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The Antarctic Peninsula under a 1.5°C global warming scenario
What change is it locked into?

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Highlights

- Antarctic Peninsula warming in the late 20th Century was greater than anywhere else in the Southern Hemisphere.
- With a further increase in global temperatures of 0.5°C:
  - Antarctic Peninsula temperatures will increase by 1-2°C in winter and 0.5-1.0°C in summer, with up to 130 days per year above 0°C, leading to increased rain, snow and ice melt, and surface run-off.
  - Ocean turbulence will increase and deliver heat to the sea surface and coast.
  - Sea ice extent will be highly variable west of the Antarctic Peninsula.
  - Retreat of marine glacier margins will accelerate, increasing iceberg production.
  - Meltwater production will increase on ice shelves, but will likely not lead to further collapses.
  - Southward shifts in marine life distribution have been observed and will continue.
  - Ice-free land area will expand, providing habitats for native and non-native plants and invertebrates, with each likely to benefit from warming.
- Non-native species are a far greater threat to native biodiversity than the direct impacts of warming under a 1.5°C scenario.

Introduction

The UN Paris Agreement seeks to limit global warming to well below 2°C above pre-industrial levels, prompting an assessment of how to achieve a 1.5°C target[1,2]. Here, we bring together information on how a 1.5°C scenario will affect the Antarctic Peninsula, noting it has already experienced rapid change in atmospheric climate, ocean and ice conditions, and the impacts of direct human activities. Antarctic Treaty Parties, as well as other interested parties, are invited to consider the implications of these predictions for the governance of human activities in the Antarctic Peninsula over the coming decades.

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About the Antarctic Peninsula

The Antarctic Peninsula includes the Peninsula itself, its islands, and the surrounding continental shelf and ocean. For the purposes of this paper, the northerly islands, such as the South Orkney Islands, are not included. The Antarctic Peninsula extends to the southern end of George VI Sound and to the northern extent of Ronne Ice Shelf, and is divided down its lengthy mountainous spine by very strong west to east gradients in atmospheric and ocean circulation. These features shape the distinct characteristics in oceanography, glaciology and biology on either side of the Peninsula. The Peninsula is also affected by north-south changes from the fringe of the sub-Antarctic to the deep polar region.

As a consequence of regular measurements over the last 100 years, we know more about change in the Antarctic Peninsula than elsewhere on the continent. Although there is strong evidence of atmospheric warming, this is also an area of high natural variability. Annual near-surface temperatures increased by more than 2.5°C in the latter 20th Century and, at least in the northern Antarctic Peninsula, have stabilised in the last 20 years with variations of around 1.5°C year-to-year. Summer melting occurs, allowing around three per cent of the land to be snow-free.

Ice shelves around the Antarctic Peninsula have thinned and retreated, and break-up events have occurred. The collapse of Larsen A (1995) and Larsen B (2002) ice shelves caused the flow of glaciers that feed them to speed up[3,4]. Glaciers of the Antarctic Peninsula contribute around 0.09mm per year, or around three per cent, to global sea-level rise[5, 6, 7], influenced by heat provided by the ocean[7, 8, 9]. Sea ice conditions are often heavy to the east of the Antarctic Peninsula and light to the west, but there is a large degree of year-to-year variability. Marine life has been affected by humans (sealing, whaling and fishing), especially up until the 1960s (and the signing of the Antarctic Treaty), and responses to climate must be interpreted in that context. The recent exposure of new terrestrial surfaces that have been colonised by native vegetation is a clear signal of climate change.

How will the Antarctic Peninsula respond in a 1.5°C scenario?

Climate and weather. Antarctic Peninsula temperatures will increase by more than the global average in a 1.5°C scenario[2]. This level of warming has already been exceeded in the northern Peninsula[10], despite the recent pause in rising temperatures in the region[11]. Regional temperatures could increase by 1-2°C in winter and 0.5-1.0°C in summer beyond current levels[12]. Warming of 1°C from today will result in a 50 to 150 per cent increase in days per year above 0°C, from a range of 25 to 80 days in the northern Antarctic Peninsula to between 35 and 130 days. While there has been a 10 to 20 per cent increase in precipitation, and an increase in extreme precipitation events[13], there is unlikely to be much further increase beyond current levels[12]. The greatest change in atmospheric circulation affecting the Peninsula is a weakening of the circumpolar summer westerly winds in response to stratospheric ozone recovery. Increased levels of surface water run-off (from rain and snow/glacial melt) and/or melting of any thin layers of frozen sediment may alter the strength of the ground considerably, albeit for limited periods of the year. Such change may have an impact on station buildings and, potentially, airstrips.

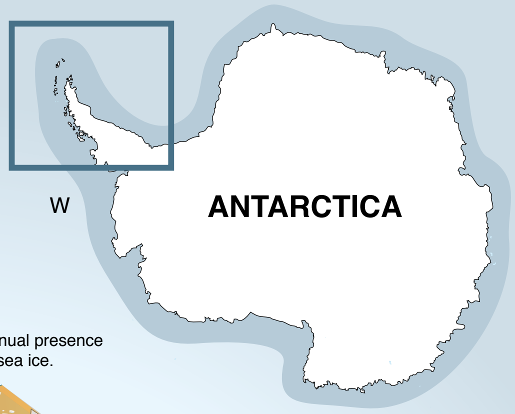
Ocean conditions. The west of the Peninsula is influenced by warm Circumpolar Deep Water (CDW), in contrast to the east of the Peninsula where waters are much colder[14]. The Southern Ocean is warming[15], but we have no clear evidence that the Polar Front is moving as a result of this change[16]. However, the CDW is both warming and becoming shallower[17], and the amount of turbulence in the Southern Ocean is increasing[18]. We expect these trends to continue.

Sea ice. The two sides of the Antarctic Peninsula have very different sea ice conditions. The ice edge is generally at a higher latitude on the Peninsula's west compared with the east. In summer, virtually the whole Bellingshausen Sea is free of sea ice, but on the east in the Weddell Sea, the sea ice typically extends to the northern end of the Antarctic Peninsula and is thicker so, even in the summertime, the highest classification ice-breaking ships can have great navigational difficulty. Since satellite records began around 30 years ago, there has been a modest increase in total annual Antarctic sea ice extent, though the variability from year to year is large[19], and regional and seasonal changes are mixed. To the west, annual sea ice extent has decreased by around six to ten per cent per decade with the greatest changes in autumn and summer[20]. The length of the sea ice season on the west of the Peninsula has also reduced by around four days[21]. We expect increased sea ice variability on the west of the Peninsula, compared with the east, as the climate warms. These changes will increasingly need to be accounted for by shipping.

Land ice. Antarctic Peninsula glaciers are steep and fast flowing, and respond rapidly to climate change[6]. Ocean warming is likely to cause accelerated recession of glaciers that are in contact with the sea, with slower recession driven by atmospheric changes for glaciers that end inland. Thinning and recession of glaciers that extend from the land into the ocean, known as marine-terminating glaciers, are therefore expected to accelerate, driven largely by increased upwelling of warm CDW. Once the marine-terminating glaciers retreat to their land margins they will experience slower thinning and recession. In southern Palmer Land, glaciers are grounded deeply below sea level which could lead to significant glacier retreat[16]. Under a 1.5°C scenario, glaciers on land will experience more melting than at present[16, 22], causing increased surface run-off.

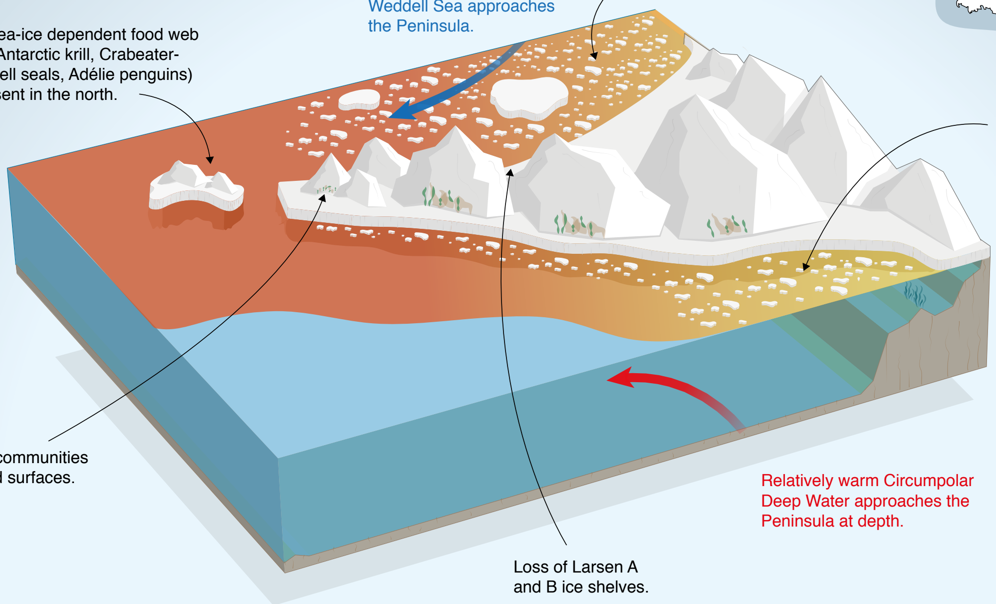
THE ANTARCTIC PENINSULA UNDER A GLOBAL 1.5°C SCENARIO

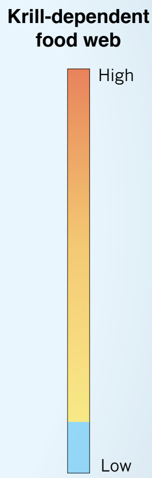
An assessment of how atmospheric, oceanographic, glaciological and biological processes may be affected if global average temperatures are limited to 1.5ºC above pre-industrial levels (i.e. another 0.5ºC increase globally).



SITUATION TODAY AT 1°C of GLOBAL WARMING

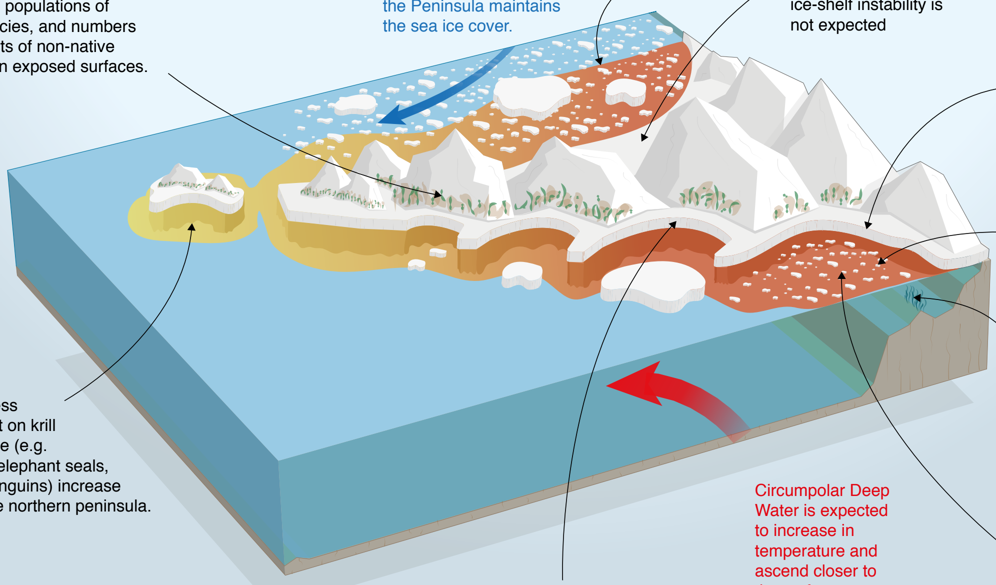
25-80 days per year above 0°C in the northern Peninsula





CHANGES EXPECTED UNDER 1.5°C OF GLOBAL WARMING

35-130 days per year above 0°C in the northern Peninsula



Ice Shelves. It is likely that Antarctic Peninsula ice shelves will continue to thin, primarily due to increased surface melting[23,24]. If meltwater collects in ponds, it could cause ice-shelf bending and fracture; a process implicated in the collapse of Larsen B[25]. However, surface rivers may help prevent some of this ice-shelf instability by transporting meltwater into the ocean[26]. Ice shelves will also thin in response to melting of their undersides by warm ocean water[27]. While ice-shelf thinning increases the likelihood of icebergs breaking off, the largest ice shelves (e.g., Larsen C and George VI) have sufficient surface area to avoid catastrophic failure.

Marine Ecosystems. The response of marine living systems to climate change is complicated by extraction of marine resources. Sequential over-exploitation of seals, whales and some species of fish over the last two centuries has severely perturbed the food web, making it hard to unravel its consequences from those of climate change[28]. Responses of marine life to the 1.5°C scenario will be diverse with likely changes in behaviour, physiology, geographic or depth distribution, plus evolutionary adaptation. An observed southward shift in the distribution of living things down the peninsula is likely to continue[29].

Terrestrial Ecosystems. Terrestrial biology is limited to ice-free areas, of which only a fraction is currently visibly colonised. The seasonally-exposed terrestrial area of the Peninsula is expected to expand[29]. This will provide new habitats for colonisation by native and, likely, non-native organisms. It will also lead to the coalescing of some areas that are currently isolated, and a loss of genetic diversity. Native plants and invertebrates are well adapted to the variable conditions of the Antarctic Peninsula[30,31] and are likely to benefit from modest warming[32]. However, a wide range of non-native species could survive in parts of the Antarctic Peninsula. Thus, the threat of non-native species to native biodiversity far outweighs the impacts of climate change under a 1.5°C scenario. In light of these pressures, environmental protection of the Antarctic Peninsula must remain resolute.

Conclusion

The Polar Regions have warmed twice as much as the global average since 1850, so while global temperatures have risen by 1°C, the Antarctic Peninsula has seen a temperature increase of more than 2.5°C. This has led to glacier retreat, ice shelf decay and the expansion of exposed land on which some plants have been able to grow. By restricting global temperature increase to 1.5°C, we can limit the damage to the Antarctic Peninsula's ecosystems. We cannot avoid further loss of ice, expansion of vegetation and certain invertebrate communities on land (potentially with alien species), and alteration to marine ecosystems that are still recovering from marine resource extraction decades ago. However, the ice shelves are likely to be maintained and marine life can still be protected. If we fail to restrict temperature increase to 1.5°C globally, however, the Antarctic Peninsula will experience irreversible and dramatic change.

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