Australian Government

AUSTRALIAN ANTARCTIC PROGRAM

Outlook for Policy Makers:
The Antarctic Ice Sheet and Sea Level

This document outlines strategic priorities for understanding the Antarctic Ice Sheet (AIS) and its impacts on sea-level rise due to climate change. It is drawn primarily from a recent collaborative science review led by the Australian Antarctic Division[1] and includes recent updates to projections of future change[2]. It highlights the risks posed by AIS melting to Australia and its neighbours, including in the Pacific, along with research priorities and policy recommendations.

Why is the Antarctic Ice Sheet important?

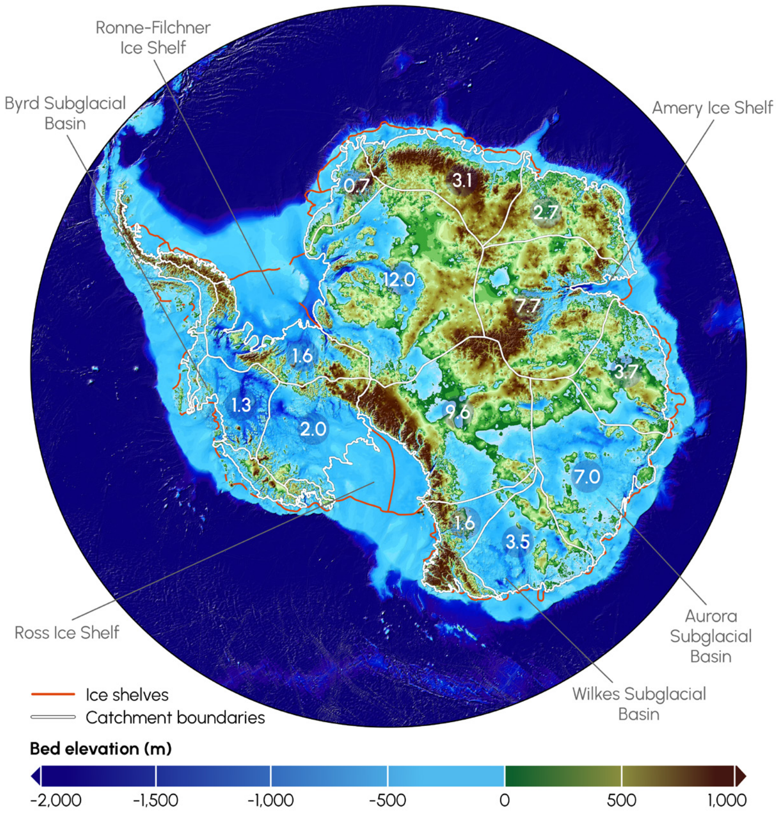
The AIS is the largest ice mass on Earth, holding enough ice to raise global sea levels by 58 metres if fully melted. The East Antarctic Ice Sheet (EAIS), which lies mostly in the Australian Antarctic Territory (AAT), contains 90% of this ice. The AIS plays a critical role in influencing sea levels, climate, weather patterns, and ecosystems. While ice loss is expected to increase with continued warming, the exact behaviour of the AIS remains uncertain. Shifts in AIS behaviour, combined with changes in ocean circulation, atmospheric warming, and the behaviour of ice shelves—floating extensions of the ice sheet that slow the flow of glacier ice into the ocean—along with interactions between the bedrock and ice sheet, can create destabilising feedback loops. Processes such as these and ice-shelf collapse may lead to irreversible and unstoppable ice loss from the AIS, significantly contributing to global sea-level rise.

Projecting the future behaviour of the AIS is challenging, due to insufficient observations and limited understanding of key processes, which has hindered the development of sophisticated simulations to help explain how the ice sheet flow might change in the future and how it interacts with other parts of the climate system. Understanding the current and future behaviour of the AIS, in particular the EAIS, and its contribution to regional and global climate and ocean systems, now and over the coming decades, remains a key priority for Australia.

Risks of rising sea levels to Australia and our neighbours

Australia faces significant risks from sea-level rise to its infrastructure, economy, ecosystems, communities, social systems, and Government functions. With much of the population and critical infrastructure located along the coast, rising sea levels will increase the frequency and severity of storm surges and flooding. **One metre of sea-level rise could cost Australia A$345 billion** in damages, with extensive losses in residential, commercial, and public infrastructure[3]. Recent estimates from insurance data suggest properties vulnerable to sea-level rise include **370,000 residential properties (3.5% of all homes within Australia) and 120,000 commercial or industrial properties**, which will soon become uninsurable due to the increasing likelihood of flooding[4]. The cost to Australia will likely be much higher, due to the uneven sea level redistribution, compounding with increased flooding and erosion events. Indigenous cultural heritage in Australia's coastal regions is also at risk[5].

Low-lying Pacific Island nations face existential threats from rising waters, which may lead to large-scale displacement of populations and the migration of climate refugees[6]. Global emissions reductions in line with the Paris Agreement[7] could lower the risk of destabilising the AIS, though considerable uncertainties remain. Australian and global efforts to understand how quickly the AIS will respond to climate scenarios are crucial to managing the sea-level rise risks to Australia and its neighbours.

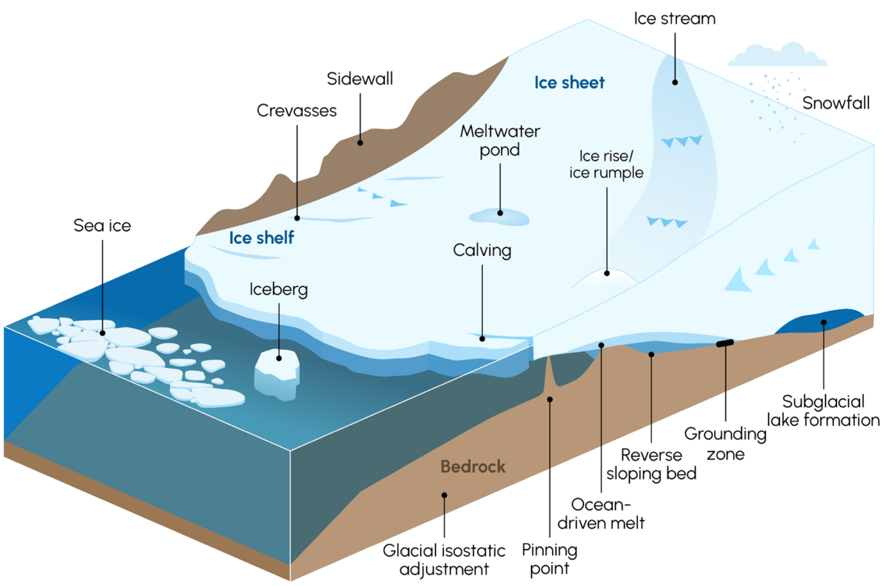


The topography of Antarctic bedrock, overlain with ice drainage basins, ice shelves and estimated global mean sea-level potential from each basin in metres[1].

Contemporary changes

The AIS is shrinking at an accelerating rate, largely driven by warming ocean temperatures. Rising temperatures have increased basal melting of ice shelves and iceberg calving, particularly in the West Antarctic Ice Sheet (WAIS) and the Antarctic Peninsula. While the EAIS has historically been more stable, recent signs of mass loss from some regions of the EAIS are raising concerns about its long-term stability. **Since 1992, Antarctica has contributed approximately 8.9 mm to global sea-level rise, accounting for about 14% of global sea-level rise since 2016[8]**.

Observations show increased snowfall in the EAIS interior has helped offset some of the mass loss, but this balance is becoming less certain. Reducing greenhouse gas emissions could play a critical role in stabilising vulnerable areas of the EAIS. In addition to slowing ice loss, lower emissions might lead to increased snowfall in the region, which could partially offset sea-level rise commitments from Antarctica.

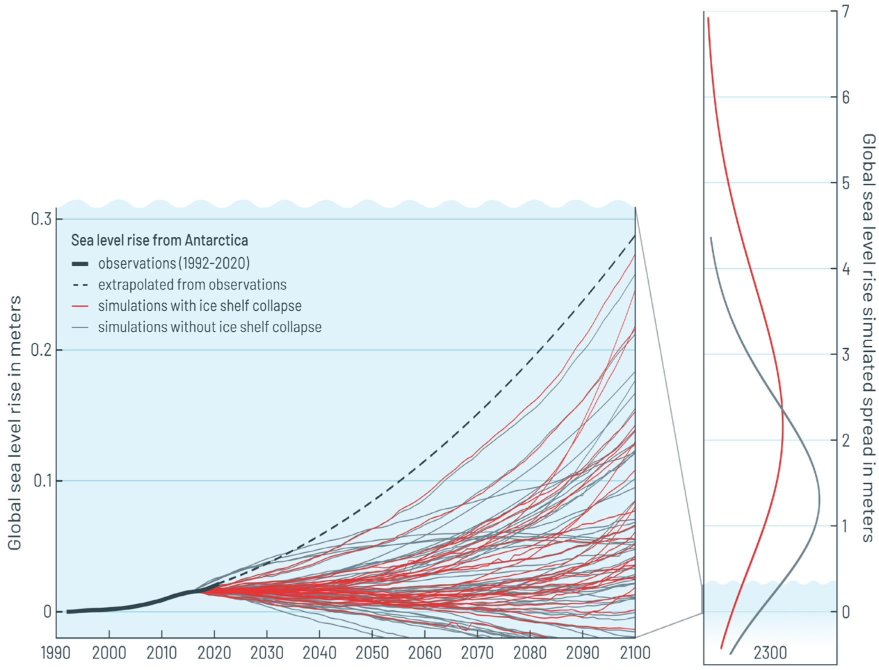


Many physical processes affect the behaviour of the Antarctic Ice Sheet[1].

Future projections

By 2100, under high-emission scenarios, sea-level rise from Antarctica is projected to be below 30 cm, potentially reaching 4.4 m by 2300, according to 2024 updates based on new ice sheet models. These projections assume ongoing mass loss from the AIS without the collapse of major ice shelves. However, if ice-shelf collapse occurs, as has already been observed in parts of WAIS and the Antarctic Peninsula, sea-level rise could be significantly higher. Extreme but plausible scenarios project an additional 1.1 m on average, with the possibility of reaching 6.9 m by 2300. Increased snowfall over the EAIS may offset some ice loss in specific regions, potentially reducing Antarctica's overall sea-level contribution.

These 2024 revisions focus specifically on contributions from the ice sheet, whereas the IPCC 6th Assessment Report from 2021 projected 1.1 m of global sea-level rise by 2100 under high-emission scenarios, accounting for all sources of sea-level rise. This includes thermal expansion of the oceans, melting from Greenland, land water storage, and mountain glaciers. In extreme cases where the AIS undergoes rapid melting or partial collapse, the IPCC projected global sea levels could rise by over 2 m, with the potential to reach 5 m by 2150 in a 'low-likelihood, high-impact' scenario. These varying projections underscore the complexity and uncertainty in future sea-level contributions, reinforcing the need for further research to refine these estimates. The IPCC acknowledges the **"deep uncertainty" about the AIS's potential contributions to sea-level rise**[9].



Future projections of AIS contributions to sea level rise with, and without, ice sheet collapse under high emissions climate scenarios[2], alongside actual observations[8] and the likely trajectory extrapolated from observations.

For Australia, sea-level rise is expected to be 1.3 times higher than the global average by 2100 under medium-emission scenarios[1]. By 2050, extreme flooding events that once occurred once per century could become 20–30 times more frequent, even without additional AIS melt[9]. The combination of higher sea-level contributions from the AIS and increased storm severity will intensify flooding risks, necessitating targeted adaptation strategies for vulnerable coastal areas and populations.

Challenges in understanding the deep uncertainty

Limitations in understanding risks of collapse and rapid retreat: Insufficient data on key processes and vulnerable regions complicates predicting tipping points for ice-shelf collapse. Collapse events are rarely observed, due to their infrequency. Without new knowledge, accurately forecasting the timing and scale of ice loss remains challenging, presenting significant hurdles for long-term planning and the development of adaptation strategies.

Ice-sheet modelling uncertainty and climate forcing Impacts: Inconsistencies in ice-sheet models, especially regarding ice retreat, create a larger spread of projections than do the forcings applied from different climate models. This is largely due to these models being poorly constrained by sparse observational data. This underscores the importance of refining ice-sheet models with new knowledge to improve predictions of ice-sheet behaviour and its contribution to sea-level rise.

Lack of knowledge of interconnected processes: Complex and dynamic interactions between the AIS, atmosphere, ocean, sea ice, and bedrock are poorly understood. These components influence each other through feedback mechanisms that can operate at different times, contributing to uncertainty in projections, as feedback mechanisms can either amplify or mitigate AIS loss.

Insufficient data to inform projections: Critical processes, such as in the subglacial environment (which influences ice movement), grounding zones (where ice transitions from land to ocean), and ice-shelf rifts (cracks that can lead to collapse), are not well understood and are difficult to observe. Enhanced observations of the AIS, including those of relative sea level and ocean circulation, in the data-sparse Southern Ocean, are essential.

Socio-economic factors: Diverse risk perceptions and uncertainties in projections complicate unified adaptation strategies, especially under high-emission scenarios. This requires flexible planning that addresses varying impacts and mitigation strategies.

Priorities for action

Research investment and leadership:

Prioritise research on the AIS to reduce uncertainties in sea-level projections and cultivate the next generation of scientists. Focus specifically on the EAIS, as its vast ice volume represents the largest source of uncertainty. Fieldwork in vulnerable areas of the EAIS, complementary laboratory investigations, sustained observations, and integration with satellite and remote sensing data are essential to improving projections of AIS contributions to sea levels.

Advanced simulations and monitoring:

Prioritise the development of advanced simulations to improve understanding of key processes and drivers, such as ice-cliff collapse and subglacial hydrology, and mapping the geometry of the AIS and surrounding environment. This is needed to inform more accurate models and future projections. Integrating modelling and observations will better inform decision-makers.

Sea-level redistribution:

Measure the impacts of changes in the AIS at both regional and global scales by monitoring relative sea-level redistribution, especially in regions where data are sparse, like the Southern Ocean. This global perspective highlights the interconnected nature of relative sea-level changes.

Interdisciplinary and international collaboration:

Foster global collaboration to leverage global expertise focused on the AIS and sea level changes, especially in vulnerable regions of the EAIS. Collaborative efforts to share knowledge and resources will improve research quality and accelerate progress.

Adaptive planning:

Implement adaptive coastal planning for Australia's vulnerable coastlines, regularly updating sea-level risk scenarios. Invest in resilient infrastructure and adaptation strategies, including flood modelling and the protection of cultural heritage sites, such as Indigenous lands.

Resilient infrastructure:

Prepare for extreme sea-level rise scenarios through adaptive planning and priority investments in resilient infrastructure, like elevated roads and flood defences, and monitor coastal erosion and inundation. A proactive approach will reduce the risks to communities and critical systems from severe disruptions, minimising long-term damage and economic losses.

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[1] The Antarctic Ice Sheet and sea level: contemporary changes and future projections. Galton-Fenzi, B.K. and others (in-press; 2025),In M. Meredith and others (eds), "Antarctica and Planet Earth", Taylor & Francis Group. https://doi.org/10.4324/9781003406471

[2] Evolution of the Antarctic Ice Sheet over the next three centuries from an ISMIP6 model ensemble. Seroussi, H. and others (2024). Earth's Future, https://doi:10.1029/2024EF004561.

[3] https://www.climatecouncil.org.au/how-will-sea-level-rise-impact-your-city/ - AUD$226 billion in 2014, adjusted for inflation and scaled for population growth which has occurred primarily in cities.

[4] https://aoninsights.com.au/rapid-sea-level-rise-what-is-the-risk/

[5] https://soe.dcceew.gov.au/indigenous/pressures/climate-change

[6] https://www.dfat.gov.au/geo/pacific/development-assistance/climate-change-and-resilience

[7] https://unfccc.int/process-and-meetings/the-paris-agreement

[8] Mass balance of the Greenland and Antarctic ice sheets from 1992 to 2020. Otosaka, I.N., and others, (2023) Earth Syst. Sci. Data 15, 1597–1616, https://doi.org/10.5194/essd-15-1597-2023. extrapolated from rates at 2020 to 2024.

[9] IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.Cambridge University Press, United Kingdom and New York, NY, USA, http://doi:10.1017/9781009157896

Background image: Lenneke Jong

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