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The Antarctic Peninsula under a 1.5°C global warming scenario

What change is it locked into?

MARTIN SIEGERT¹, ANGUS ATKINSON², ALISON BANWELL³, MARK BRANDON⁴, PETER CONVEY⁵,
BETHAN DAVIES⁶, ROD DOWNIE⁷, TAMSIN EDWARDS⁸, BRYN HUBBARD⁹, GARETH MARSHALL⁵,
JOERI ROGELJ¹, JANE RUMBLE¹⁰, JULIENNE STROEVE¹¹, DAVID VAUGHAN⁵

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.

1. Grantham Institute, Imperial College London, Exhibition Road, South Kensington, London SW7 2AZ, UK
2. Plymouth Marine Laboratory, Prospect Place, Plymouth, PL1 3DH, UK
3. Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, Boulder 80309 CO, USA.
4. School of Environment, Earth and Ecosystem Sciences, Open University, Milton Keynes, MK7 6AA UK
5. British Antarctic Survey, NERC High Cross, Madingley Road, Cambridge, CB3 0ET, UK
6. Centre for Quaternary Research, Department of Geography, Royal Holloway University of London, Egham, TW20 0EX, UK
7. WWF UK, The Living Planet Centre, Rufford House, Brewery Rd, Woking GU21 4LL, UK
8. Department of Geography, King's College London, London, WC2R 2LS, UK
9. Department of Geography & Earth Sciences, Aberystwyth University, Aberystwyth, SY23 3DB, UK
10. Polar Regions Department, UK Foreign & Commonwealth Office, W2.80 King Charles Street, London SW1A 2AH, UK
11. Centre for Polar Observation and Modelling, University College London, Gower Street, London, WCE 1BT, UK

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 (2007) 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 scenario². This level of warming has already been exceeded in the northern Peninsula¹⁰, despite the recent pause in rising temperatures in the region¹¹. Regional temperatures could increase by 1-2°C in winter and 0.5-1.0°C in summer beyond current levels¹². 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 events¹³, there is unlikely to be much further increase beyond current levels¹². 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 colder¹⁴. The Southern Ocean is warming¹⁵, but we have no clear evidence that the Polar Front is moving as a result of this change¹⁶. However, the CDW is both warming and becoming shallower¹⁷, and the amount of turbulence in the Southern Ocean is increasing¹⁸. 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 large¹⁹, 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 summer²⁰. The length of the sea ice season on the west of the Peninsula has also reduced by around four days²¹. 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 change⁶. 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 retreat¹⁶. 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 1.5°C above pre-industrial levels (i.e. another 0.5°C increase globally).

SITUATION TODAY AT 1°C of GLOBAL WARMING

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

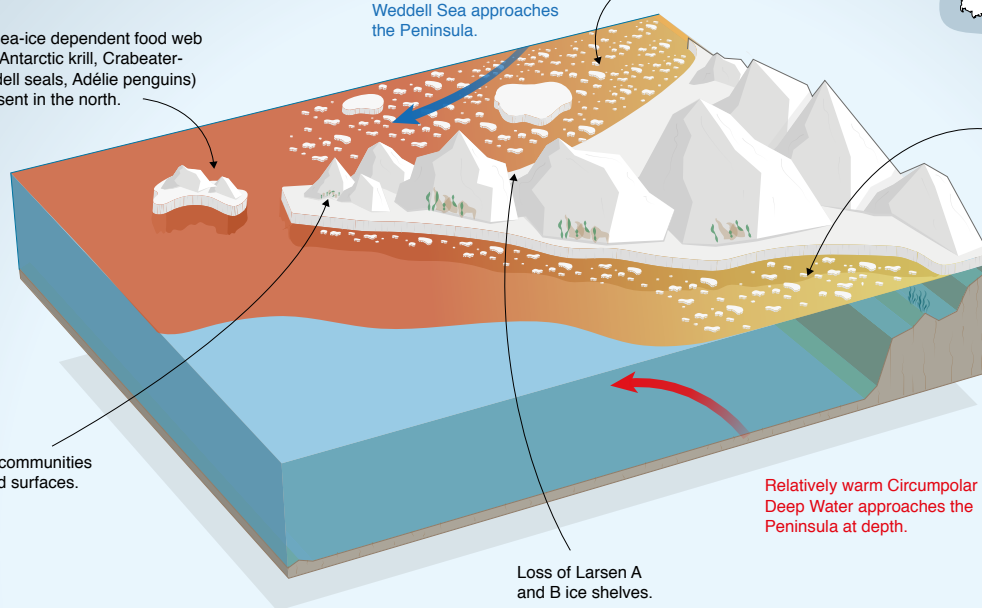
Krill and sea-ice dependent food web (e.g. with Antarctic krill, Crabeater- and Weddell seals, Adélie penguins) is still present in the north.

Terrestrial communities on exposed surfaces.

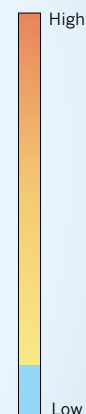
Cold water circulating clockwise around the Weddell Sea approaches the Peninsula.

Annual presence of sea ice.

The sea ice is typically further south on this side of the Peninsula.



Krill-dependent food web



CHANGES EXPECTED UNDER 1.5°C OF GLOBAL WARMING

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

Increasing populations of native species, and numbers and impacts of non-native species, on exposed surfaces.

Species less dependent on krill and sea ice (e.g. fur seals, elephant seals, gentoo penguins) increase around the northern peninsula.

Cold water circulating clockwise around the Weddell Sea approaches the Peninsula maintains the sea ice cover.

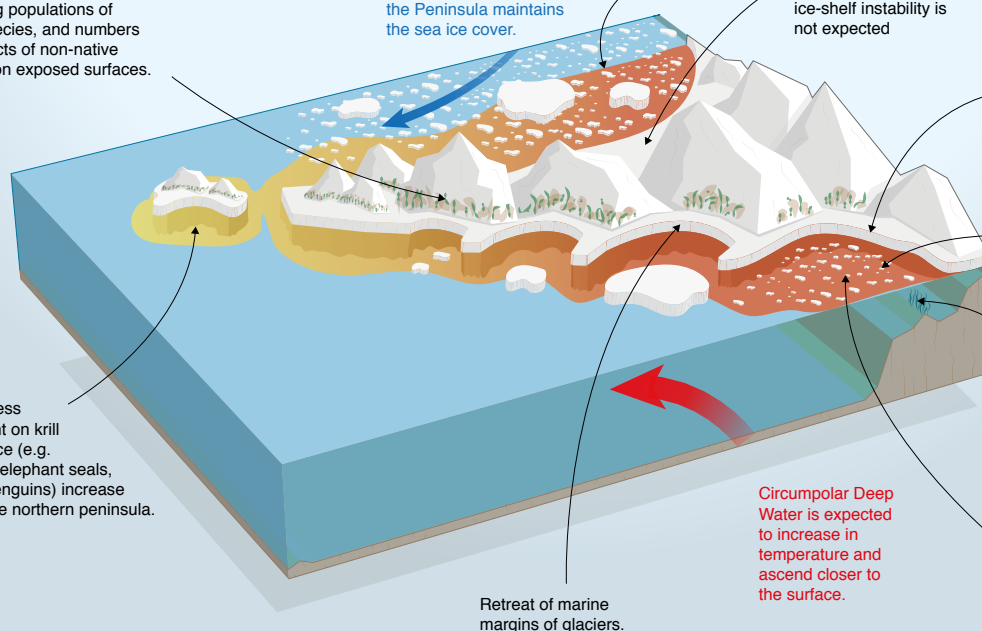
Sea ice every year here.

Increased surface melting on glaciers and ice shelves. Wholescale ice-shelf instability is not expected

Productive new habitat may open up with the reduced ice shelves, glaciers and sea ice.

Sea ice limited and variable west of the peninsula.

Bottom-dwelling species with limited dispersal capability stressed by impacts from icebergs, changes in surface productivity, warming and ocean acidification.



Circumpolar Deep Water is expected to increase in temperature and ascend closer to the surface.

Retreat of marine margins of glaciers.

Krill and sea-ice dependent food web displaced southward down 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 B²⁵. However, surface rivers may help prevent some of this ice-shelf instability by transporting meltwater into the ocean²⁶. Ice shelves will also thin in response to melting of their undersides by warm ocean water²⁷. 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 change²⁸. 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 continue²⁹.

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 expand²⁹. 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 warming³². 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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About the authors

Professor Martin Siegert is Co-Director of the Grantham Institute, and an Antarctic glaciologist. He specialises in using airborne geophysical measurements to understand the flow and form of polar ice sheets. In 2013 he was awarded the Martha T Muse Prize for Antarctic Science and Policy by the Tinker Foundation.

Dr. Angus Atkinson is a senior plankton ecologist at Plymouth Marine Laboratory. He has maintained a long-standing interest in the response of zooplankton to climate change, with focus on polar food webs and particularly on Antarctic krill.

Dr. Alison Banwell is a Research Fellow at the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado Boulder. She is a glaciologist who is primarily interested in the polar regions, and currently specialises in Antarctic ice-shelf hydrology and dynamics through modelling, remote sensing and fieldwork.

Professor Mark Brandon is an oceanographer with over 25 years experience, based at the Open University. He has a track record of successful large projects and extensive public engagement.

Professor Peter Convey is a polar terrestrial ecologist and has been working with the British Antarctic Survey in both polar regions for over 30 years. He has wide interests in all aspects of terrestrial ecosystems, but particularly in biodiversity, biogeography and human impacts in the polar regions.

Dr. Bethan Davies is a Senior Lecturer in Quaternary Geology at Royal Holloway, University of London. She is a glacial geologist interested in the interaction between glaciers and climate over multiple timescales.



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Dr. Rod Downie is the Chief Polar Advisor at WWF. Rod has led WWF's polar programme in the UK since 2011, following 14 years with the British Antarctic Survey. He has completed 15 field seasons in the Antarctic, totalling more than two-and-a-half years living and working on the ice.

Dr. Tamsin Edwards, is a climate scientist at King's College London, specialising in testing and assessing uncertainties for climate models, especially for the Antarctic and Greenland ice sheet contributions to future sea level rise. She is also an experienced communicator, involved in public engagement with science.

Professor Bryn Hubbard is a field glaciologist, specializing in borehole-based investigations of the three-dimensional physical structure of ice masses. This research focuses on, for example, firnification processes, englacial ice temperature and deformation, and the links between glacier motion and hydrology.

Dr. Gareth Marshall is a senior climatologist at the British Antarctic survey.

Dr Joeri Rogelj is a Lecturer in Climate Change at the Grantham Institute researching how our understanding of the Earth system can affect climate policy. He served as a Coordinating Lead Author on the Special Report on

Global Warming of 1.5°C of the Intergovernmental Panel on Climate Change.

Jane Rumble joined the Polar Regions Department in the Foreign & Commonwealth Office in 2003, and she has been Head of the Department since January 2007. In this role, Jane leads on all Antarctic issues for the UK Government and oversees the UK's engagement with the Arctic Council. Jane was made an OBE at the Queen's Birthday Honours in June 2018 for services to Polar science, marine conservation and diplomacy; and was made an honorary Doctor of Science by Leeds University in July 2018.

Professor Julianne Stroeve sea-ice scientist at University College London who specialises in remote sensing of the polar regions. She was recently awarded a Canada 150 Research Excellence Chair at the University of Manitoba.

Professor David Vaughan is the Director of Science at the British Antarctic Survey. He has a distinguished career in understanding ice sheets and the cryosphere and in 2017 he was awarded an OBE for services to science.