glaciers would eventually lose 39 per cent of their 2020 mass (range 15–55 per cent) and add 113 millimetres to the sea.[57] Greenland's 27 centimetres belong in the same column. No policy made today saves that ice.

Choosable loss is everything beyond it. On the equilibrium arithmetic, the difference between 1.5 °C and the current-policy road is the difference between keeping half the world's glacier ice and keeping a quarter. That gap is not a forecast. It is a decision, and it is still open.

> *“Committed” and “choosable” are different words. Doomism lives in the space where they are allowed to blur.*

Exhibit 2 · Committed and choosable: what the next tenth of a degree is worth

Two independent model studies of the world’s glaciers (excluding the ice sheets)



Committed even if warming stopped today: 39% of 2020 glacier mass (range 15–55%), about 113 mm of sea-level rise. Every 0.1 °C beyond costs roughly another 2%.

CAVEAT

Panel A is change by 2100; panel B is the long-run end state after centuries of adjustment, so the two are not directly comparable. Panel B shows central values for 1.5 °C and 2.7 °C; their multi-model ranges are published in the source and not drawn here. The paper’s 2.7 °C current-policy benchmark predates UNEP’s 2025 estimate of 2.8 °C.

Sources: Rounce et al., Science (2023); Zekollari et al., Science (2025).

Exhibit 2. The committed and the choosable. Sources: Rounce et al. 2023; Zekollari et al. 2025.

Reversibility is where the choice acquires its urgency. It is tempting to believe that if we overshoot, carbon removal can bring the ice back later. The emerging literature says: slowly, partially, and at a price. Schuster and colleagues modelled a world that climbs to 3 °C and returns to 1.5 °C by 2300. Its glaciers lose about 16 per cent more mass by 2200, and 11 per cent more by 2500, than in a world that never overshoots. Where glaciers do regrow, they lock water away as they grow, so rivers run lower for decades to centuries: a phenomenon the authors call “trough water”.[58] UNEP estimates that reversing each 0.1 °C of overshoot would require permanently removing about five years of current global CO_2 emissions.[59]

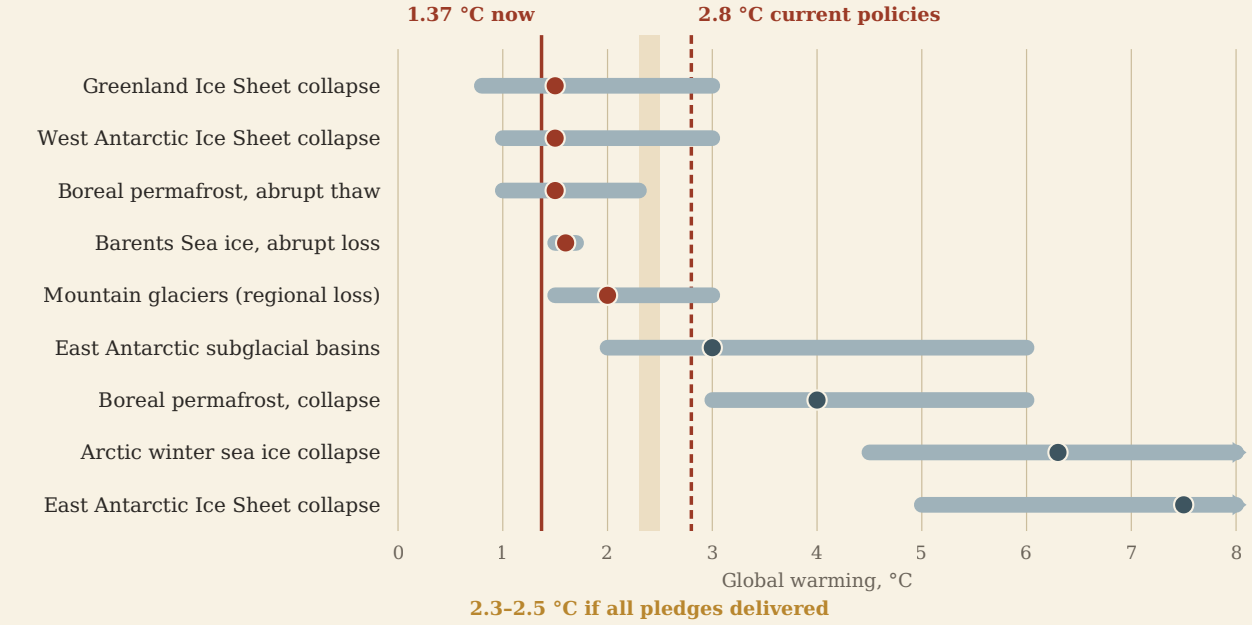
The lesson is not that repair is impossible. It is that a tonne not emitted now buys far more ice than a tonne removed later.

Tipping elements sharpen the same point. The most-cited synthesis places the thresholds for the Greenland and West Antarctic ice sheets, and for abrupt thaw of boreal permafrost, around 1.5 °C, each with wide ranges; for Greenland, anywhere from 0.8 to 3 °C.[60] A study published in March 2026 mapped the Antarctic sheet basin by basin. It found a

first threshold, possibly as low as 1–2 °C, beyond which about 40 per cent of West Antarctica's marine ice is set on a path to long-term collapse, and suggested the process may already be under way in places.[61] Crossing such a threshold commits loss rather than delivering it overnight. Ice-sheet collapse unfolds over centuries to millennia, and a brief overshoot may be survivable if temperatures come back down quickly. The synthesis's lead author has been plain that crossing some of these thresholds would lock in serious impacts without triggering runaway warming.[62] Arctic summer sea ice is not treated as a tipping element at all: its loss tracks temperature, and it would return if temperature fell.[63]

Exhibit 3 · Cryosphere tipping elements against the road we are on

Assessed threshold (dot; brick if below 2.5 °C) and plausible range (bar), °C above pre-industrial



CAVEAT

Thresholds are expert-assessed central estimates and ranges with differing confidence (lower for permafrost than for Greenland). Crossing a threshold commits change that may take centuries to millennia to unfold; a brief overshoot may be survivable. Arctic summer sea ice is absent because its loss is not considered self-perpetuating. Ranges beyond 8 °C are truncated (arrow).

Sources: Armstrong McKay et al., Science (2022), Table 1; Forster et al. (2026); UNEP Emissions Gap Report 2025.

Exhibit 3. Thresholds against the road. Sources: Armstrong McKay et al. 2022; Forster et al. 2026; UNEP 2025.

VIII. The evidence, tiered

Dossier box · The prognosis, sorted by strength of evidence

Fact

All 19 glacier regions lost mass in 2024, the third year running. Glaciers lost about 390 gigatonnes a year over 2016–2025. Both ice sheets have been in net loss throughout the satellite era. Arctic sea ice has declined in every month since 1979. Glacier loss scales roughly linearly with warming.

Strong inference

Around 39 per cent of 2020 glacier mass (range 15–55) is committed at today's temperature. Greenland has committed about 27 centimetres of sea-level rise. The Arctic will be practically ice-free in September at least once before 2050. Many glacier basins are past peak water, most Himalayan basins near mid-century. The 2020–2023 ice-sheet slowdown is variability, not reversal. Sea-ice loss is darkening the planet and amplifying warming. Emperor penguins and several polar bear subpopulations are in decline tied to sea-ice loss.

Contested

Whether parts of the West Antarctic Ice Sheet are already past a tipping point; a 2026 basin-by-basin study suggests some may be. The causes and persistence of Antarctic sea-ice lows since 2016. The exact location of tipping thresholds, whose ranges remain wide. Attribution of individual collapses, Rasuwa included, to warming rather than to local geology. The trend in total Antarctic krill abundance. How far the Atlantic overturning circulation will weaken.

Speculation

Sea-level rise approaching 2 metres by 2100 under very high emissions, which the IPCC says cannot be ruled out but assesses at low confidence.[64] Engineered stabilisation of an ice sheet this century. Permafrost carbon feedbacks beyond currently assessed ranges.

IX. Slow it

The first lever is the only one that addresses the cause. The title of the Rounce paper says it plainly: every increase in temperature matters. For glaciers, each tenth of a degree avoided is roughly 2 per cent of the world's ice kept.

The curve is bendable, and has already bent. When the Paris Agreement was adopted, current policies pointed to warming just under 4 °C; UNEP now places them just under 3 °C.[65] That is not success. It is proof that the trajectory answers to effort. Cost curves explain much of the bend: between 2010 and 2024 the average cost of electricity from new utility-scale solar fell 90 per cent, and battery storage costs fell 93 per cent.[66]

There is a precedent for a global atmospheric problem being solved rather than merely managed. Under the Montreal Protocol nearly 99 per cent of banned ozone-depleting substances have been phased out, and the ozone layer is on course to return to 1980 values around 2066 over Antarctica and 2040 elsewhere.[67] The hole took decades to open and will take decades to close. But it is closing, because the world decided it should.

X. Manage it

The second lever accepts that committed loss is coming and asks how few people it need harm.

Blatten is the template: monitoring that sees the precursors, authority that acts on them, and residents who trust the warning enough to leave. The Himalaya has its own record. Nepal lowered Tsho Rolpa by three metres in 2000, and Imja by 3.4 metres in 2016 after six months' work by army engineers and about a hundred local volunteers above 5,000 metres, with an automated warning system installed downstream.[68] Bhutan's Thorthormi project, which set out to lower the lake by five metres, was carried out largely by hand because heavy machinery could not safely work the moraines.[69]

These are real successes, and honest reporting must add the qualification the engineers themselves give. At both Nepali lakes, scientists had recommended lowering by ten to twenty metres; budgets stopped the work at about three. Nepal is now preparing to drain four more lakes, and experts warn that lowering a lake is not the same as removing its risk.[70] In Rasuwa, alerts were blunted by the speed of the flood and by reliance on SMS alone.[71] Management works. Underfunded management works partially.

The money shows the same gap. The Fund for responding to Loss and Damage had attracted pledges equivalent to about US$823 million by mid-2026, and its start-up phase allocates US$250 million across 2025 and 2026.[72] Estimates of developing countries' annual loss-and-damage needs run to hundreds of billions of dollars.[73] The United Nations declared 2025 the International Year of Glaciers' Preservation and 2025–2034 the Decade of Action for Cryospheric Sciences.[74] The declarations are right. Seven benchmark glaciers across the Hindu Kush Himalaya is what they are currently buying.

XI. Repair it

The third lever is the least mature. It deserves neither ridicule nor salesmanship.

In September 2025 a team led by the glaciologist Martin Siegert assessed the five most-developed polar geoengineering concepts: stratospheric aerosol injection; sea curtains anchored to the seabed to hold warm water off ice shelves; thickening or brightening sea ice; pumping meltwater from beneath fast-flowing glaciers; and ocean fertilisation. None, they concluded, can be relied on in the coming decades. No field experiments existed for sea curtains or sea-ice brightening, basal-water removal had gone no further than limited drilling, and each concept carried environmental risk and, in some cases, no governance framework at all.[75]

The strongest counter-case comes from the researchers doing the fieldwork. The UK's Advanced Research and Invention Agency has committed £56.8 million to 22 climate-cooling research projects, arguing that ignorance is not safety: if the world ever faces a decision about intervention, it should face it with evidence.[76] In May 2026 the first peer-reviewed full-season trial of winter flooding to thicken Arctic sea ice, run by Real Ice at Cambridge Bay, Nunavut, reported a measurable effect on the ice through both the growth and melt seasons.[77]

Both positions can be true at once. At its actual readiness level, sea-ice thickening is a local field experiment; sea curtains and basal-water removal are concepts and models; none is a plan. Research that is governed, community-consented and published in full is defensible. Research that becomes an argument for delay is not. The only repair technology operating at planetary scale today is the carbon we choose not to emit.

Exhibit 4 · The record of things that worked

Measured, cited results: evidence that the levers move when pulled

The curve has bent

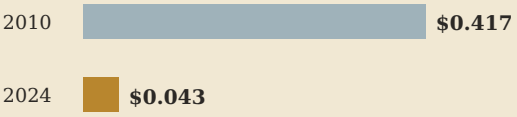
Warming projected under current policies



Still far above 1.5 °C: bent, not solved.

Clean power got cheap

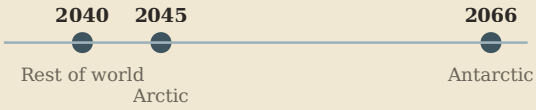
Utility-scale solar, average cost per kWh (US$)



−90% solar; battery storage −93% (2010–2024).

An atmospheric crisis, being mended

Montreal Protocol: nearly 99% of banned ozone-depleting substances phased out. Projected return to 1980 ozone values:



Warning and engineering save lives

Blatten, 2025: about 300 residents evacuated nine days before the Birch Glacier collapse.

Nepal: Tsho Rolpa lowered 3 m (2000); Imja lowered 3.4 m (2016), with downstream early warning.

Recommended lowering was 10–20 m.

CAVEAT

"Worked" means risk reduced or a trend bent, not a problem finished. Current-policy warming remains near 3 °C; ozone recovery takes decades; Nepal's lakes were lowered by a fraction of what scientists advised because budgets ran out; Blatten had days of visible precursors that many collapses, possibly including Rasuwa, do not give.

Sources: UNEP (2025); IRENA (2025); WMO/UNEP ozone assessment (2022–23); blue News (2025); New Humanitarian (2017); Asia News Network (2026).

Exhibit 4. What worked, and its limits. Sources: UNEP; IRENA; WMO/UNEP; blue News; Asia News Network.

XII. The Reversibility Wager

Every dossier ends with a named position and a way to test it. This one is a theory of repair.

The Reversibility Wager. A large share of the ice now melting is already committed. But the share that survives (half the world's glacier ice or a quarter; two metres of long-term sea-level rise or six) is still being decided, mostly by emissions this decade, and the human toll of what is committed can be cut sharply by monitoring, warning and money. Acting on the choosable fraction will produce measurable results within a human lifetime, and the evidence will show whether it is working.

Three objections deserve their strongest form.

It is already committed. The fatalist case: warming is baked in, the ice is gone, emissions policy is theatre. The answer lies in the very models the fatalist would cite. Committed loss is real, perhaps 39 per cent of glacier mass, but

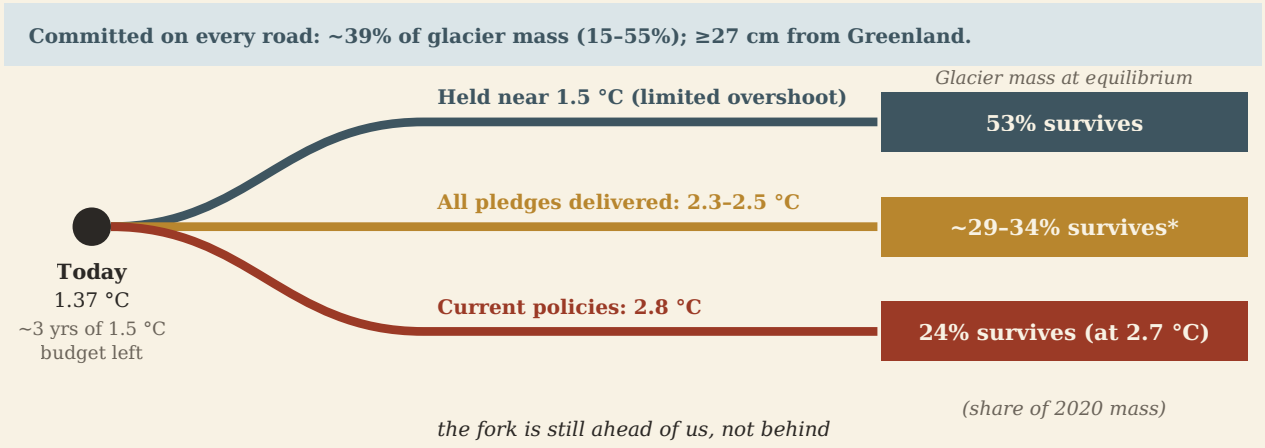
the equilibrium difference between 1.5 °C and 2.7 °C is a further 29 percentage points of the world's glacier ice. Fatalism takes the committed number and quietly applies it to the whole.

Just adapt. The adaptation-only case: mitigation is failing, so spend on walls, warnings and relocation. Adaptation is indispensable, but the ice sets its limits. Peak water cannot be engineered around once the reservoir in the mountains is gone, and Nepal's lakes show adaptation already rationed by budget at today's warming. Every tenth of a degree raises the bill.

Moral hazard. The sceptic's case: research into intervention invites delay. This is the strongest of the three and partly right; the Siegert assessment is its best evidence. The answer is sequencing and governance, not ignorance. Research small, publish everything, deploy nothing ungoverned, and never count an unbuilt technology as a tonne avoided.

Exhibit 5 · The scenario gap is a decision still open

From today's warming to three roads, and what each leaves of the world's glacier ice



CAVEAT

*The pledges outcome is the author's linear interpolation between the source's 1.5 °C and 2.7 °C cases, not a modelled result. Equilibrium takes centuries; the roads describe end states, not 2100. Overshooting and returning costs extra ice for centuries (Schuster et al. 2025), so the roads are not interchangeable later.

Sources: Zekollari et al. (2025); Box et al. (2022); Forster et al. (2026); UNEP (2025).

Exhibit 5. The fork ahead. Sources: Zekollari et al. 2025; Box et al. 2022; Forster et al. 2026; UNEP 2025.

How we would know it's working

The wager can be falsified. These are the indicators, and the timescales on which they should move.

Within five years: global fossil CO_2 emissions have peaked and are falling; the loss-and-damage fund has turned most pledges into disbursements; the number of WGMS-standard reference glaciers in the Hindu Kush Himalaya rises above seven.

Within ten to fifteen years: the rate of human-induced warming reported in the annual *Indicators of Global Climate Change* falls measurably below 0.27 °C a decade; deaths per glacier-hazard event fall wherever early warning has been installed; the share of newly deglaciated land under protection rises from today's less than half.

Within a decade or two of warming stabilising: Arctic September sea-ice extent stops declining. Sea ice is the fastest reader of the wager, because its loss tracks temperature without a long memory. If temperature steadies and the ice does not, the premise is wrong.

Over decades: observed glacier losses track the projections for the warming actually delivered. If emissions fall and glaciers keep losing mass at rates the models reserve for much hotter worlds, then more is committed than we think, and the wager must be revised toward the pessimists. That, too, would be knowledge worth having.

XIII. The hand on the lever

Go back to the two valleys. In one, a village lies under rubble and its people are alive to rebuild it. In the other, a nation is still counting. The ice did not choose between them. People, instruments and budgets did.

The same is true at the scale of the planet. The ledger of loss is written in gigatonnes, and much of it is already in ink. But the largest number in this dossier is not a loss. It is the gap between 24 and 53 per cent: the share of the world's glacier ice still waiting on a decision.

That decision is not abstract. It is a vote, a pension fund, a grid connection, a seawall in Funafuti, a data-sharing protocol on a Himalayan river, a budget line for a gauge below a glacial lake. It is a hand on a lever, and the lever still moves.

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Provisional figures. The Rasuwa casualty figures are provisional government bulletins and have changed repeatedly. Tipping-point values in Exhibit 3 were checked against Armstrong McKay et al. (2022), Table 1, as reproduced in independent sources. Where a figure rests on a secondary or wire source, the endnote says so. The pledges outcome in Exhibit 5 is the author’s interpolation and is labelled as such.

Method. Written to the Dossier Method: four-tier evidence sorting, counter-arguments in their strongest form, and a named, falsifiable position. Direct quotation kept to a minimum; all figures paraphrased from their sources.