Australian Government

Department of Climate Change, Energy, the Environment and Water

Australian Antarctic Division

AUSTRALIAN ANTARCTIC PROGRAM

Submission

Call for Inputs for the *Belém Mission to 1.5*

Antarctica and the Southern Ocean: Implications of a Temperature Overshoot

Date: 30 June 2026

About the Australian Antarctic Program

The Australian Antarctic Program is coordinated by the Australian Antarctic Division, which is part of the Commonwealth Department of Climate Change, Energy, the Environment and Water. Science partners of the Australian Antarctic Program include Australian government agencies, organisations and academic institutions.

Science activities of the Australian Antarctic Program are guided by the Australian Antarctic Science Decadal Strategy: 2025-2035. This includes increasing understanding of the Antarctic and Southern Ocean climate system, its environments and biodiversity, and their responses to climate change. This work includes ongoing monitoring and interdisciplinary field campaigns in East Antarctica and the Southern Ocean, and the development of Australia's Earth System Model to accurately include key Antarctic atmospheric, ice and ocean processes. The focus is on quantifying and predicting climate changes and ice loss in Antarctica and the Southern Ocean to inform adaptation, conservation and mitigation decisions for Australia, our region and the world.

This work, together with a focus on the best-available science and evidence, forms the basis of our knowledge, perspective and expertise in preparing this submission in support of the *Belém Mission to 1.5* initiative.

This submission has been prepared by lead representatives from the Australian Antarctic Division, Australian Antarctic Program Partnership, Australian Centre for Excellence in Antarctic Science and Securing Antarctica's Environmental Future.

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Executive Summary

As lead representatives of Australia's Antarctic Science community, we welcome the opportunity to contribute our knowledge, perspective and expertise to inform discussions and help shape the *Belém Mission to 1.5* initiative.

Key messages

Stabilising the Earth's climate and limiting the magnitude and duration of a temperature overshoot above 1.5°C is urgently required to reduce the likelihood of further abrupt changes, irreversible impacts, and far-reaching global consequences caused by the response of Antarctica and the Southern Ocean to anthropogenic climate change.

- Antarctica and the Southern Ocean are fundamental components of the global climate system and changes in this region have global reach. They influence global ocean circulation, Australian and Pacific weather patterns and global sea level rise.
- Future climate risks, losses and damages depend on decisions made today, which will influence both the scale of impacts and our capacity to respond effectively.
- Each additional increment of warming above 1.5°C will intensify the impacts of anthropogenic climate change, and increase the risk of long term, catastrophic changes.
- Abrupt, rapid and potentially self-perpetuating changes are already occurring throughout the Antarctic and Southern Ocean region. Even a relatively small and brief temperature overshoot increases the risk of crossing critical Antarctic thresholds, with long-lasting or irreversible impacts. This includes collapse of parts of the Antarctic Ice Sheet, which would lead to multi-metre sea level rise exceeding the average elevation of some Pacific Island nations and megacities including Bangkok and Shanghai.
- Continued decline of Antarctic sea ice has potential to amplify climate warming via complex feedbacks, as it has in the Arctic – with major implications for the region and world.
- Biodiversity impacts intensify with higher temperatures, loss of sea ice, and more extreme events, risking irreversible ecological losses including extinctions.
- Climate driven changes to physical and biological systems will pose significant challenges for Antarctic and Southern Ocean environmental management, conservation and international governance frameworks.
- An emphasis on technological solutions to reduce global temperature after exceeding 1.5°C does not address the scale or urgency of the challenge, and may not reduce the risks of crossing critical thresholds in the Antarctic region.

Recommendations for action

- Antarctica and the Southern Ocean should be considered within the United Nations Framework Convention on Climate Change (UNFCCC) climate negotiations as a core component of the Earth system. Changes in this region and the crossing of critical thresholds are directly relevant to assessing climate risks, hazards, losses and damages globally – now and into the future.
- Prioritisation of, and sustained investment in, long-term observation and monitoring in the Antarctic and Southern Ocean region is needed. This will improve understanding of how the region is contributing to global climate change, and accuracy of global climate models and future climate projections.

1. Introduction

Thank you for the opportunity to contribute to the *Call for Inputs for the Belém Mission to 1.5*. This submission has been prepared as a collaboration between lead representatives from: the Australian Antarctic Division, Department of Climate Change, Energy, the Environment and Water; Australia's three major university-based Antarctic research programs – the Australian Antarctic Program Partnership, and Australian Centre for Excellence in Antarctic Science and Securing Antarctica's Environmental Future Special Research Initiatives; and the Australian Antarctic Program Chief Scientist.

Our submission considers the:

- Global context of current warming trends, remaining global carbon budget and the concept of a temperature overshoot;
- Current climate change threats facing Antarctica and the Southern Ocean, and the consequences of a temperature overshoot;
- Implications for management and governance in the region; and
- Recommendations for action.

2. Global context

The goal of the Paris Agreement is to hold global average temperature to well below 2°C and pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels[1]. Prior to the Paris Agreement in 2015, the world was on track to warm by about 4.0°C by 2100[2]. Based on current policies, projected warming is about 2.8°C, and 2.3–2.5°C if nations' Nationally Determined Contributions are implemented in full. This is still well above the Paris Agreement goal[3].

As of early 2026, the remaining carbon budget for a 50% chance of limiting warming to 1.5°C was nearly exhausted, with only 3–4 years remaining (assuming 2025 emissions levels)[4]. Exceeding the Paris climate target of 1.5°C is now considered likely by 2030[5]. Achieving long-term temperature stabilisation at or below 1.5°C will therefore require a temporary

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[1] UNFCCC (2015) Adoption of the Paris Agreement. https://unfccc.int/sites/default/files/english_paris_agreement.pdf.
[2] UNEP (2015) The Emissions Gap Report 2015. United Nations Environment Programme.
[3] UNEP (2025) Emissions Gap Report 2025: Off target – Continued collective inaction puts global temperature goal at risk. https://doi.org/10.59117/20.500.11822/48854.
[4] Friedlingstein, P., *et al.* (2025) *Earth. Syst. Sci. Dat.*, https://doi.org/10.5194/essd-18-3211-2026; Forster, P.M., *et al.* (2026) *Earth. Syst. Sci. Dat.,* https://doi.org/10.5194/essd-18-3889-2026.
[5] Kirchengast, G. & Pichler, M. (2025) *Commun. Earth. Environ.*, 6, 402. https://doi.org/10.1038/s43247-025-02368-0; UNEP (2025) Emissions Gap Report 2025: Off target – Continued collective inaction puts global temperature goal at risk. https://www.unep.org/resources/emissions-gap-report-2025; WMO (2025) State of the Climate Update for COP30. https://library.wmo.int/viewer/69674/download?file=State-Climate-2025-Update-COP30_en.pdf.

overshoot, followed by the successful sustainment of large-scale net-negative emissions to bring global average temperature down[6].

The consequences of a temperature overshoot depend on its magnitude, duration and the temperature at which long-term stabilisation occurs[7]. Even a relatively small-magnitude, short-duration exceedance increases the risk of crossing Earth system thresholds, with long-lasting or irreversible impacts, including in Antarctica and the Southern Ocean. Critically, we cannot be confident that temperature decline after a temperature overshoot is achievable[8].

3. Antarctica and the Southern Ocean – current climate change impacts and consequences of a temperature overshoot

The Antarctic region exerts a profound influence on the global climate system, both responding to and influencing climate through feedbacks that have the potential to accelerate climate change[9]. It hosts unique biodiversity and ecosystems, and while traditionally there is a perception that Antarctica is inherently protected due to its remoteness and the governance focus on environmental stewardship through the Antarctic Treaty System[10], it is now experiencing growing direct and indirect pressures from human activities[11]. These pressures are compounded by climate change, and risks and adverse impacts increase with every increment of warming[12]. There is growing evidence that abrupt and potentially irreversible changes due to climate change are already underway in the region[13].

3.1 Atmosphere

Key messages

- Atmospheric conditions strongly influence Antarctic climate through temperature, precipitation, wind and extreme events[14].
- Further warming is projected across Antarctica under all future emissions scenarios.
- Globally, the atmosphere may respond relatively quickly to a decrease in atmospheric greenhouse gas concentrations after a peak; however, feedbacks and interactions may sustain changes, resulting in high near-term and continuous long-term warming.

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[6] IPCC (2023) Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate. IPCC, Geneva, Switzerland, 1–34. https://doi.org/10.59327/IPCC/AR6-9789291691647.001.
[7] Reisinger, A., *et al.* (2025) *Annu. Rev. Environ. and Resour.*, 50, 185–217. https://doi.org/10.1146/annurev-environ-111523-102029.
[8] Schleussner, CF., *et al.* 2024. *Nature,* 634, 366–373. https://doi.org/10.1038/s41586-024-08020-9.
[9] Alexander, S., *et al.* (2025) Antarctica and Climate Change Technical Report. A technical report for the National Climate Risk Assessment. Australian Climate Service, Australia
[10] Ibid.
[11] Carter, Z.T., *et al.* (2025) *Nat. Ecol. Evol.,* 9, 1885–1896. https://doi.org/10.1038/s41559-025-02814-4.
[12] IPCC (2023) Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland, 1–34. https://doi.org/10.59327/IPCC/AR6-9789291691647.001.
[13] Abram, N.J., *et al.* (2025) *Nature*, 644, 621–633. https://doi.org/10.1038/s41586-025-09349-5.
[14] Davies, B.J., *et al.* (2026) *Front. Environ. Sci.*, 13, 1730203. https://doi.org/10.3389/fenvs.2025.1730203.

- Every increment of warming leads to more pronounced and widespread changes in mean climate and extremes, including in Antarctica and the Southern Ocean, and amplifies the region's contribution to climate-related risks and hazards in the Southern Hemisphere, including in Australia and the Pacific.

Average Antarctic surface air temperature is now 1.44°C above the 1961–1990 baseline[15], with the Antarctic Peninsula warming at around three times the global average[16]. Rising air temperatures increase surface melt of ice shelves around the margins of the Antarctic Ice Sheet, contributing to instability and long-term ice loss. Precipitation is expected to increase as the atmosphere continues to warm, with more falling as rain rather than snow, especially in coastal regions[17]. Changing atmospheric temperature and precipitation patterns drive widespread and abrupt environmental changes, such as ice shelf collapse, expansion of ice-free areas and ecological shifts, particularly in coastal regions and across the sea-ice zones[18]. Further warming is projected across Antarctica under all future emissions scenarios. Importantly, some impacts such as ice shelf collapse, expansion of ice-free areas and ecological shifts may not reverse even if global temperature returns to 1.5°C after an overshoot[19].

Extreme events in Antarctica, including heatwaves, atmospheric rivers[20], intense precipitation and strong near-surface wind events, are already occurring and are virtually certain to become more pronounced in future[21]. These events can cause temperatures tens of degrees above average, with severe impacts. For example, in March 2022, an extreme event caused temperatures to rise 30–40°C above average over widespread parts of East Antarctica[22], possibly contributing to the rapid disintegration of the Conger-Glenzer Ice Shelf[23]. An atmospheric river associated with this event increased snowfall in some areas and contributed to Antarctic Ice Sheet growth for a short period of time, highlighting the non-uniform and complex nature of Antarctica's response to extreme events. Similarly, a prolonged winter heatwave in 2024 saw temperatures exceed long-term means by over 9°C for 17 consecutive days in parts of East Antarctica. Anthropogenic warming contributed nearly 10% (0.7°C) of this, and more than doubled its likelihood. Such events are projected to increase between six and 26 times in frequency by 2100, depending on the emissions scenario[24]. In early June 2026, Esperanza Station on the Antarctic Peninsula experienced a heatwave where the highest temperature recorded was 15.4°C, which is about 20°C above

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[15] Global Climate Highlights 2025 (2025) https://climate.copernicus.eu/global-climate-highlights-2025.
[16] Davies, B.J., *et al.* (2026) *Front. Environ. Sci.*, 13, 1730203. https://doi.org/10.3389/fenvs.2025.1730203.
[17] Alexander, S., *et al.* (2025) Antarctica and Climate Change Technical Report. A technical report for the National Climate Risk Assessment. Australian Climate Service, Australia.
[18] Vignon, É., *et al*. (2021) *Geophys. Res. Lett.*, 48. https://doi.org/10.1029/2020gl092281.
[19] McKay, D.I.A. *et al.* (2022) *Science*, 377, eabn7950. https://doi.org/10.1126/science.abn7950.
[20] Atmospheric rivers are long, narrow (up to a few hundred kilometres wide), shallow (up to a few kilometres deep) and transient corridors of strong horizontal water vapour transport that are typically associated with a low-level jet stream ahead of the cold front of an extratropical cyclone (IPCC 2021)
[21] Siegert, M.H., *et al.* (2023) *Front. Environ. Sci.*, 11, 229283. https://doi.org/10.3389/fenvs.2023.1229283.
[22] Wille, J., et al., (2024) *J. Clim.*, 37, 757—778. https://doi.org/10.1175/JCLI-D-23-0175.1.
[23] Alexander, S., *et al.* (2025) Antarctica and Climate Change Technical Report. A technical report for the National Climate Risk Assessment. Australian Climate Service, Australia.
[24] Tang, H., *et al.* (2026) *npj Clim. Atmos. Sci.,* 9, 122. https://doi.org/10.1038/s41612-026-01392-x.

the long-term June average of close to -6.2°C. Extreme temperatures were also recorded at two other Antarctic Peninsula stations[25].

Atmospheric circulation over Antarctica and the Southern Ocean strongly influences Southern Hemisphere weather and climate, including in Australia. Strengthening and poleward-shifting westerly winds, driven primarily by ozone depletion and rising atmospheric greenhouse gas concentrations[26], influence temperature, rainfall and drought in southern Australia. Sudden Stratospheric Warming events over Antarctica in late winter or early spring[27] can contribute to enhancing bushfire risks in eastern Australia by pushing the westerly wind belt northwards towards southern Australia, which then blocks moist easterly airflow along the east coast, causing hotter, drier conditions in Australia's eastern coastal regions. For example, the 2019 Antarctic Sudden Stratospheric Warming event contributed to Australia's "Black Summer" fires by promoting prolonged hot and dry conditions across New South Wales and southern Queensland[28].

3.2 The Antarctic Ice Sheet and sea level rise

Key messages

- Ice sheet response to temperature overshoot depends on peak warming and how long temperatures remain above critical thresholds.
- Crossing critical thresholds can trigger irreversible ice loss that continues even if global temperature later declines.
- Temperature overshoot therefore risks committing the Antarctic Ice Sheet to long-term, irreversible loss[29], and even temporary exceedance of thresholds may result in persistent sea level rise lasting centuries to millennia[30].
- Current mitigation efforts may not be sufficient to avoid self-sustained Antarctic ice loss. Decisions on greenhouse gas emissions made now and in the near future will determine Antarctica's contribution to future sea level rise[31].

The Antarctic Ice Sheet is a significant contributor to global sea level rise, with its contribution tripling since the 1990s[32]. From 1992 to 2020, Antarctica lost around 2671 ± 530 billion tonnes of ice, raising global sea level by 7.4 ± 1.5 mm[33]. The West Antarctic Ice Sheet is particularly

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[25] Marambio and San Martín bases; Fučkar, N.S., *et al*. (2026) High temperatures over the Antarctic Peninsula in June 2026 strengthened by human-driven climate change | Zenodo.

[26] Li, X., *et al.* (2025) Chapter 3 Global atmospheric influence on Antarctica. In: Meredith, M.P., J. Melbourne-Thomas, A.C. Naveira Garabato, M. Raphael (Eds). *Antarctica and the Earth System* pp. 43-64. https://doi.org/10.4324/9781003406471-3.

[27] Lim, E.-P., *et al.* (2019) *Nat. Geosci.,* 12, 896–901. https://doi.org/10.1038/s41561-019-0456-x.

[28] Bureau of Meteorology 2019. The air above Antarctica is suddenly getting warmer – here's what it means for Australia (accessed 15/05/2026).

[29] Klose, A. K., *et al.* (2024) *Cryosphere*, 18, 4463–4492, https://doi.org/10.5194/tc-18-4463-2024; Stokes, C.R. *et al.* (2025) *Commun. Earth. Environ.,* 6, 351. https://doi.org/10.1038/s43247-025-02299-w.

[30] Mengel, M., *et al.* (2018) *Nat. Commun.,* 9, 601. https://doi.org/10.1038/s41467-018-02985-8.

[31] Coulon, V., *et al.* (2025) *Nat. Commun.,* 16, 10385. https://doi.org/10.1038/s41467-025-66178-w.

[32] Galton-Fenzi, B.K., *et al.* (2024) Outlook for policy makers: the Antarctic ice sheet and sea level. Australian Antarctic Data Centre, 1–4. https://doi.org/10.26179/Q3FX-8P19.

[33] Otosaka, I. N. *et al.* (2023) *Earth Syst. Sci. Dat.*, 15, 1597–1616, https://doi.org/10.5194/essd-15-1597-2023

vulnerable because it is largely grounded below sea level. Ice shelf thinning from warm ocean waters drives grounding line retreat and instability[34]. West Antarctic Ice Sheet collapse could occur at 1–2°C of warming and raise global sea level by about 3 metres[35], indicating that the tipping point of West Antarctic Ice Sheet loss is within the Paris Agreement goal and could already have been reached[36]. While the East Antarctic Ice Sheet has historically been more stable, some regions, including the Totten and Denman glaciers in the Australian Antarctic Territory, are showing signs of rapid change. These are also marine-based systems, known to have collapsed previously during warm interglacial periods and have thresholds for instability projected at 2–3°C of warming – still within current warming projections for this century[37].

While scientific efforts are focused on providing greater certainty on Antarctica's contribution to sea level rise in the latter part of this century and beyond, the contributions expected in the coming decades are strongly predictive and can provide critical information for decision-making today[38]. Beyond the next 50 years, predictability reduces and by 2100, projected Antarctic contributions to sea level rise range from -1.4 to +15.5 cm and -7.6 cm to +30 cm depending on the emissions scenario[39]. Beyond 2100, contributions could accelerate to +1.7 m by 2200 and +4.4 m by 2300, with catastrophic consequences and reshaping of the world's coastlines[40].

3.3 Sea ice

Key messages

- Antarctic sea ice has declined dramatically since 2016 in all seasons and all sectors, with a major deficit in winter coverage since 2023.
- Climate models project near-total sea ice loss in summer and substantial winter reductions by the end of the 21st century[41].
- Given recent rapid changes, the likelihood of irreversible loss, ecosystem collapse and cascading climate impacts will increase with a larger and/or longer temperature overshoot.

Antarctic sea ice plays crucially important roles in climate, ecosystems and ocean circulation and processes. It forms a bright insulative layer on the Southern Ocean surface and injects vast amounts of dense brine into the underlying ocean water on forming, and vast amounts of freshwater on melting. Its area typically spans from around 3 million square kilometres in

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[34] Naughten, K.A., *et al.* (2023) *Nat. Clim. Chang.*, 13, 1222–1228. https://doi.org/10.1038/s41558-023-01818-x; Zheng, H. *et al.* (2026). *Sci. Adv.,* 12, eaea0652, https://doi.org/10.1126/sciadv.aea0652.

[35] Winkelmann, R., *et al.* (2026) *Nat. Clim. Chang.*, 16, 341–349. https://doi.org/10.1038/s41558-025-02554-0.

[36] Lau, S.C.Y., *et al.* 2023 *Science,* 382, 1384–1389. https://doi.org/10.1126/science.ade0664.

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[38] McCormack, F.S., *et al.* (2026) *Nature,* 654, 609–613. https://doi.org/10.1038/s41586-026-10614-4

[39] Seroussi, H. *et al.* (2020) *Cryosphere*, 14, 3033–3070; IPCC (2021) Ocean, Cryosphere and Sea Level Change. In 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, Cambridge, United Kingdom and New York, NY, USA, pp. 1211–1362, https://doi.org/10.1017/9781009157896.011.

[40] Seroussi, H. *et al.* (2024) *Earth's Futur.,* 12, e2024EF004561.

[41] Holmes, C. R., *et al*. (2022). *Geophys. Res. Lett.*, 49, e2021GL097413. https://doi.org/10.1029/2021GL097413.

summer to around 19 million square kilometres in winter, but has declined sharply since 2016 in all regions and in both summer and winter[42]. This decline is unprecedented in the satellite record (since 1979) and exceeds natural variability over recent centuries[43]. Furthermore, annual sea ice duration has shortened in many regions around Antarctica, with later formation and earlier retreat. These trends are linked to both changes in atmospheric circulation and increasing upper-ocean heat[44].

Loss of sea ice can indirectly contribute to sea level rise, by exposing damaged ice shelf margins to wave action[45], leading to increased ice shelf calving and even entire ice shelf disintegration, causing acceleration of grounded-ice discharge into the ocean[46]. Because ice shelves buttress inland ice, their destabilisation can accelerate ice sheet mass loss, contributing to global sea level rise.

Sea-ice decline also affects climate through altered ocean-atmosphere heat exchange, including increased heat absorption by darker, ice-free waters[47], and affects ocean stratification and circulation[48]. These processes reinforce feedbacks that further accelerate warming and ice loss[49].

3.4 Southern Ocean heat, carbon uptake and circulation

Key messages

- The Southern Ocean may be more sensitive to climate change than previously assumed[50]. A weaker Antarctic Overturning Circulation resulting from climate change would reduce carbon uptake, slow oxygen supply to the deep ocean, alter nutrient cycles, shift rainfall patterns over mid-latitude countries, and potentially accelerate ice shelf loss and sea level rise.
- Model projections indicate that the higher the emissions scenario, including the magnitude and duration of temperature overshoot, the greater the acceleration of deep ocean warming due to a slowdown in Antarctic Overturning Circulation, and the greater the global implications for climate and ecosystems[51].

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[42] Parkinson, C.L. (2019) *Proc. Natl. Acad. Sci. U.S.A.*, 116, 14414–14423. https://doi.org/10.1073/pnas.1906556116.
[43] Fogt, R.L., *et al.* (2022) *Nat. Clim. Chang.,* 12, 54–62. https://doi.org/10.1038/s41558-021-01254-9; Raphael, M.N., *et al.* (2025) *Commun. Earth Environ.,* 6, 131. https://doi.org/10.1038/s43247-025-02107-5.
[44] Purich, A., & Doddridge, E.W. (2023) *Commun. Earth. Environ.,* 4, 314. https://doi.org/10.1038/s43247-023-00961-9.
[45] Reid, P.A., & Massom, R.A. (2022) *Nat. Commun.,* 13, 1164. https://doi.org/10.1038/s41467-022-28676-z ; Teder, N.J., *et al.* (2025) *Nat. Geosci.,* 18, 599–606. https://doi.org/10.1038/s41561-025-01713-4
[46] Massom, R.A., *et al.* (2018) *Nature,* 558, 383–389. https://doi.org/10.1038/s41586-018-0212-1. Scambos, T. A., *et al.* (2004) *Geophys. Res. Lett.*, 31, L18402, https://doi.org/10.1029/2004GL020670
[47] Abram, N.J., *et al.* (2025) *Nature*, 644, 621–633. https://doi.org/10.1038/s41586-025-09349-5
[48] Meredith, M., *et al.* (2022) Polar Regions. In: *The Ocean and Cryosphere in a Changing Climate*, Cambridge University Press, Cambridge UK., 203–320, https://doi.org/10.1017/9781009157964.005.
[49] Alexander, S., *et al.* (2025) Antarctica and Climate Change Technical Report. A technical report for the National Climate Risk Assessment. Australian Climate Service, Australia
[50] Gunn, K.L., *et al.* (2023) *Nat. Clim. Chang.,* 13, 537–544. https://doi.org/10.1038/s41558-023-01667-8
[51] Li, Q., *et al.* (2023) *Nature,* 615, 841–847. https://doi.org/10.1038/s41586-023-05762-w

The Southern Ocean is the primary ocean region that removes anthropogenic carbon dioxide from the atmosphere[52]. It also absorbs most of the heat that the world's oceans store[53], playing a key role in slowing the rate of anthropogenic climate change. While this moderates atmospheric warming, it leads to ocean acidification that is detrimental to some forms of marine life[54]. The region also drives global ocean circulation through the formation of Antarctic Bottom Water, which redistributes heat, carbon and oxygen around the world's oceans[55]. This overturning circulation has been essential for climate stability over the last 11,000 years[56]. Changes in the strength of overturning circulation have widespread climate impacts, including through shifting the location of rainfall that Southern Hemisphere mid-latitude countries depend upon.

Since the early 1990s, bottom water formation around some parts of Antarctica has declined by around 30%[57]. Drivers include reduced sea-ice formation[58] and increased freshwater input from Antarctic Ice Sheet melt[59]. This slowdown is occurring earlier and faster than most climate models projected[60].

The world's strongest surface ocean current, the Antarctic Circumpolar Current, may also slow by 20% under a high emissions scenario, impacting global ocean circulation and the transport of low-latitude ocean heat to the Antarctic region[61].

3.5 Biodiversity change

Key messages

- Biodiversity impacts intensify with higher temperatures, loss of sea ice, and more extreme weather and climate events.
- Minimising the magnitude and duration of the temperature overshoot is therefore essential for limiting irreversible ecological losses, including extinctions.

Antarctic terrestrial and marine biodiversity, including species, populations and ecosystems, is already responding to climate change and impacts will intensify with further warming[62]. Polar marine species including Antarctic krill, penguins and seals, are shifting southwards, especially along the Antarctic Peninsula. Declines in the abundance of some species have led to their

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[52] Dong, Y. *et al.* (2024) *Sci. Adv*., 10. https://doi.org/10.1126/sciadv.adn5781; Frölicher, T.L., *et al.* (2015) *J. Clim*., 28, 862–886. https://doi.org/10.1175/JCLI-D-14-00117.1; Gruber, N., *et al.* (2023) *Nat. Rev. Earth Environ.*, 4, 119–134. https://doi.org/10.1038/s43017-022-00381-x.
[53] Huguenin, M.F., *et al.* (2022) *Nat. Commun.,* 13, 4921. https://doi.org/10.1038/s41467-022-32540-5.
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[56] McManus, J.F., *et al.* (2004). *Nature,* 428, 834–837. https://doi.org/10.1038/nature02494.
[57] Zhou, S., *et al.* (2023) *Nat. Clim. Chang.,* 13, 701–709. https://doi.org/10.1038/s41558-023-01695-4
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[60] Heuzé, C., *et al.* (2015) *J. Clim.,* 28, 2917–2944. https://doi.org/10.1175/JCLI-D-14-00381.1.
[61] Sohail, T., *et al*. (2025) *Environ. Res. Lett*., 20, 034046. https://doi.org/10.1088/1748-9326/adb31c.
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reclassification by the International Union for the Conservation of Nature Red List to higher threat categories, including from Least Concern to Vulnerable (southern elephant seal), Least Concern to Endangered (Antarctic fur seal) and Near Threatened to Endangered (emperor penguin)[63].

Projections indicate that the greater the temperature rise above pre-industrial levels, the larger the consequences for biodiversity. In marine systems, most changes are negative and associated with declining sea-ice extent and duration, loss of ice shelves[64], and ocean acidification[65]. The emperor penguin faces quasi-extinction (population decline beyond recovery) under higher emission pathways[66]. Thus, overshoot of 1.5°C presents a significant threat to the future of this iconic species. Analyses for other species suggest similar negative outcomes[67].

On land, warming, changing precipitation patterns (including shifts from snow to rain) and increasing wind speeds are reorganising plant and invertebrate communities[68], alongside increasing biosecurity risks and the potential for establishment of invasive species[69].

Terrestrial systems also show that the greater the temperature rise, and the more intense and long-lasting the associated extreme events, the greater the changes to species and the communities they comprise[70]. Responses are likely to differ between major groups and regions of Antarctica, which means reorganisation of what are currently unique systems. A system-wide change in extreme Antarctic environments dominated by chemosynthesis, to environments dominated by globally common photosynthesis, is expected to increase with every increment of temperature rise above pre-industrial levels[71].

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[63] Fretwell, P.T. (2026) *Commun. Earth Environ.,* 7, 192. https://doi.org/10.1038/s43247-026-03231-6; IUCN (2026) Emperor penguin and Antarctic fur seal now Endangered due to climate change. Emperor penguin and Antarctic fur seal now Endangered due to climate change – IUCN Red List - Press release | IUCN (accessed 24/04/2026).
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4. Implications for Antarctic and Southern Ocean policy and decision-making

4.1 Environmental management

Key messages

- Human activities and the management of those activities and environmental protection in Antarctica and the Southern Ocean will face increasing challenges from climate change.
- If thresholds are exceeded, and Antarctica and the Southern Ocean undergo abrupt and/or irreversible change to their physical and biological systems, this would have profound impacts on human health and safety, built infrastructure and environmental management in the region.

Climate change interacts with human activities in the Antarctic and Southern Ocean region, including scientific research, tourism and fishing, creating complex, cumulative impacts that worsen with every increment of global warming. This increases the need for long-term environmental and biological monitoring to detect and respond to ecological change across terrestrial and marine systems and inform management decisions.

Challenges to environmental management and human activities in Antarctica and the Southern Ocean region from climate change include:

- Impacts on Antarctic and sub-Antarctic infrastructure from coastal erosion, sea level rise and extreme weather events;
- Sea ice decline provides access to areas previously inaccessible posing risks to environmental management;
- Unpredictable weather, sea ice conditions and extreme events pose increased risk and hazards to national Antarctic programs operations, tourism operations, airfields and other transportation activities[72];
- Disruption to ecosystem structure and function, including changes to krill distribution and abundance resulting from physical changes such as sea ice loss, ocean warming and extreme events will affect Antarctic and Southern Ocean species and commercial fisheries managed by the Commission for the Conservation of Antarctic Marine Living Resources[73] ;
- Changing climate and environmental conditions will require enhanced disaster management, including coordinated multinational and commercial responses to disease spread and other rapid-onset crises[74];
- Marine and terrestrial protected areas have fixed boundaries that may no longer align with shifting species distributions and expanding or contracting habitats, requiring an adaptive management framework; and

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[72] Siegert, M., *et al.* (2026) *Commun. Earth Environ.*, 7, 445. https://doi.org/10.1038/s43247-026-03629-2.
[73] Doddridge, E.W., *et al.*, (2025) *PNAS Nexus*, 4, pgaf164. https://doi.org/10.1093/pnasnexus/pgaf164.
[74] Bode, M. *et al.* (2026) *PNAS* 123, e2535757123. https://doi.org/10.1073/pnas.2535757123.

- Increasing biosecurity risks that threaten the integrity of Antarctic ecosystems.

4.2 Governance

Key messages

- The Antarctic Treaty System (ATS) is collection of regionally focused agreements with relatively limited membership and is not equipped to address global greenhouse gas emissions, which remain the province of the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement.
- Closer and more formal linkage between the Antarctic Treaty System, its states parties' representatives and the UNFCCC process is needed to ensure Antarctic scientific research informs, and is informed by, global climate change mitigation pathways.

Antarctic governance faces growing challenges as climate-driven change interacts with increasing human activity from science, fishing and tourism. Decisions within the ATS are made by consensus, which has given the system remarkable stability but means coordinated responses can take time to develop, a constraint that matters as climate risks accelerate. As a regional regime focused on protecting the Antarctic Treaty Area, the ATS was not designed to address global greenhouse gas emissions, which remain the province of the UNFCCC and the Paris Agreement.

This points to an opportunity. The ATS is one of the most successful examples of science-led international cooperation, and its environmental record, including the comprehensive protection of the continent and the prohibition of mineral resource activity, shows what anticipatory, coordinated action can achieve. Bringing that same spirit to climate change negotiations means strengthening the connection between Antarctic governance and the global climate governance processes, especially as climate change and its impacts do not recognise boundaries or jurisdictions. Furthermore, the Scientific Committee for Antarctic Research (SCAR) is an official observer to the UNFCCC, which allows SCAR to participate in Conference of the Parties meetings, but not in decision making. SCAR is also an independent advisory body to the ATS and does not represent the states parties to the Antarctic Treaty when participating in other forums.

Closer and more formal linkage between the ATS, its states parties' representatives and the UNFCCC process is needed, building on the Antarctic Treaty parties' commitments in the *2023 Helsinki Declaration on Climate Change and the Antarctic*. This would ensure Antarctic scientific research informs, and is informed by, global mitigation pathways. Aligning the pace of cooperation with the urgency of the science is the central task ahead.

5. Summary and recommendations for action

Climate projections consistently indicate ongoing warming, ice loss, and ecosystem change under all emissions scenarios. Even with limited temperature overshoot, substantial impacts and some irreversible losses are expected. Higher emissions or extended overshoot increase the risk of crossing critical thresholds, including further ice shelf collapse and ice sheet instability, potentially leading to metres of sea level rise over coming centuries, and major disruptions to ocean circulation, biodiversity and ecosystems.

Uncertainty does not mean low risk; observations already show abrupt, potentially irreversible changes, with escalating impacts as warming intensifies. These effects have major consequences for Antarctica, the Southern Ocean and the world.

5.1 Recommendations for action

In the spirit of the *Belém Mission to 1.5* initiative the following recommendations for action have been identified as opportunities for international cooperation on climate change with a focus on Antarctica and the Southern Ocean region.

- Antarctica and the Southern Ocean should be considered within the UNFCCC climate negotiations as a core component of the Earth system. Changes in this region and the crossing of critical thresholds are directly relevant to assessing climate risks, hazards, losses and damages globally – now and into the future.
- Prioritisation of, and sustained investment in, long-term observation and monitoring in the Antarctic and Southern Ocean region to improve understanding of how the region is contributing to global climate change, and accuracy of global climate models and future climate projections.