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Policy brief:

Climate change and its impact on the Antarctic Peninsula

Contents

Highlights

- The Antarctic Peninsula, part of British Antarctic Territory, is warming rapidly, up to two times the global mean rate of 0.27°C per decade.
- Substantial and irreparable environmental damage to the Antarctic Peninsula occurs if global warming exceeds 2°C.
- Significant loss of sea ice, ice shelf collapse and glacier recession risk self-perpetuating processes that will amplify polar warming and influence global climate, ocean circulation and sea level.
- The changing Antarctic Peninsula climate has ramifications for species migration and loss, with impacts on krill, fishing, and food chains for large marine mammals. Extreme weather has led to flooded penguin nest sites and low sea ice, leading to failures of Emperor Penguin breeding colonies.
- Action to rapidly reduce carbon emissions can limit long term and severe impacts on the Antarctic Peninsula, including impacts to marine and terrestrial biodiversity and human operations, and limit wider ramifications for global systems.
- Global warming will require a more flexible and dynamic approach to marine protected areas and other initiatives designed to conserve biodiversity in the Southern Ocean and Antarctic continent.
- The UK's British Antarctic Territory encapsulates the Peninsula, and the UK's 2025 Antarctic Strategy is committed to maintaining "peaceful and lawful usage" and to continue upholding the Antarctic Treaty. Environmental changes on the Peninsula, creating a riskier and more challenging operational environment, alongside increased shipping, tourism and fishing, may place stress on the Antarctic Treaty System and associated legal instruments.

Introduction

The Antarctic Peninsula is a global biodiversity hotspot, and is a focus of tourism, scientific and fishing operations[1]. It is a sentinel for climate thresholds, with changes occurring here first, before spreading across Antarctica through oceanic and atmospheric connections. The threats it faces from a warming climate, and its capacity to amplify the global climate change signal, strengthen the case for action on climate change.

Globally averaged warming as of 2024 reached 1.34–1.41°C relative to 1850–1900 CE[2], with an average trend of +0.27°C per decade since the late 1970s[3]. Policies as of 2025 for COP30 are only enough to keep warming below 2.8°C (range 2.1–3.9°C), and the likelihood of remaining below 1.5°C of warming is 0%[4]; achievement of all near-term country pledges and long term net-zero targets would lower this estimate to 1.9°C (range 1.8–2.3°C). Therefore, we focus here on how the Peninsula will change by 2100 CE under three global warming scenarios[1,5]:

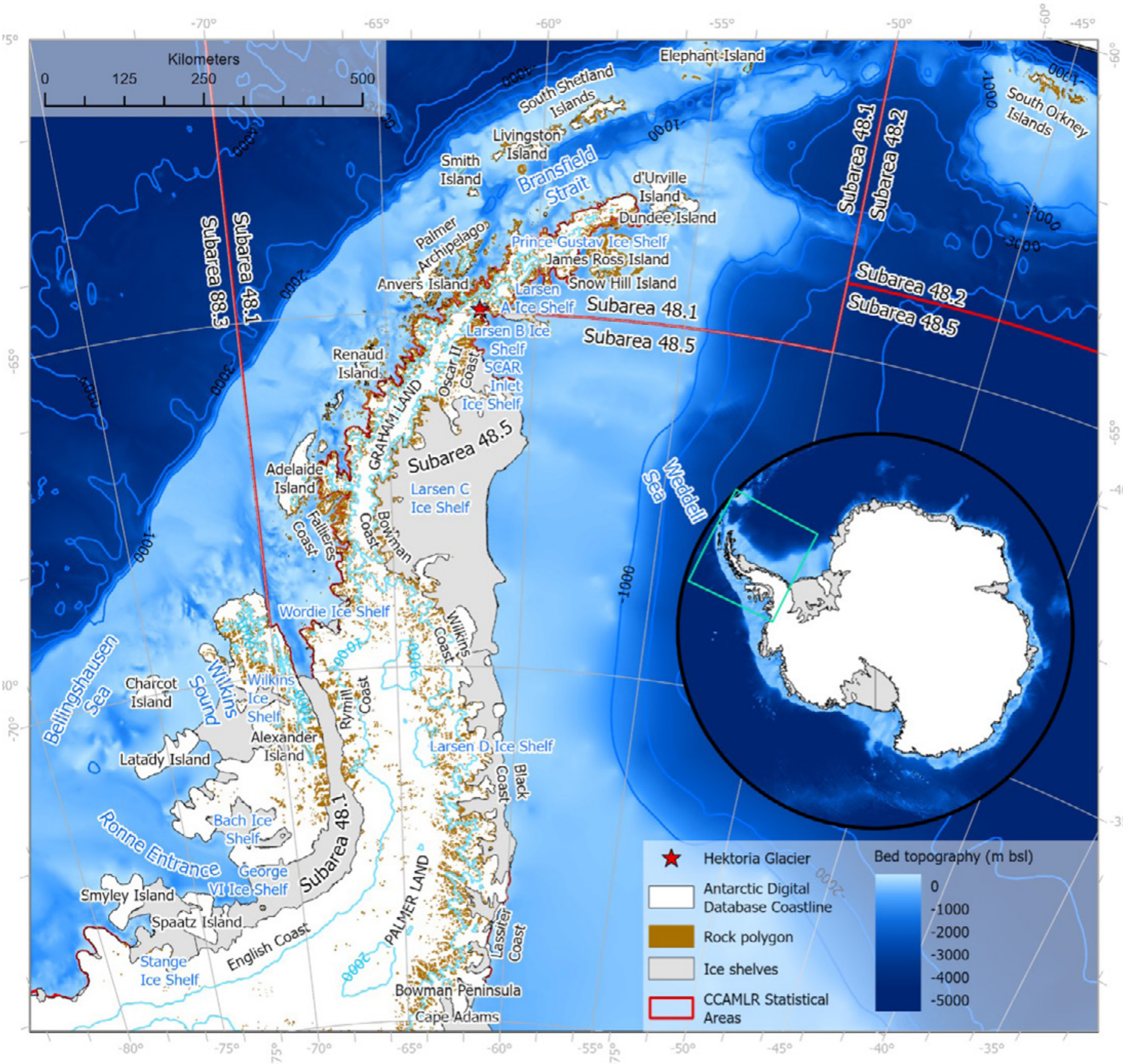
- **Shared Socioeconomic Pathway (SSP)1–2.6.** A low emissions scenario that limits warming to <2°C (*very likely* range 1.3–2.4°C) above preindustrial temperatures and is lower than that projected under current policies.
- **SSP3–7.0.** A medium-high emissions scenario that leads to global mean temperatures of 3.6°C (*very likely* range 2.8–4.6°C) above preindustrial, the lower end of which overlaps with currently projected climate.
- **SSP5–8.5.** A very high emissions scenario that leads to a mean global temperature change of 4.4°C (*very likely* range 3.3–5.7°C) above preindustrial5.

We build on a previous report on the impacts of the Antarctic Peninsula under a lower emissions scenario with 1.5°C of global warming[6,7], a future scenario that is now unachieveable[4].

About the Antarctic Peninsula

The Antarctic Peninsula is a spine of alpine-style mountains with glaciers mostly terminating in the ocean, in seasonal or landfast sea ice (sea ice attached to the shore), or in floating ice shelves (Figure 1). The main Peninsula is 98.6% ice covered and contains enough ice to raise global sea levels by 0.27 m[8] on full melting. Much of the glacier ice is only a few hundred metres thick and is grounded (i.e. the bed is resting on bedrock) above sea level, except for the Bellingshausen Sea sector in the south, where the bed is below sea level (Figure 1). Around the Peninsula, floating landfast sea ice and ice shelves help to buttress the glaciers and inhibit calving[9] (where chunks of ice split from the glacier and float away).

Figure 1. The location and main features of the Antarctic Peninsula. Coastline, ice shelves and 1000 m contours derived from the Antarctic Digital Database (v7.3).



The changing Antarctic Peninsula

Atmospheric warming

The Antarctic Peninsula has been warming at rates of 0.3°C to 0.5°C per decade since the 1950s. Relative to preindustrial temperatures, SSP1–2.6 will see warming of near surface temperatures of 2.4°C across the Antarctic Peninsula by 2100, +0.6°C warmer than the present day. SSP3–7.0 will see warming of 5.0°C, +3.4°C warmer than the present day. Although precipitation will increase marginally under this scenario (+0.4 mm/day relative to present day), the fraction falling as snow will decrease by 3.7 percentage points (Figure 2).

SSP5–8.5 will see warming of 5.8°C relative to preindustrial by 2100, far higher than the global mean. These temperatures are 4.2°C warmer than the present day, and although precipitation would likely increase, the fraction falling as snow will decrease by 5.3% (Figure 2). These higher temperatures would result in a longer melt season, with the number of days greater than 0°C increasing from 19.7 days today to 38.7 days in SSP3–7.0 and 48.1 days in SSP5–8.5.

Extreme events

Extreme weather events are already occurring more frequently on the Antarctic Peninsula[10]. Extreme temperatures in February 2020 and 2022 resulted in exceptionally high surface melting[11,12], reduced sea ice and failure of some penguin breeding colonies[13]. Heat waves will become more frequent and last longer under all future warming scenarios to 2100, with much stronger trends under higher warming scenarios[14] (Figure 2).

Atmospheric rivers are elongated corridors of warm, moist air that deliver extreme precipitation and high surface melt events to the Peninsula[15]. For example, July 2023 saw rainfall and surface temperatures of +2.7°C on the northern Peninsula during winter[16]. Increased frequency of atmospheric rivers will result in more frequent rain events, accelerating glacier mass loss[15], surface melt (and subsequent refreezing, forming impermeable ice layers), and meltwater ponding on ice shelves[17].

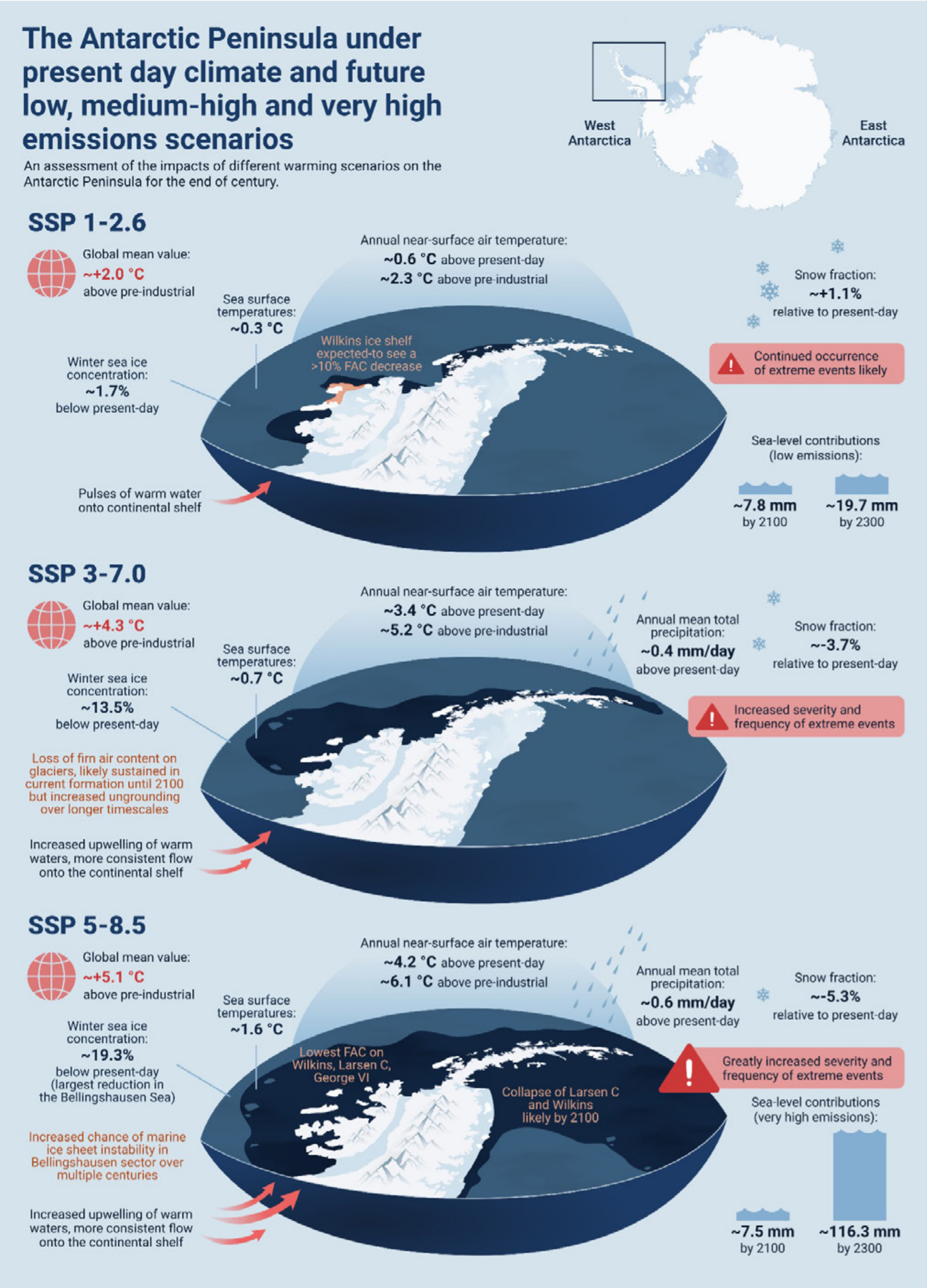


Figure 2. Summary of changes to the Antarctic Peninsula under different climate projections.
Firn is snow older than one year. FAC is firn air content.

Ocean heating

The ocean around the Antarctic Peninsula is warming rapidly[18]. Increased winds are driving upwelling of warm Circumpolar Deep Water current onto the continental shelf in the Bellingshausen Sea[19], southwestern Peninsula, leading to the recession of marine-terminating glaciers[18,20]. Southern Ocean sea surface temperature warming by 2100 ranges from ~0.3°C for SSP1–2.6, ~0.7°C for SSP3–7.0, to ~1.6°C for SSP5–8.5[21]. Under the lower emissions scenario, upwelling warm water is limited to pulses onto the continental shelf, whereas under higher emissions, continuous warm water flow occurs[22] (Figure 2).

Marine heat waves with surface temperature anomalies of up to +3°C[23] in 2022–2024 were associated with the three lowest recorded summer Antarctic sea ice extents[2]. Such heat waves are intensifying in frequency and magnitude, a trend that will continue under global warming[24], leading to increased sea ice lows, frontal melting of marine-terminating glaciers[12], and stress on biological systems[24].

Sea ice (frozen sea water)

Sea ice cover in the Bellingshausen Sea sector has undergone large winter declines since the late 1970s, and since 2015 in the Weddell Sea, accounting for a large portion of the continent-wide minimum in 2023[25]. Sea ice around the whole continent has undergone a sudden, stepwise decrease in extent since 2016, with behaviour poorly captured by models, and may now be entering a new state of continued decline[26].

Under SSP1–2.6, changes in sea ice concentration remain modest until 2100. Under SSP3–7.0, summer sea ice reductions of 10% are projected. SSP5–8.5 would result in winter reductions of 20% and summer reductions of 12%[1] (Figure 2).

Summers with low sea ice cover impact glacier calving, encouraging glacier recession[9], and change the rate of Antarctic Intermediate Water formation. This would affect ocean heat and carbon uptake, impacting marine ecosystems and undermining food chains. Further loss of Antarctic sea ice over the remainder of the century risks self-perpetuating processes and polar amplification of warming[26], influencing global climate.

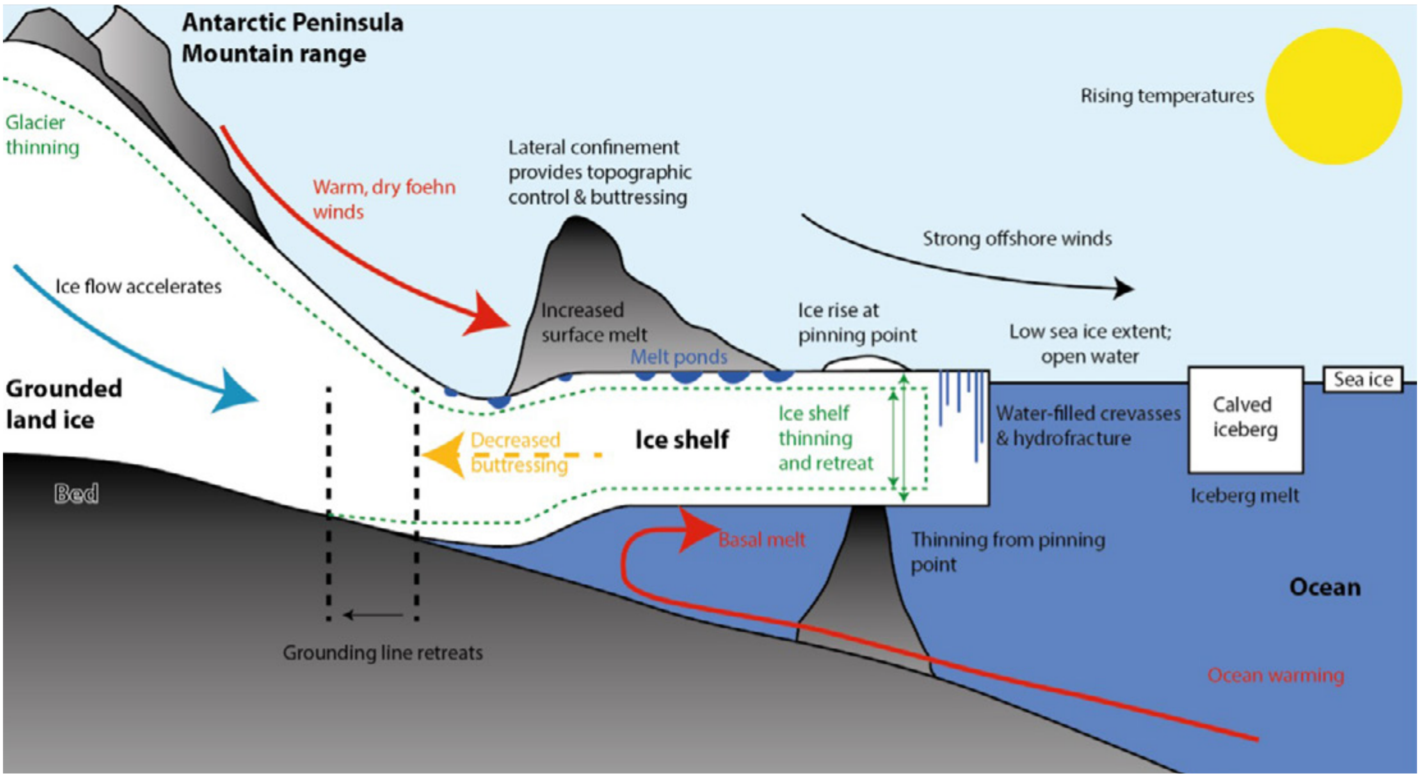


Figure 3. Schematic illustration of some key processes acting on Antarctic ice shelves and consequences for grounded land ice. The Grounding Line is the point at which the ice floats; upstream of this, the ice is grounded on the bed, whilst below the grounding line, the ice is floating.

Ice shelves (floating extensions of glaciers)

Ice shelves fringe 75% of Antarctica's coastline and support glacier stability by buttressing the flow of land ice[27] (Figure 3). They are vulnerable to warming from above and from below. Increased melting from the base of the ice shelves, associated with upwelling warm ocean currents, is driving long-term thinning, reducing buttressing[28]. Meanwhile, regional warming drives increased surface melt and ponding, which can destablise ice shelves via hydrofracture. Warming sea surface temperatures and offshore winds reduce landfast sea ice, in turn accelerating calving of icebergs from the ice shelves[9,29,30]. This combination of processes led to the total collapse of the Prince Gustav (1995), Larsen A (1995), and Larsen B (2002) ice shelves[31-33]. Following such collapses, upstream grounded glaciers accelerated and thinned due to the decrease in buttressing[34,35].

More frequent heat waves and atmospheric rivers will increase surface melt[1], while ocean heating will reduce sea ice extent and duration, and melt ice shelves from below[22]. High surface melt already occurs on many Antarctic Peninsula ice shelves, including Wilkins, George VI and Larsen C[11], and will increase under 2–4°C of warming[36]. Under SSP5–8.5, Larsen C and Wilkins ice shelves could collapse by 2100 CE (Figure 2)[17]. Ice sheet simulations that include ice shelf collapse result in substantially higher mass loss from the Antarctic Peninsula[37].

Land ice (grounded ice above sea level)

Glaciers across the Antarctic Peninsula are receding, losing a total of 13 billion tonnes of ice per year[38], with recent record rates of retreat (e.g. 8.2 km from November to December 2022 at Hektoria Glacier[39]). This mass loss is forced by atmospheric and ocean warming[40], disintegrating landfast sea ice[30], and glacier acceleration[20] following ice-shelf thinning. This mass loss contributes to global sea level rise[38], influences wider ocean circulation[41] and lowers regional albedo, enhancing warming.

Under SSP1–2.6, these trends will continue, with some mass loss potentially offset by higher snowfall[42]. Under SSP3–7.0, increased runoff, densification of firn (snow that has survived at least one year) and increased surface meltwater could impact the basal hydrology of glaciers, leading to seasonal velocity changes[43]. Grounding line retreat and ice shelf collapse is likely under SSP5–8.5, with the Bellingshausen Sea particularly vulnerable[37,42]. Positive feedback processes, such as ice shelf collapse, marine ice sheet instability in the Bellingshausen Sea[37] or rapid calving across areas of flat sea bed[39], will accelerate glacier recession and lead to irreversible grounding line retreat on human timescales.

Marine ecosystems

Marine ecosystems are already being impacted by warming, for example by increased release of sediments as glacier fronts retreat, affecting sea-bed dwelling species[44], extreme weather leading to flooded penguin nest sites[45] and low sea ice leading to failures of emperor penguin breeding colonies[13]. Increased storminess, reduced sea ice and ocean warming are likely to enhance colonisation by non-native marine species[1]. Ranges of key pelagic (open ocean) species such as krill and salps are projected to continue their southward contraction[46]. A reduction in stable sea ice would result in reduced survival capacity for iconic faunas such as emperor penguins, which depend upon it[26], and for which there is still no agreement on enhanced protection.

Contraction of Antarctic krill distribution over the last 80 years has been highly erratic, making future changes hard to predict. A reduction in krill biomass due to a reduction in the number of swarms is associated with sea ice reductions, since krill feed on sea-ice algae[47]. Reduced krill biomass has implications for krill predators, such as whales, seals and penguins[48], as well as for regulating Southern Ocean commercial fisheries and annual catches. This could become increasingly contentious between those parties that fish and those that do not. It could also decrease carbon sequestration, since less fast-sinking krill waste material would reduce the efficiency of carbon export to the sea floor[49]. A reduction in krill could also jeopardise delicate negotiations to secure an Antarctic Peninsula Marine Protected Area.

Terrestrial ecosystems

Land ecosystems are of considerable conservation importance due to high levels of endemic species[1] (species that are native and restricted to a certain place). They are threatened by climate warming or changes in precipitation phase or volume, the anthropogenic introduction of non-native invasive invertebrate and plant species, and the impacts of an expanding human footprint. Further, some native microbial and invertebrate species may already be reaching their upper thermal limits, driven by increasingly frequent and more intense extreme weather events[50]. Vegetation extent may expand as a result of increased water availability, and monitoring is required. Increased liquid precipitation risks flooding terrestrial ecosystems, and can accelerate snow loss, decreasing the snow algae habitat (an important Peninsula primary producer)[51].

Risk to operations and "peaceful and lawful usage"

The majority of Antarctic tourism and krill fishing[49] occurs in the Peninsula region, alongside scientific activities across 44 research facilities[52]. Increased precipitation falling as rain challenges Antarctic field equipment, which traditionally has not been designed to be waterproof. Refreezing rain is debilitating for airstrips and disrupts operations. Loss of stable landfast sea ice, and potentially increased iceberg numbers from calving glaciers and ice shelves, will impede marine operations[53]. Coastal erosion, ice recession, sea level rise and sea ice changes may drive changes in facility resilience and choice of new infrastructure location. New facility designs will be needed to accommodate permafrost melt, increasing temperatures, rainfall, and extreme weather events[10]. This will add a further financial burden for polar science operations.

Increasing geopolitical interest means that Antarctic infrastructure development is likely to expand further. Research stations are a clear way for nations to demonstrate 'effective presence' and, with increasing accessibility, the counter-claimed Antarctic Peninsula (Argentina, Chile, UK) will remain a geopolitical hotspot[54]. Tourism is increasing rapidly, and the waters around the Peninsula are attracting increasing commercial fishing[49]. Sea ice decline will facilitate new commercial and tourist ship routes and longer operating seasons, accelerating the increase in human footprint and environmental impacts. Conversely, ice shelf collapse could increase large iceberg presence, endangering shipping.

Whatever climate change scenario is considered, the Antarctic Treaty and associated legal instruments, including the CCAMLR (UN Commission for the Conservation of Antarctic Marine Living Resources) Convention, will be placed under further stress. Competition for commercial krill fishing may challenge further progress on marine protected areas and place further pressure on catch limits for CCAMLR Area 48.1 (Figure 1). The Peninsula will likely become a riskier operational environment, with attendant dangers of pollution incidents, accidents and disasters involving tourists, fishing operations, and national scientific operators.

Conclusions

The future of the Antarctic Peninsula depends on choices made today. Already, changes are occurring rapidly in the region. Across all scenarios, but especially in the higher emissions scenarios, the response to climate change is amplified by feedbacks and synergies within the system. This may drive irreversible change and hamper adaptation and management efforts. Each additional increment of warming escalates changes in the Antarctic Peninsula, leading to worldwide and regional challenges including loss of key species, sea level rise, and challenges to polar operations and fisheries. Secondly, the Peninsula is a rare window to study how climate change will impact the wider polar region, with internationally coordinated infrastructure and collaboration. Continued funding for scientific observation and model development is needed to deliver the knowledge required for informed management and conversation.

The UNFCCC Paris Agreement seeks to limit global warming to well below 2°C above pre-industrial levels, with a target of 1.5°C[55]. This remains a legal, moral, and political obligation, affirmed by the International Court of Justice (2025)[56]. However, current policies are only sufficient to keep warming below 2.8°C with a 66% chance[4], and, with increasing nationalism and protectionism[57], and rising inequalities characterising the global community, we risk severe impacts and loss.

Antarctic Treaty parties and other stakeholders are invited to consider the implications of these scenarios and predictions for the governance of human activities in the Antarctic Peninsula, and for the long-term, irreversible ramifications of emissions rises in the coming decades. National science and environmental protection and management programmes need to anticipate and adapt to a rapidly changing operational environment. Without policy change to alter the trajectory of environmental change, the Antarctic Peninsula will continue to experience the numerous and varied impacts described in this brief. These will change this unique environment irreversibly, with global consequences.

This briefing also contributes to the United Nation's International Year of Glaciers' Preservation 2025 (Figure 4).

Figure 4. The United Nations has designated 2025 as the International Year of Glaciers' Preservation to highlight the importance of glaciers. https://www.un-glaciers.org/en

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