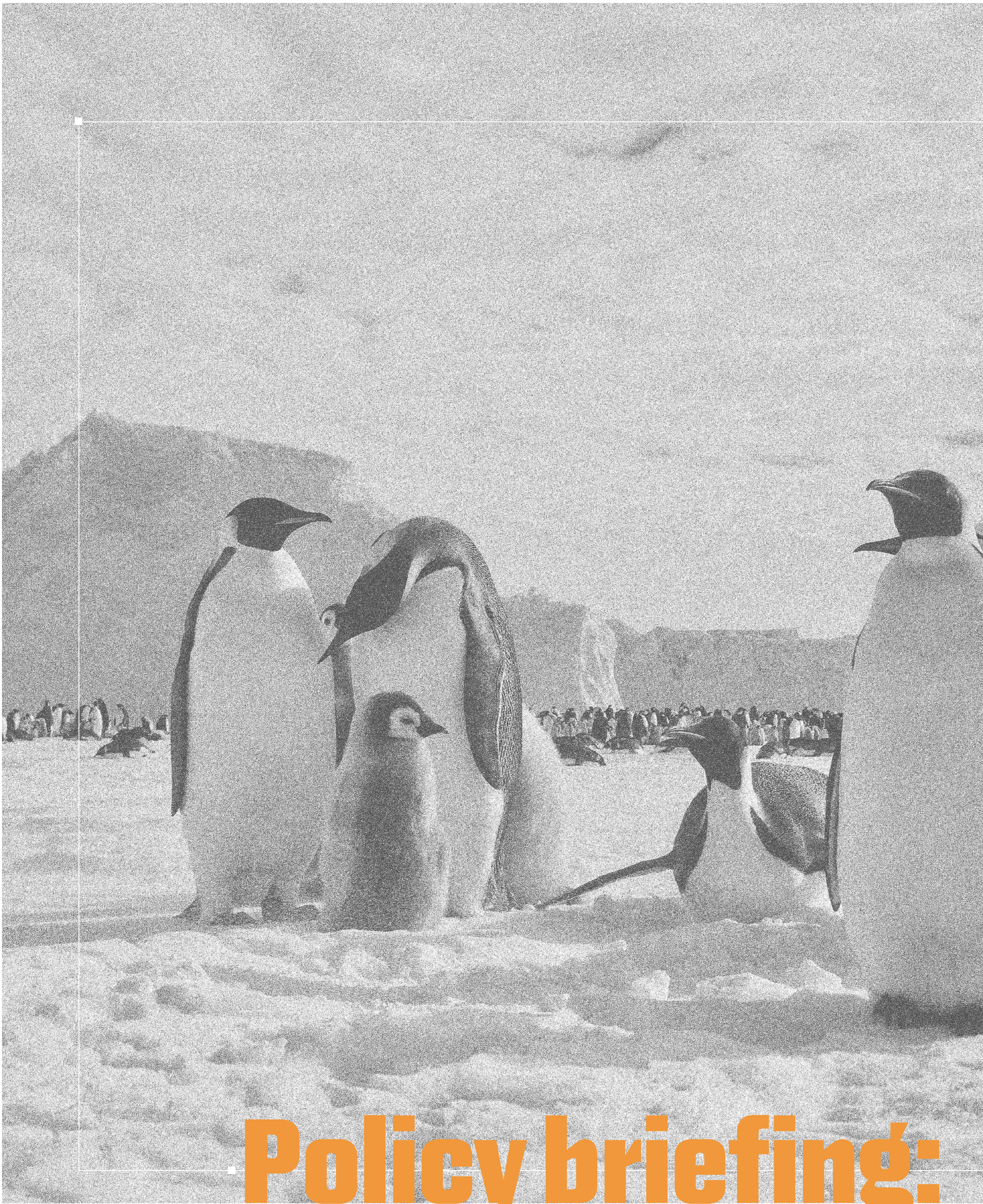
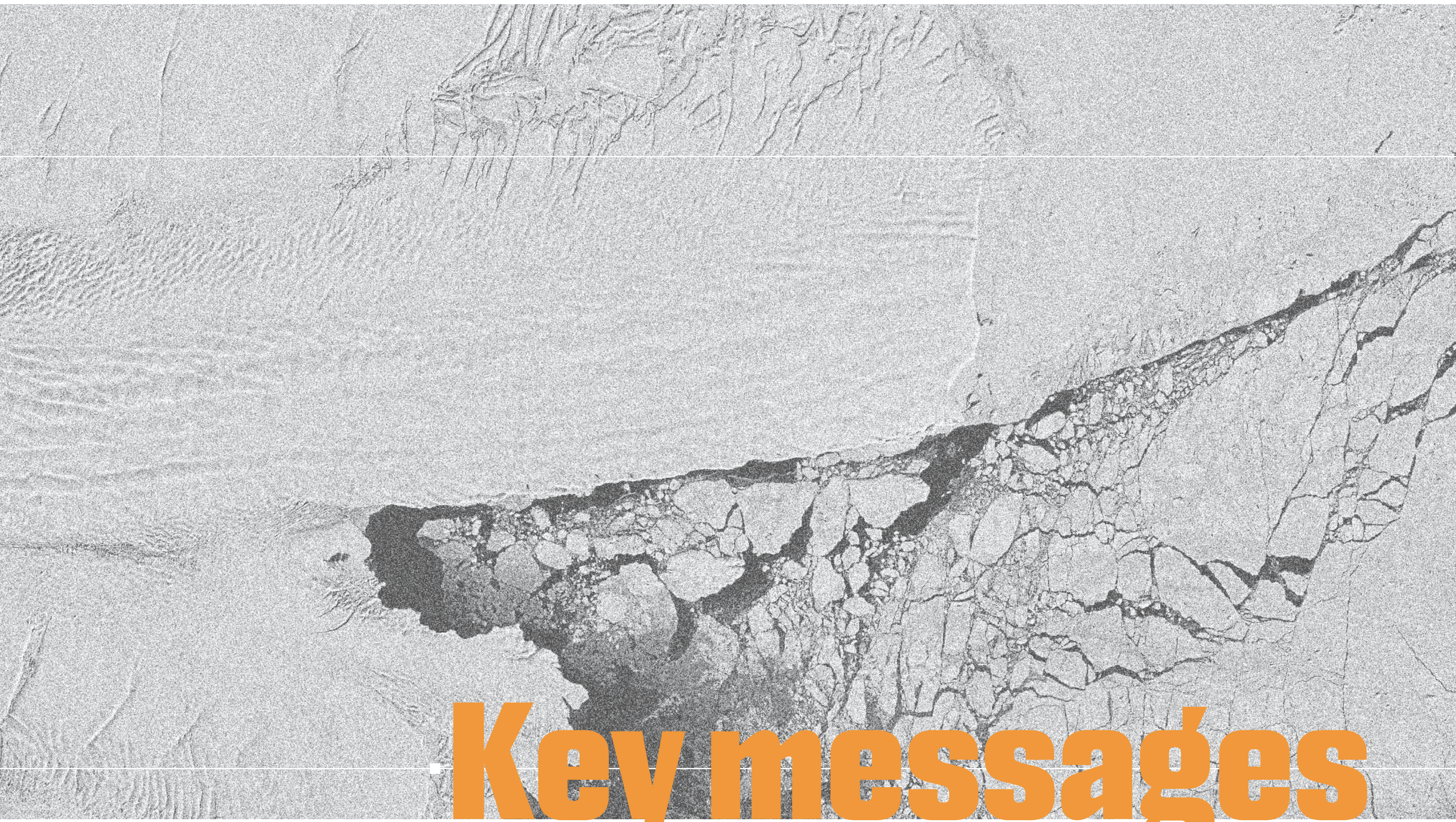


Policy briefing:

Abrupt changes in the Antarctic environment



Key messages

Abrupt changes are developing across Antarctica's ice, ocean and biological systems.

Antarctic systems interact so that a change in one part can increase the risks of triggering abrupt change in other parts of Antarctica and the Southern Ocean.

For Australia, abrupt Antarctic changes are expected to bring:

- increased vulnerability to coastal infrastructure and communities due to accelerating sea level rise;
- intensified global warming through reduced carbon dioxide removal by the Southern Ocean;
- amplified regional warming due to Antarctic sea-ice loss; and
- reduced rainfall over Southern Hemisphere continents from shifting weather patterns.

The unexpectedly rapid loss of Antarctic sea ice since 2014 is unfolding much faster than sea ice declines in the Arctic. Further Antarctic sea-ice loss is potentially unstoppable even after global climate is stabilised.

A marked slowdown in deep ocean circulation that is generated around the Antarctic continent is being observed and is expected to worsen. This slowdown in Antarctic overturning circulation could occur at twice the rate of weakening in its better-known North Atlantic equivalent, and would reduce the circulation of carbon, nutrients and oxygen in the deep ocean.

We are nearing the tipping point where about 3 metres of sea level rise from the West Antarctic Ice Sheet will become unstoppable, with major consequences for generations to come.

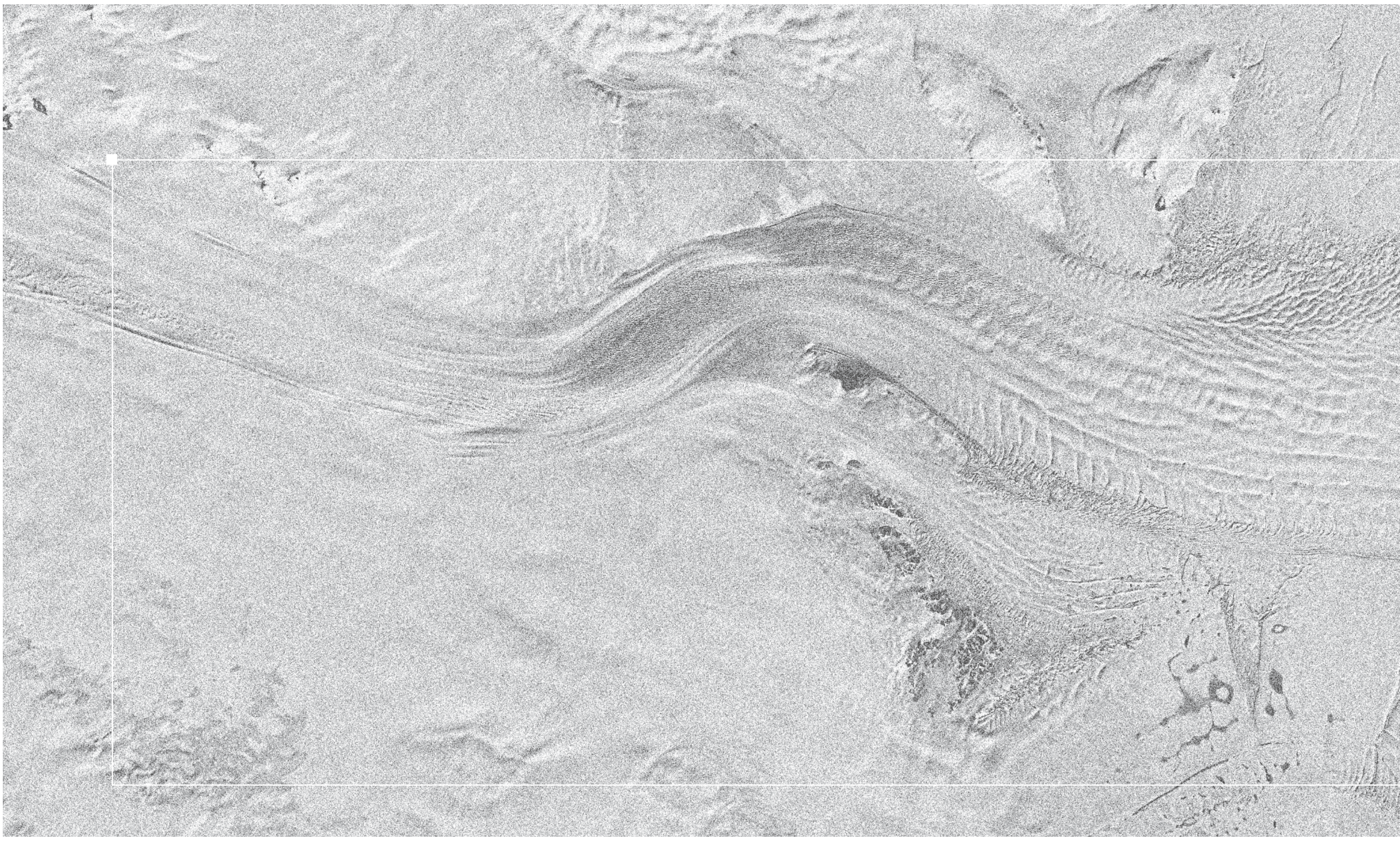
The floating ice-shelf extensions of the Antarctic Ice Sheet will continue to melt and thin due to warming ocean waters, and abrupt collapse events due to heatwaves and wave-driven fracturing are also emerging.

Substantial ecosystem transformations are underway in Antarctic marine and terrestrial environments. Of particular concern are impacts on sea-ice-dependent species, including heightened extinction risk for emperor penguins as their breeding habitat is compromised.

Existing efforts through the Antarctic Treaty System to reduce non-climatic pressures on Antarctica's biological systems and establish protected areas are critical for building resilience, but to be effective they must be in addition to decisive policy action that mitigates global climate changes.

The only way to avoid further abrupt Antarctic changes and their impacts is to reduce CO_2 emissions rapidly enough to limit global warming to as close to 1.5°C as possible.

Even with transformative emission reduction actions, plausible futures including multiple abrupt changes from Antarctica should be considered by governments, businesses and communities in their planning for future climate and sea-level rise impacts.



What are abrupt changes?

Abrupt changes are shifts in climate or environmental conditions that occur much faster than normal or expected variability. These abrupt changes are often referred to as regime shifts, and in some cases they can involve passing tipping points within the Earth system. Abrupt changes usually involve self-amplifying feedbacks, which means that they can be difficult or even impossible to reverse.

Abrupt changes are particularly relevant for decision making around future climate risks. They can result in "surprises" that challenge effective adaptation to climate changes.

Over past decades, many parts of the Antarctic environment showed a much more muted response to human-caused climate warming than the Arctic. It was unclear if the abrupt changes and tipping points that are well known for the Northern Hemisphere had equivalents in the Antarctic. But multiple abrupt changes in Antarctica and the Southern Ocean are now being discovered and are expected to worsen.

Antarctic sea ice

After decades of seemingly defying global warming, the sea ice covering the ocean around Antarctica has declined precipitously since 2014. This abrupt regime shift is unprecedented compared to natural variations in Antarctic sea ice over past centuries that can be reconstructed from historical climate observations and ice cores. Even after global climate is stabilised, it is possible that Antarctic sea ice will continue to be lost causing sustained impacts on the Antarctic environment and our regional climate.

The dramatic loss of Antarctic sea ice has implications for species that rely on ice for habitat and breeding; it reduces the stability of ice shelves around the Antarctic coast; and it can contribute to slowing of the deep ocean overturning circulation that is initiated around the Antarctic coast. Similar to the process that is causing rapid climate warming across the Arctic, the loss of Antarctic sea ice has the potential to amplify climate warming in our region by reducing the amount of energy from the sun that is reflected back to space.

How fast is abrupt?

The speed at which abrupt changes develop differs across parts of the Antarctic system. Abrupt collapse of Antarctic ice shelves can occur on timescales of days; abrupt loss of Antarctic sea ice unfolds over months to years; while the processes of unstoppable ice sheet loss take place over decades to centuries or more.

Even where abrupt Antarctic changes take long periods of time to fully develop, the triggering, speed and magnitude of these changes will be set by greenhouse gas emission choices made over the coming years to decades.

Antarctic deep ocean circulation

The movement of water into and through the deep ocean is a key function of Earth's climate system. Collapse of this overturning circulation in the North Atlantic is a known tipping point risk as Earth's climate continues to warm. We now know a similar risk is developing through the slowdown of the Antarctic branch of the global ocean overturning. This slowdown is being observed in ocean measurements, and climate models project it will worsen into the future. The impacts of this include reducing the natural drawdown of carbon dioxide from the atmosphere into the deep ocean, which would intensify human-caused global warming.

The slowdown of Antarctic Overturning Circulation has been linked primarily to meltwater being added to the ocean around Antarctica through the melting of ice shelves. In Antarctica, the close proximity of marine-based ice (parts of the ice sheet that are in contact with the ocean because they sit on land that is below sea level) to areas of dense, deep-water formation creates a reinforcing feedback connecting changes in ocean circulation to accelerating ice-shelf and ice-sheet loss.

Antarctic ice sheets and ice shelves

The West Antarctic Ice Sheet and marine-based parts of the East Antarctic Ice Sheet are known global tipping elements. Substantial amounts of ice are already being lost from the West Antarctic Ice Sheet and contributing to global sea level rise.

Antarctic Ice Sheet stability can be considered the wild card for future sea level rise estimates, holding the greatest potential for rapid increases, but also the greatest uncertainty. Unstoppable loss of the West Antarctic Ice Sheet is expected to be triggered at global warming levels of less than 2°C. The 3 metres of sea level rise this would generate would have vast economic, societal and environmental impacts for centuries to come. Improving knowledge of the geology and hydrology beneath the Antarctic Ice Sheet could be pivotal for improving predictions of where, and how quickly, ice will be lost as the ocean and atmosphere continue to warm.

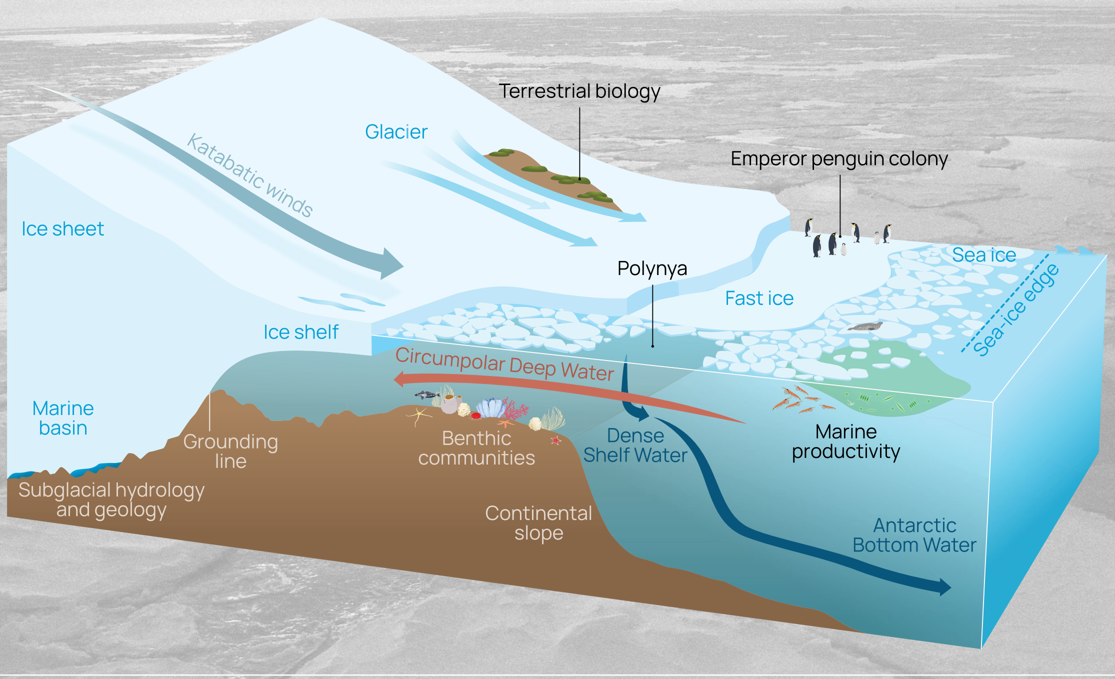
Floating ice shelves, where the Antarctic Ice Sheet meets the surrounding ocean, are critical for slowing the flow of ice off the Antarctic continent. Even under best-case CO_2 emission reduction scenarios these floating ice shelves will continue to melt and thin this century because of the extra ocean heat they are in contact with. Ice-shelf collapse can happen very abruptly due to weakening from surface melting during heatwaves, or from newly emerging processes like increased wave-driven fracturing as was observed for the Conger-Glenzer ice shelf collapse in March 2022.

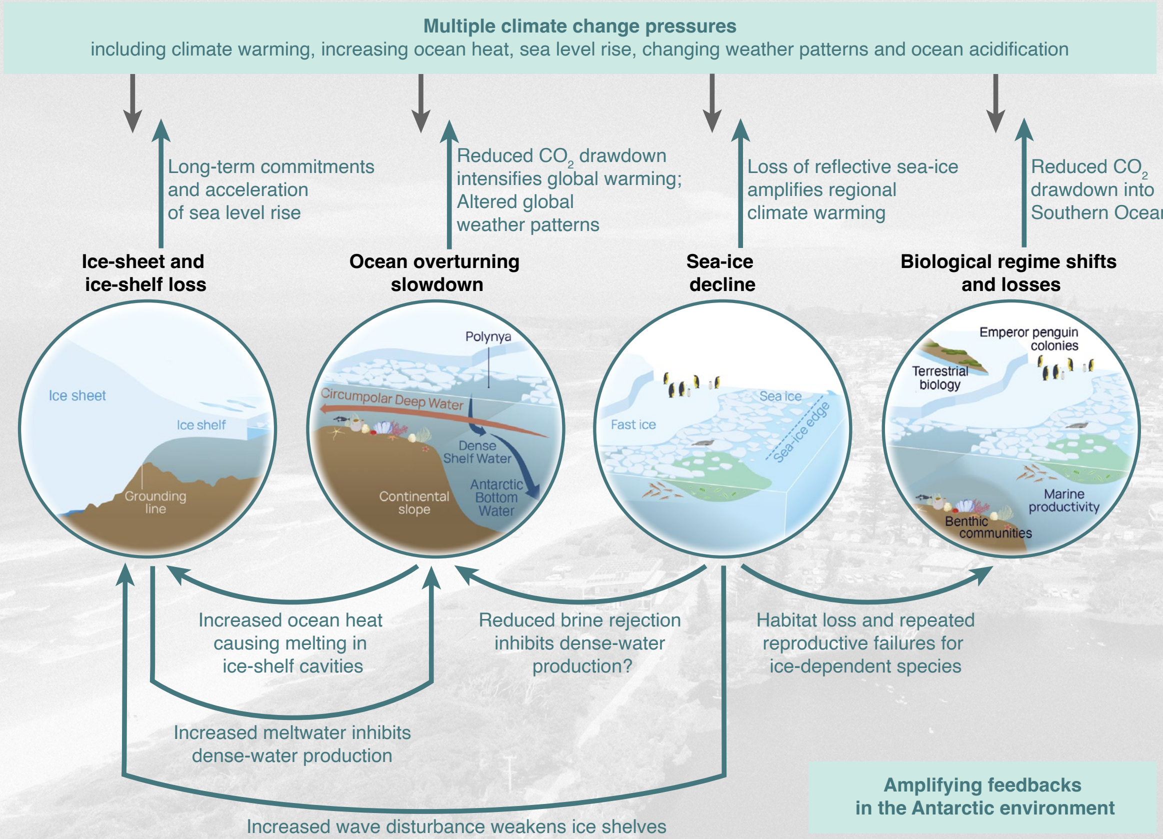
Antarctic and Southern Ocean life

The unique ecosystems of Antarctica and the Southern Ocean are also showing signs of abrupt change. Habitat changes are associated with winners and losers. Examples include the expansion of some plant species as previously ice-covered land becomes available, the replacement of ocean floor filter-feeder communities with macroalgae when ice shelves collapse, or declines in krill as their habitat beneath sea ice is lost.

Emperor penguins rely on stable land-fast sea ice for breeding, and episodes of early ice breakout prior to chick fledging have resulted in instances of complete colony breeding failures. These events are compounding in time and space; that is, they are affecting colonies around the whole Antarctic continent in the same breeding season, and many colonies have experienced multiple breeding failure events over the past decade.

Key components of the Antarctic environment that are important in understanding abrupt changes in this region. Figure from Abram *et al.*, 2025, Nature.





Abrupt changes in the Antarctic environment have multiple reinforcing/amplifying interactions across the Antarctic and Southern Ocean system and with global climate changes. Figure adapted from Abram *et al.*, 2025, Nature.

Climate change-related impacts on Antarctic and Southern Ocean life may be worsened by other non-climatic stressors, including human pressures and the current outbreak of avian influenza. Existing policy efforts through the Antarctic Treaty System to reduce non-climatic pressures and establish protected areas for Antarctic and Southern Ocean ecosystems will have benefits, but must be supplemented with decisive policy action aligned to international climate agreements to secure the future of Antarctic ecosystems and their iconic species.

What do decision makers need to know?

Abrupt changes in Antarctica have direct consequences for Australia, our region and the world. Some of the most pressing concerns are how quickly ice will be lost from the Antarctic continent and what this means for sea level rise impacts along our coasts; how changes in Southern Ocean productivity and deep circulation could reduce the drawdown of CO_2 from the atmosphere and worsen climate warming; and how sustained sea-ice decline and ocean circulation changes will alter the weather and climate in Australia and beyond.

Proposals for geoengineering solutions to slow Antarctic warming and ice loss are gaining attention, but scientific assessments show that these are not feasible in coming decades, and could even be environmentally dangerous. Limiting global warming to as close to 1.5°C as possible through drastic greenhouse gas emission reductions is the only certain way to reduce the risk of triggering multiple abrupt changes and passing tipping points in the Antarctic environment.

Decision-makers will need to work with uncertainties about when and how quickly abrupt changes in the Antarctic environment will unfold. This uncertainty arises from unknowns in how quickly the world will reduce greenhouse gas emissions to limit global warming, and our incomplete understanding of vulnerabilities in the Antarctic environment to a warming climate. Using storyline approaches that incorporate the impacts and costs of abrupt Antarctic changes amongst our plausible futures will enable governments, businesses and communities to respond to future climate risks.

Research is continuing to improve the detection, understanding and predictability of abrupt changes in the Antarctic environment. This depends on sustaining Antarctic and Southern Ocean observing systems, better characterising areas of concern for abrupt change, developing long-term reconstructions of how the Antarctic system behaved before observations began and during previous warm periods in Earth's history, and building improved modelling capabilities that can capture abrupt change processes in Antarctica and the Southern Ocean. These priorities will contribute to impactful Antarctic and Southern Ocean science that supports Australia's national interests.

Areas of concern in Australia's Antarctic Territory

Australia claims 42% of the Antarctic continent and has a responsibility for environmental stewardship of this region of East Antarctica.

Within the Australian Antarctic Territory, the Wilkes and Aurora subglacial basins and the Denman and Lambert glaciers may be particularly vulnerable to abrupt ice loss that contributes to global sea level rise. Dense water formation sites offshore of Adélie Land and Prydz Bay/Cape Darnley are also critical locations within the Australian Antarctic Territory for driving deep ocean overturning. Multiple emperor penguin colonies along the coast of the Australian Antarctic Territory have experienced at least one episode of catastrophic breeding failure over the last decade.

Areas of concern in the Australian Antarctic Territory for abrupt ice sheet loss (dark blue circles), slowdown of dense shelf water production (light blue circles), and where colony-scale emperor penguin breeding failures have been observed due to early fast ice breakout (penguin icons).

This briefing document is based on collaborative research that contributes to delivering the **Australian Antarctic Science Decadal Strategy**. It was led through the Australian Centre for Excellence in Antarctic Science, along with Securing Antarctica's Environmental Future, the Australian Antarctic Program Partnership and the Australian Antarctic Division, as well as international collaborators.

This briefing is based on the following publication:

Abram, N.J., Purich, A., England, M.H., McCormack, F.S., Strugnell, J.M., Bergstrom, D.M., Vance, T.R., Stål, T., Wienecke, B., Heil, P., Doddridge, E.W., Sallée, J.-B., Williams, T.J., Reading, A.M., Mackintosh, A., Reese, R., Winkelmann, R., Klose, A.K., Boyd, P.W., Chown, S.L. and Robinson, S.A. (2025). Emerging evidence of abrupt changes in the Antarctic environment. *Nature*, https://doi.org/10.1038/s41586-025-09349-5.

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A Special Research Initiative of the Australian Research Council

SAEF
Securing Antarctica's Environmental Future
Australian Research Council Special Research Initiative

AAPP
Australian Antarctic Program Partnership

Australian Government
Department of Climate Change, Energy, the Environment and Water
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