Submission to the Joint Standing Committee on the National Capital and External Territories
Inquiry into the importance of Antarctica to Australia's national interests

ARC Centre of Excellence for Climate Extremes

and

ARC Centre of Excellence for Weather of the 21st Century

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12 April 2024

Committee Secretary
Joint Standing Committee on the National Capital and External Territories
PO Box 6021
Parliament House
Canberra ACT 2600

Dear Committee Chair,

The ***ARC Centres of Excellence for Climate Extremes*** and the ***Weather of the 21st Century*** welcome the opportunity to make a joint submission, attached below, to the federal Inquiry into the importance of Antarctica to Australia's national interests.

The Centre for Climate Extremes works to understand and reduce Australia's vulnerability to climate extremes through leading the development of fundamental climate science and improving models which analyse the extremes of the past and predict the extremes of the future.

Weather of the 21st Century is researching how Australia's weather is being reshaped by climate change, and what this means for our weather resources and high impact weather.

Both centres comprise of five partner universities - The University of New South Wales, Monash University, The Australian National University, The University of Melbourne and The University of Tasmania, as well as multiple national and international partner organisations.

We commend the Joint Standing Committee on the National Capital and External Territories for inquiring into this invaluable area. Thank you for the opportunity to make a submission on this topic and offer the expertise of our combined Centres on any matters arising from this submission.

Yours sincerely,

Professor Andrew Pitman, AO, FAA
Centre Director
ARC Centre of Excellence for
Climate Extremes

Professor Christian Jakob
Centre Director
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Weather of the 21st Century

Executive Summary

As Australian Centres of Excellence in climate research, the ***ARC Centres of Excellence for Climate Extremes*** and the ***Weather of the 21st Century*** confirm the importance of Antarctica to Australia's national interest. The focus of our submission concentrates on '***developing a better understanding of global environment and climate science***', as outlined in the terms of reference for this inquiry.

Australia plays a dominant role as a leader in Antarctic research globally and is pivotal to facilitating and contributing to the overall research effort and community.

The current conditions in Antarctica are concerning, with alarming rates of decline in sea ice pointing to a possible regime shift, potentially an indicator of a tipping point element. Our submission highlights the need for further research in this area.

There are multiple complex mechanisms at work that influence Antarctic, Australian and global climate, including atmospheric and ocean circulation, glacier melt and sea level rise. Further research is needed to deepen our understanding on how these mechanisms work.

Research efforts are supported by a foundation of research computing infrastructure and data which are essential to ensure the research is effective. Using paleoclimate data, obtained from natural archives such as ice cores, allows us to examine Antarctica's behaviour over a long time period and only the continued support of these fundamental sources of data collection and analysis can progress Antarctic research.

This submission is intended to inform the committee on the most recent developments in Antarctic research to demonstrate the importance of Antarctica to Australia's national interests and by extension global interests. We reiterate the need to maintain and continue research into this vital area and make a number of recommendations which we hope the committee will consider.

Recommendations

We make the following recommendations to the committee to consider.

1. Maintain Australia's role as a world class research leader in Antarctica.
2. Support priority research on Antarctic sea ice to investigate the risk of recent extremes and future changes to Australia's communities.
3. Ensure Australia's climate modelling capability is maintained through long-term government support for scientific model development and the Australia's Earth System simulator national research infrastructure (ACCESS-NRI).
4. Maintain and strengthen the research infrastructure needed to collect and analyse data such as ice core data from high snowfall sites.
5. Support Australia's research community long term to investigate and pursue new research directions while being resourced accordingly.

Submission

Antarctica plays an important role in shaping Australian climate and its coastline as well as a global role in the climate system of the Earth[1]. Its influence is far-reaching. Climatically, its effects include Australian rainfall and sea level rise. Ecologically, Antarctica's changing climate is impacting[2] regional biodiversity at species level through the food chain, e.g. marine fisheries. Geopolitically, pressure is also a factor through Antarctica's global connectivity and potential for minerals and energy.

It is essential that the Australian scientific community, in close cooperation with international partners, continues to build an Australian understanding of Antarctic climate processes. This research has direct implications for the Australian and global climate; it is vital for understanding how our climate is changing, and for informing climate mitigation policies and adaptation decisions. Climate science research in Antarctica highlights the importance of 'blue sky' research and its foundational outcomes to applied science such as information on climate tipping points, climate geoengineering solutions, water resources in Australia and global sea level rise.

This submission therefore concentrates on the importance of Antarctica for Australia's national interests in '***developing a better understanding of global environment and climate science***', as outlined in the terms of reference for this inquiry.

Australian Antarctic research - a respected leader in the global research community

Australian Antarctic research provides information for our national interest as well as being an essential part of global research with many international organisations collaborating with Australia and utilising its findings. Australia plays a leadership role in maintaining high quality research which informs and supports many other organisations such as the National Oceanic and Atmospheric Administration (NOAA) and the British Antarctic Survey. Australia is the mainstay of world-class, respected, cutting-edge research in Antarctica.

Multiple research groups and agencies have a presence in Antarctica. Their expertise, in their distinct areas, combines to provide a global effort to understand and further our understanding in this complex area. Academic research collaborations allow Antarctic researchers to tackle the complexity involved in researching this sometimes inhospitable continent together. Researchers can benefit by gaining access to resources they would not otherwise have, for instance funding, equipment, or international expertise.

Recommendation 1: Maintain Australia's role as a world class research leader in Antarctica

Recent conditions - a regime shift in Antarctic sea ice?

Recent climate observations from Antarctica show alarming rates of decline in sea ice. Over the last two years, both the southern hemisphere summer (2022/23) and winter (2023) sea ice extent were at a record low. The winter sea ice maximum extent was over 1 million square kilometres less than the previous record with very low Antarctic Sea ice extent throughout 2023. This is unmatched in historical observations[3].

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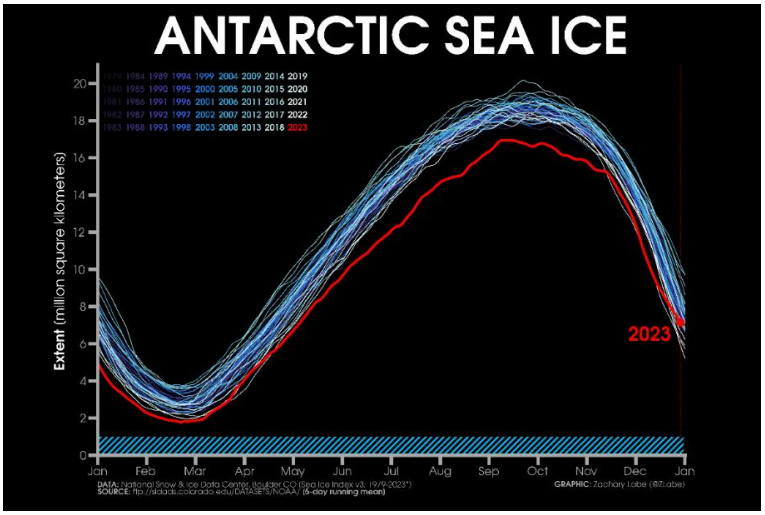
[1] https://www.atse.org.au/news-and-events/article/how-antarctic-science-helps-us-understand-australian-climate/

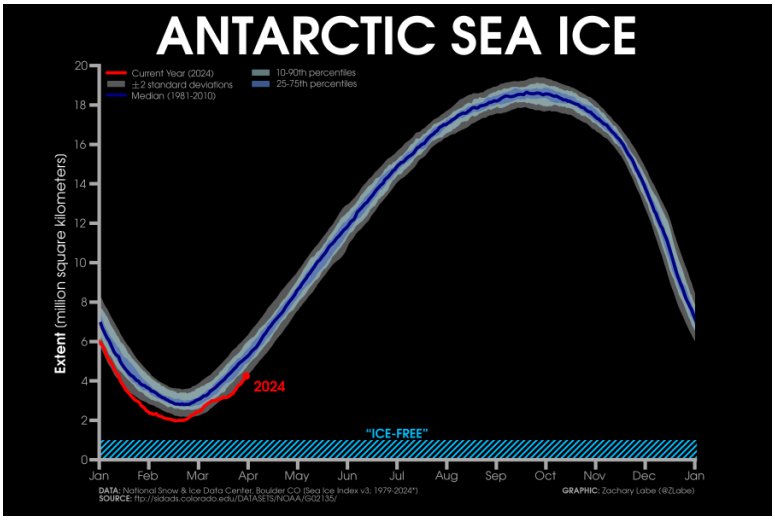
[2] https://www.theguardian.com/environment/2024/apr/06/simply-mind-boggling-world-record-temperature-jump-in-antarctic-raises-fears-of-catastrophe?ref=upstract.com

[3] https://climateextremes.org.au/the-state-of-weather-and-climate-extremes-2023/



Annual Antarctic Sea ice extent since the start of the satellite records in 1979. The anomalous record of 2023 is highlighted in red. Source: https://zacklabe.com/antarctic-sea-ice-extentconcentration/ Dr Zachary Labe.

For Antarctica in 2024, sea-ice reached its seasonal minimum in February 2024, tying with 2022 for the second-lowest extent in the satellite record[4]. After decades of high ice coverage, this is concerningly an abrupt transition. Australian-led research points to a possible regime shift now underway in Antarctic sea ice[5].



Current Antarctic sea ice extent (NSIDC, DMSP SSM/I-SSMIS F-18) in addition to climatology (blue, 1981-2010) and 2 standard deviations from the mean (updated 4/1/2024). Source: https://zacklabe.com/antarctic-sea-ice-extentconcentration/

Changes in Arctic sea ice are a well-known tipping point element, a term used to describe large-scale components of the Earth system that may pass a tipping point[6]. These elements can undergo an abrupt change in state, which becomes self-perpetuating and irreversible for a very long time[7]. It isn't yet known if Antarctic sea ice could also represent a similar tipping point element, partly

[4] Chilling Reality: Antarctic Sea Ice Hits Near-Historic Lows (scitechdaily.com)

[5] https://journals.ametsoc.org/view/journals/clim/37/7/JCLI-D-23-0479.1.xml

[6] https://doi.org/10.1073/pnas.0705414105

[7] https://theconversation.com/dangerous-climate-tipping-points-will-affect-australia-the-risks-are-real-and-cannot-be-ignored-222737

because the ability to replicate observed Antarctic sea ice variability and change, in climate models, is currently poor. What is clear, however, is that the magnitude of sea ice loss from Antarctica in the past decade[8] rivals the amount of sea ice that has been lost from the Arctic in the past four decades, and that recent Antarctic sea ice loss has broken records by an amount that has been scientifically staggering.

The decline of Antarctic sea ice extent has implications for Australia. Sea ice is important to Earth's heat budget, to carbon dioxide exchange between the ocean and atmosphere, and to global deep ocean circulation patterns; these all directly influence Australia's weather and climate.

Sea ice provides key services for marine ecosystems and the recent extreme decline in sea ice will drive habitat loss for penguins, seals and whales. It will reduce prey availability, be detrimental to krill, and generally impact the biological productivity of the Southern Ocean. This could affect local fisheries over decades to come. The recent changes in sea ice counterintuitively result in difficulties for shipping and in accessing Antarctica. Traditionally, stable sea ice is used as a bridge between vessels and the land. Thinner ice that breaks and moves more easily, and increasing icebergs formation due to the lack of sea ice that holds ice shelves together, compound to make logistics around Antarctica increasingly difficult[9].

Conversely, the behaviour of weather phenomena, sometimes a long distance from Antarctica, including Australia, has an effect on Antarctic climate. A number of publications (e.g. Meehl et al 2019[10]; Wang et al 2019[11]; Purich and England 2019[12]) have shown that tropical climate variability from the Indian Ocean can strongly affect Antarctic sea ice extent, with influences from the Pacific and Atlantic also shown to have a link.

A more complete understanding of the recent Antarctic sea ice extremes and their implications and potential consequences is subject to on-going research both in Australia and abroad. The ability to project Antarctic sea ice changes over decades to come will be hugely beneficial to Australian adaptation activities .

Recommendation 2: Support priority research on Antarctic sea ice to investigate the risk of recent extremes and future changes to Australia's communities.

Antarctica's role in global ocean circulation, and its implications for Australia

Understanding ocean circulation around Antarctica is critical to understanding many elements of local and global weather and climate, including implications for global sea level rise.

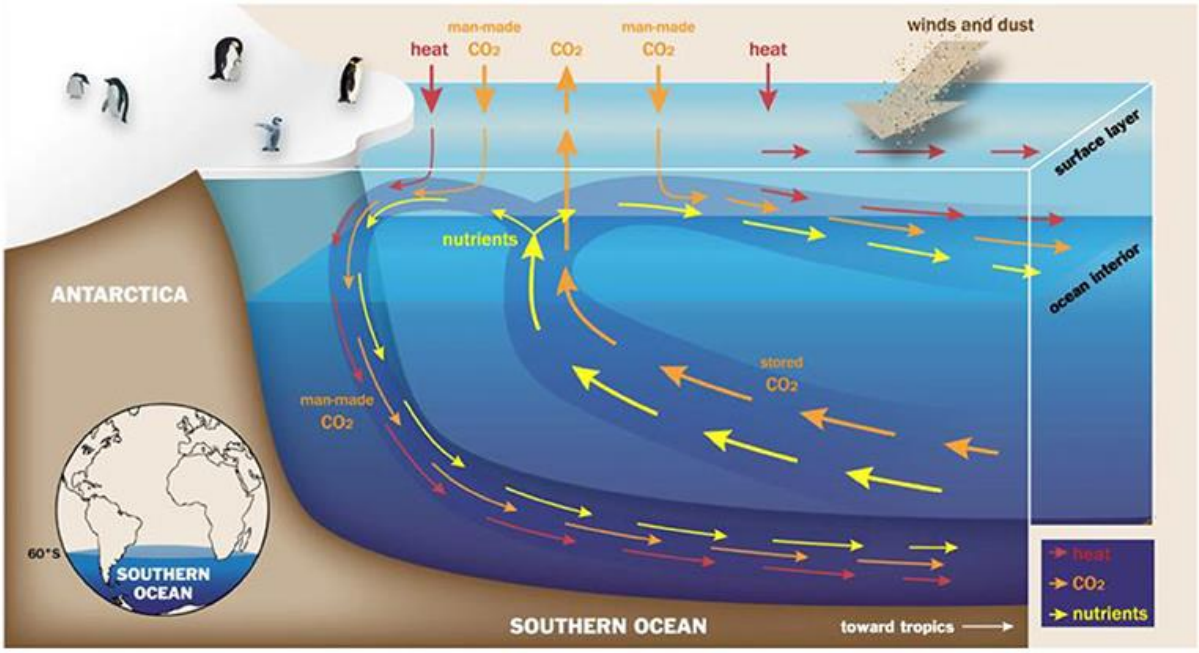
[8] https://www.nature.com/articles/s43247-023-00961-9

[9] Doddridge, Hobbs, et al., (2024), Impacts of Antarctic Summer Sea-Ice Extremes, Manuscript submitted for publication, University of Tasmania.

[10] Meehl, G.A., Arblaster, J.M., Chung, C.T.Y. *et al.* Sustained ocean changes contributed to sudden Antarctic sea ice retreat in late 2016. *Nat Commun* 10, 14 (2019).

[11] https://doi.org/10.1029/2018JD029601

[12] https://doi.org/10.1029/2019GL082671



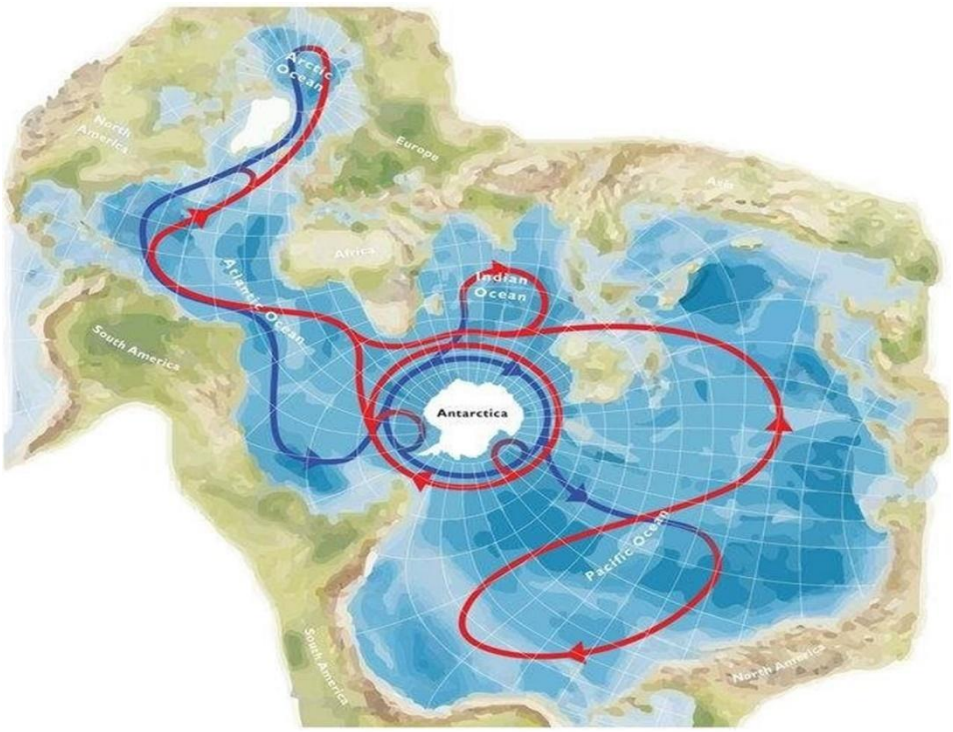
Vertical circulation in the Southern Ocean and its impact on global climate. Man-made carbon dioxide and heat enter the ocean from the atmosphere and are carried into the deep ocean. Natural carbon dioxide and nutrients that have been stored in the deep ocean travel back up to the surface (adapted from IPCC).
Source: https://kids.frontiersin.org/articles/10.3389/frym.2023.1054758

Antarctica is at the centre of a global network of ocean currents called the "overturning circulation". As sea ice forms on the ocean around Antarctica, the fresh water freezes and leaves behind salt that results in the formation of very dense water[13].

The cold and salty dense water sinks towards the seafloor and spreads out to all major ocean basins. Deep water, which originally formed around Antarctica, can even be found in the Northern Hemisphere[14]. Deep ocean circulation is a key component of transporting heat, salt and nutrients, and the redistribution of water helps to regulate the climate and marine ecosystems around the globe.

Australian-led research[15] has shown that projected increases in Antarctic ice melt are set to drive a substantial slowdown in the Antarctic overturning circulation over the coming decades, resulting in large and widespread warming of deep waters with a net slowdown of the ocean circulation of just over 40% projected to occur by 2050. These changes are expected to profoundly alter the ocean overturning of heat, fresh water, oxygen, carbon and nutrients, with impacts on the global ocean and climate for centuries to come.

[13] Orsi, A H, Johnson, G C, Bullister, J L, 1999, Circulation, mixing and production of Antarctic Bottom Water, Progress in Oceanography, 55-109.
[14] Johnson, Gregory C., 2008, Quantifying Antarctic Bottom Water and North Atlantic Deep Water volumes, Journal of Geophysical Research: Oceans, doi:10.1029/2007JC004477.
[15] https://www.nature.com/articles/s41586-023-05762-w



Schematic representation of the global overturning circulation with surface flow in red and deep flow in blue highlighting the importance of the Southern Ocean in the global ocean circulation. Source: Meredith et al. (2019)[16]

Movement of the warm water from the intermediate levels of the ocean onto the continental shelf around Antarctica can lead to melting of the Antarctic ice shelves from below[17]. This is a factor that can accelerate ice loss and global sea level rise, and in parts of Antarctica this process, combined with parts of the ice sheet that sits on ground below sea level, has the potential to lead to tipping points in the Antarctic ice sheet where further ice loss becomes unstoppable even if global climate is stabilised.

Glacier melt and sea level rise

The Antarctic Denman Glacier is the deepest known glacier on Earth (sitting on ground that is more than 3.5km below sea level) and has the potential to raise global sea levels by around 1.5 metres if destabilised. The Denman Glacier is the focus of an on-going Australian-led multidisciplinary campaign to better quantify this system. Other areas of concern for the East Antarctic ice sheet in a warming climate include the Wilkes and Aurora sub-glacial basins. It is thought that substantial ice loss from these regions could be averted if the Paris Agreement to limit warming to below 2°C is satisfied[18].

Ice is already being lost from Antarctic ice shelves and ice sheets, and this meltwater plays an important role in modifying ocean circulation and sea ice formation[19]. The importance of meltwater

[16] Meredith, Michael P. 2019 The global importance of the Southern Ocean and the key role of its freshwater cycle. Ocean Challenge, 23 (2). 27-32.

[17] Adusumilli, Susheel, Fricker, Helen Amanda, Medley, Brooke, Padman, Laurie, Siegfried, Matthew R, 2020, Interannual variations in meltwater input to the Southern Ocean from Antarctic ice shelves, Nature Geoscience, doi:10.1038/s41561-020-0616-z.

[18] https://doi.org/10.1038/s41586-022-04946-0

[19] https://doi.org/10.1175/JCLI-D-22-0457.1

to the ocean circulation extends to influences on weather patterns and shifting rainfall patterns in the tropical Pacific for example. This can have knock-on impacts on our climate in Australia.

Importantly though, this process isn't currently included in the global climate model simulations that are used to estimate future climate changes around the world, including Australia. This is a critically important omission in our ability to accurately model long-term future climate changes. Work to improve Australia's Earth System simulator that forms part of Australia's national research infrastructure (ACCESS-NRI) now includes a priority to incorporate an interactive ice sheet into Australia's climate modelling capability. This will enable a detailed assessment of risks of changes in Antarctica to mainland Australia.

Recommendation 3: Ensure Australia's climate modelling capability is maintained through long-term government support for scientific model development and the Australia's Earth System simulator national research infrastructure (ACCESS-NRI).

Using Antarctica to gain a long-term understanding of Australia's climate

Antarctica holds some of the earth's oldest ice, with ice sheets several kilometres deep. As snowfall accumulates on the Antarctic ice sheets and glaciers, atmospheric gases, water vapour and tiny particles like dust and sea-salt from the time of snowfall are trapped in the snow. Over time, each layer of snow is compressed by the weight of new snowfall which eventually forms ice. These layers of ice preserve a near continuous chronological record of past changes in climate and atmospheric gas composition. We can extract this past climate information by drilling ice cores. Acting like time capsules, the ice cores increase our understanding on how atmospheric carbon dioxide affected surface temperatures in the past[20].

Looking at past events gives an indication of how a warming climate may affect us now. For example, ice core records have recently shown how gradual climate warming in the past can result in very rapid destabilisation and loss of ice in vulnerable parts of Antarctica[21].

Ice cores from parts of Antarctica that receive high annual snowfall can also tell us past information about Southern Hemisphere climate variability and extremes. Ice cores have allowed us to understand the Southern Annular Mode - a major factor in driving rainfall variability in southern parts of Australia. They provide the insights to show that rising greenhouse gases and ozone depletion have caused the Southern Annular Mode to move to its highest level over at least the last 1000 years, and to show that climate models have deficiencies in replicating the range of natural variability of this climate mode[22]. Crockart et al.,[23] found that the sea-salt concentration in ice core records, which indicate atmospheric circulation and Southern Ocean wind conditions, are linked to El Niño Southern Oscillation.

These links help us understand regional climate variability that influences Australian climate, including rainfall, temperature and fire weather extremes, but on a much longer timescale than is possible from instrumental climate records alone. Ice cores from high snowfall regions in East Antarctica are particularly valuable for understanding past climate variability in Australia and providing context to climate change projections.

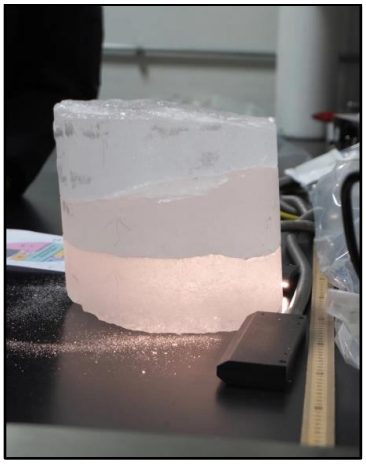
[20] https://www.scientificamerican.com/article/inside-the-race-to-find-earths-oldest-ice/

[21] https://doi.org/10.1038/s41561-024-01375-8

[22] DOI: 10.1038/NCLIMATE2235

[23] https://doi.org/10.5194/cp-17-1795-2021

The Law Dome ice core record has a weather scale connection (e.g. high and low pressure systems stretching between Antarctica and Australia) to Australian rainfall[24] and indicates that what we consider as 'typical' rainfall years based on the past 120 years of data from rainfall gauges, are not typical at all, with periods over the past 2000 years that are wetter (increased flood hazard) and drier (increased drought hazard) than our observations[25,26]. This has implications for water resource infrastructure and policy decisions[27].



Cut section of very old ice from Allan Hills at the National Science Foundation Ice Core Facility in Colorado. Credit: Peter Neff/COLDEX. Source: https://www.scientificamerican.com/article/inside-the-race-to-find-earths-oldest-ice/

Recommendation 4: Maintain and strengthen the research infrastructure needed to collect and analyse data such as ice core data from high snowfall sites.

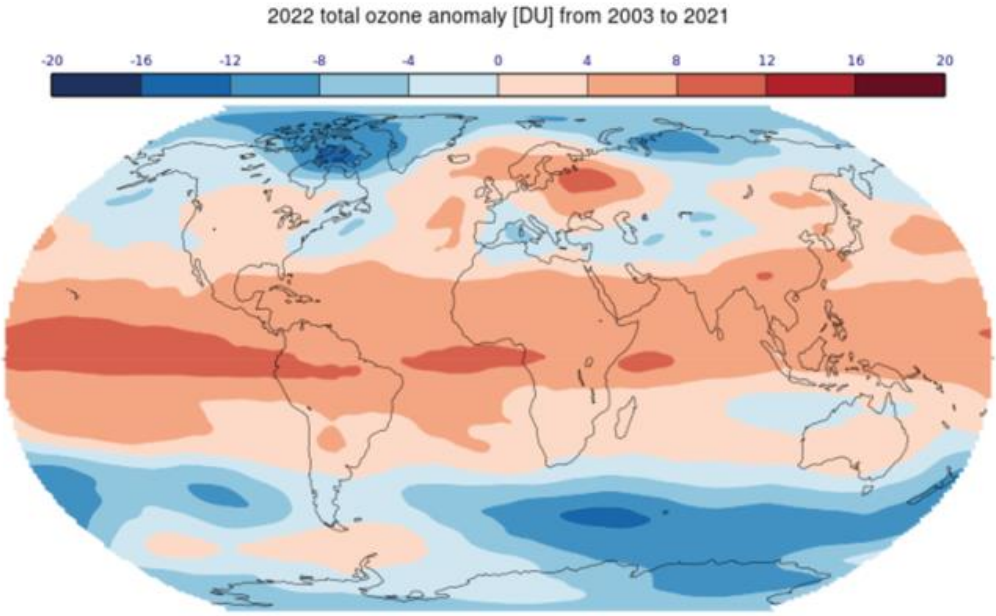
Antarctic ozone hole

The protective nature of the Earth's ozone layer, against harmful solar ultraviolet radiation and its human and environmental damage, has been well documented. Observed thinning during the 1980s resulted in the Montreal Protocol in 1987, a treaty phasing out ozone depleting chemicals[28], and now the Antarctic ozone hole is starting to heal[29].

Additionally, the ozone layer also has a role in decreasing surface warming and therefore mitigating anthropogenic climate change. Goyal et al.,[30] found as much as 1.1°C warming has been avoided over parts of the Arctic and future climate benefits correspond to about a 25% mitigation of global warming. However, since 2020 there have seen surprisingly large ozone holes forming each spring and prolonging into summer. Understanding what drives these year-to-year fluctuations in the ozone hole is critical for understanding our summer climate.

[24] https://unsw.zoom.us/j/83695112267
[25] https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2014GL062447
[26] https://www.nature.com/articles/s43247-022-00359-z
[27] https://www.sciencedirect.com/science/article/pii/S221458182030080X
[28] https://earthobservatory.nasa.gov/world-of-change/Ozone
[29] https://library.wmo.int/idurl/4/66208
[30] https://doi.org/10.1088/1748-9326/ab4874

For example, Gillett et al.,[31] investigated the observed relationship between the small spring Antarctic ozone holes and hotter summer surface temperatures over Australia, finding climate models required further refinement to simulate this link. Improving our modelling of ozone-weather interactions could lead to better seasonal predictions of Australian climate, with implications for agriculture.



Deviation of the 2022 annual mean total ozone column from the 2003 to 2021 climatology. Source: *Copernicus Atmosphere Monitoring Service Reanalysis (Inness et al., 2019)*

Antarctic polar vortex

The Antarctic polar vortex is the band of strong winds encircling Antarctica. Variations in the stratospheric Antarctic polar vortex can induce hot and cold extremes in Australia, including modifying fire risk in eastern Australia[32]. This Antarctic climate processes has been found to be a key factor in driving Australia's Black Summer bushfire disaster[33]. Surprisingly, the smoke from these extreme fires rivalled the magnitude of a moderate volcanic eruption and was pushed high into the stratosphere, where it then played a role in worsening the ozone hole over Antarctica in subsequent years[34]. This demonstrates how closely connected Australia's climate is to Antarctica, and how there are still climate processes that are still to be discovered, let alone understood.

Recommendation 5: Support Australia's research community long term to investigate and pursue new research directions while being resourced accordingly.

[31] https://doi.org/10.1175/JCLI-D-18-0273.1

[32] Lim, EP., Hendon, H.H., Boschat, G. et al. Australian hot and dry extremes induced by weakenings of the stratospheric polar vortex. Nat. Geosci. 12, 896–901 (2019). https://doi.org/10.1038/s41561-019-0456-x

[33] Abram, N.J., Henley, B.J., Sen Gupta, A. *et al.* Connections of climate change and variability to large and extreme forest fires in southeast Australia. *Commun Earth Environ* 2, 8 (2021). https://doi.org/10.1038/s43247-020-00065-8

[34] Solomon, S. *et al. Nature* https://doi.org/10.1038/s41586-022-05683-0 (2023).