Glacier change in Antarctica

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Introduction

Figure 1. The Antarctic Peninsula. An orthographic projection of NASA's Blue Marble data set (1 km resolution). By Anna Frodesiak.

What is happening around the Antarctic Peninsula? This is a region of very rapid warming, and this has resulted in a whole suite of glaciological changes. What are the implications of this change for us? How do glaciers respond to climate change, how are they related and linked, and what is driving these changes? This article summarises glaciers and climate change around the Antarctic Peninsula.

Temperatures are rising

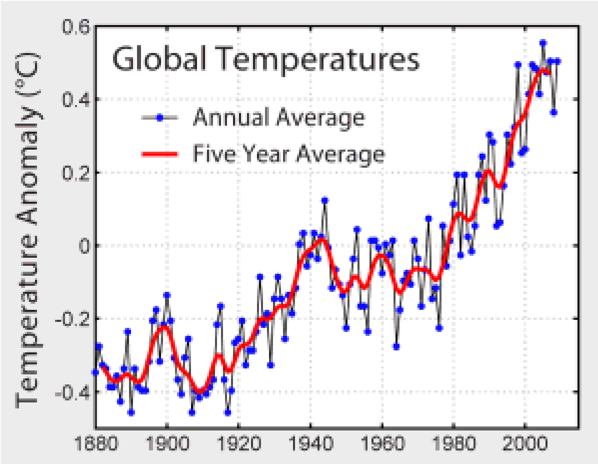


Figure 2. This image shows the instrumental record of global average w:temperatures as compiled by the w:NASA’s w:Goddard Institute for Space Studies. (2006) “Global temperature change”. Proc. Natl. Acad. Sci. 103: 14288-14293. Following the common practice of the w:IPCC, the zero on this figure is the mean temperature from 1961-1990. This figure was originally prepared by Robert A. Rohde from publicly available data and is incorporated into the Global Warming Art project. Wikimedia Commons.

Climate change is strongly affecting Antarctica. Around the Antarctic Peninsula, temperatures are warming at a rate that is approximately six times the global average. Air temperatures increased by ~2.5°C from 1950-2000[1]. Regional rapid warming here began in the 1930s[2]. The annual mean air temperature -9°C isotherm has moved southwards, resulting in ice-shelf collapse and glacier recession[3]. A recent ice core from James Ross Island shows that warming in this region began around 600 years ago and then accelerated over the last century. This rate of warming is unusual, but not unprecedented[4]. Warming over the Antarctic Peninsula is exacerbated by a strengthening of the Antarctic Oscillation, which is a periodic strengthening and weakening of the tropospheric westerlies that surround Antarctica[5]. Changing pressure patterns result in flow anomalies, with cooling over East Antarctica and warming over the Antarctic Peninsula.

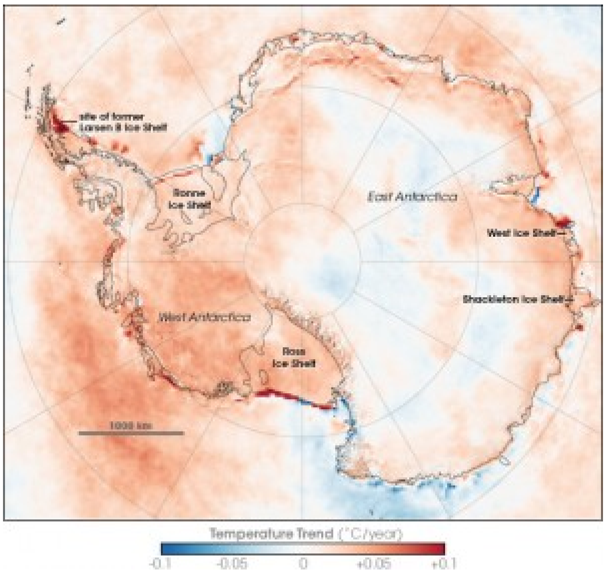


Figure 3. Antarctic temperature trends, 1981-2007. By Robert Simmon, NASA [Public domain], via Wikimedia Commons

But how unusual is this warmth? Ice core records provide a longer-term perspective on climate over the past four glacial cycles or longer[6]. The ice-core record indicates that carbon dioxide and temperature co-varied over the last 400 thousand years, which suggests a close link between these ‘greenhouse gases’ and temperature. Ice core records show that methane and carbon dioxide atmospheric concentrations are higher than at any point in the last 650,000 years[7]. The IPCC states,

> “The total radiative forcing of the Earth’s climate due to increases in the concentrations of the LLGHGs CO_2, CH_4 and N_2O, and very likely the rate of increase in the total forcing due to these gases over the period since 1750, are unprecedented in more than 10,000 years”

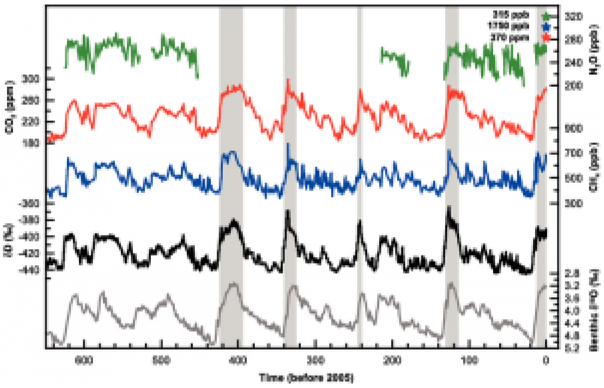


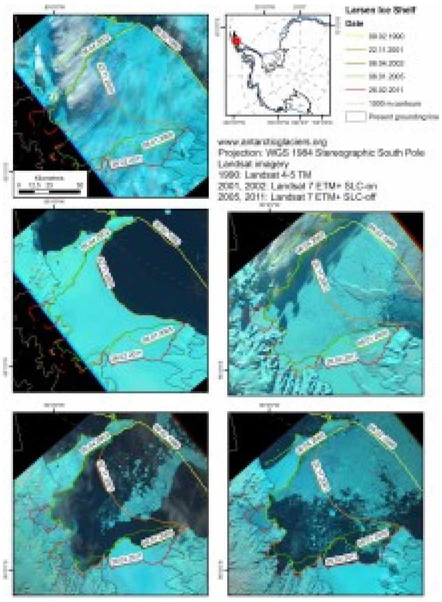
Figure 4. Ice core record of Antarctic atmospheric gases and temperature change over the past 650,000 years. From the IPCC.

Ice shelves are collapsing

Larsen Ice Shelf in 2004

What effect is this having on the glaciers of the Antarctic Peninsula? Ice shelves have disintegrated very rapidly over the last few decades[8-13], which has destabilised on-shore glaciers, which rapidly thinned and receded following removal of a buttressing ice shelf[11,14-21] (quick check – do you understand the difference between ice shelves, sea ice, ice bergs and marine-terminating glaciers?). Higher air temperatures around the Antarctic Peninsula contribute to ice shelf collapse by increasing the amount of meltwater ponding on the surface[8,9,22]. When combined with ice shelves that are thinning due to melting from below following the incursion of warm ocean currents onto the continental shelf[10,23-25], you have a recipe for rapid ice shelf disintegration. With one particularly warm summer, a thinned ice shelf that is close to its threshold is liable to break up very quickly as meltwater ponding on its surface propagates downwards and initiates iceberg calving by hydrofracture. Some of these ice shelves have collapsed for the first time[26].

Larsen Ice Shelf



Landsat images showing the collapse of the Larsen Ice Shelf. Note the blue mottled appearance in 2002, resulting from the exposure of deep blue ice.

The Larsen Ice Shelf collapsed dramatically and very rapidly in 2002, and glaciers that previously fed into the Larsen Ice Shelf have since accelerated, thinned and receded. The ice shelf disintegrated very rapidly, with the main event happening over just one warm summer. The Larsen B Ice Shelf, shown in Figure 5, has been stable throughout the Holocene and this is the first time it has collapsed in the last 10,000 years.

Pine Island Glacier

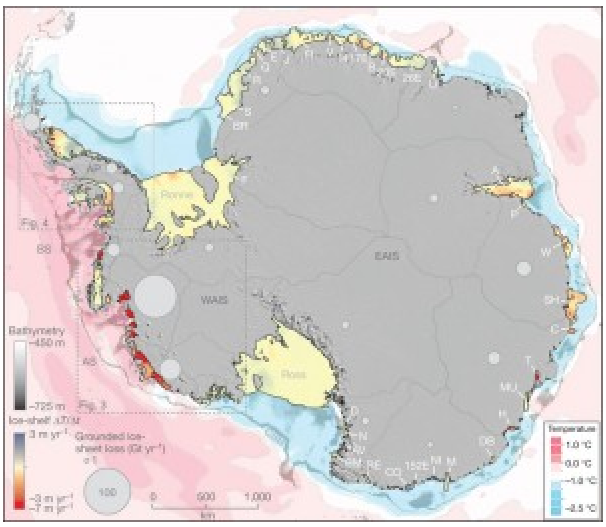


Figure 6. Antarctic ice shelf thickness changes. Note the rapid thinning of Pine Island Glacier ice shelf in West Antarctica. From Pritchard et al., 2012, Nature. Reprinted by permission from Macmillan Publishers Ltd: Nature (Pritchard et al. 2012), copyright (2012).

Ice shelves are warmed from below, and the ice shelves around Pine Island Glacier are thinning and receding. The thinning of these ice shelves may limit their ability to buttress the flow of ice from the interior of the ice sheet. Pritchard et al. (2012) say in their paper in *Nature* (Figure 6) that melting from the base of ice shelves is the primary driver of Antarctic Ice Sheet ice loss, by reducing the buttressing capability of the ice shelves. The rapid thinning of the Pine Island Glacier ice shelf is caused by warm oceanic water at depth that reaches the underside of ice shelves by travelling along troughs on the continental shelf.

Glaciers are shrinking

Glacier on the Antarctic Peninsula. From Wikimedia Creative Commons.

There is increasing evidence that glaciers around the Antarctic Peninsula are shrinking and receding. Alison Cook found that 87% of the glaciers around the Antarctic Peninsula are receding[27,28]. Other workers have found evidence of glacier recession and a measureable sea-level contribution[29]. There is evidence of widespread glacier recession around the northern Antarctic Peninsula[21,30]. Land-terminating glaciers in this region are shrinking particularly rapidly[31], which is significant, as their mass balance is more directly controlled by temperature and precipitation, compared with marine-terminating glaciers, which respond non-linearly to climate forcing.

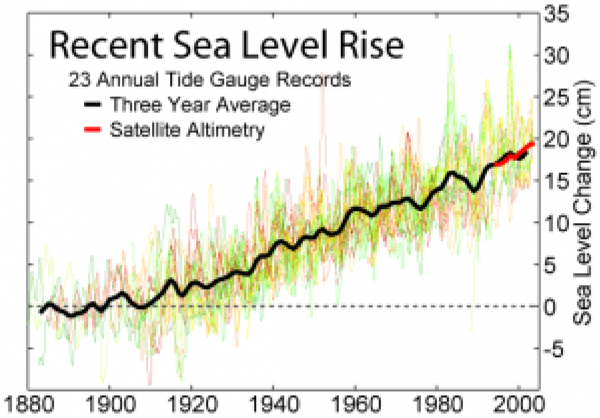
Glaciers are thinning

A paper published recently in *Geophysical Research Letters*[32] showed that glaciers around the Antarctic Peninsula are thinning. 12 glaciers around the Antarctic Peninsula showed near-frontal surface lowering since the 1960s, with higher rates of thinning for glaciers on the north-western Antarctic Peninsula. Surface lowering ceases at about 400m in altitude across all the glaciers, which may be due to increased high-altitude accumulation[32]. These marine-terminating glaciers are affected by both oceanic and atmospheric warming. The thinning of these glaciers is bringing them nearer to floatation. Kunz et al (2012) conclude that the majority of the glaciers around the Antarctic Peninsula are likely have been thinning for decades, but that the pattern of surface change is not simple. Lowering is not caused by reduced mass input, as it is not observed at higher elevations (in fact, the amount of lowering has probably been reduced by this higher precipitation).

Glaciers are accelerating

Glaciers are accelerating across the Antarctic Peninsula[33]. This may be due to the thinning observed at the glacier snouts[32,33], and combined with the thinning and recession observed across the Antarctic Peninsula, indicates that there is a climatically-driven rise in sea level from this region. Thinning glaciers are easier to float. Once warm ocean water can access the underside of a glacier, melting from below exacerbates thinning from above, resulting in increased and rapid glacier thinning[34]. Thinning glaciers accelerate as part of their dynamic response, as changes near the grounding line can impact glacier velocity some distance inland[35]. Pritchard and Vaughan (2007) argue that thinning as a result of a negative mass balance will reduce the effective stress of a glacier's bed near the margin, reducing basal resistance and increasing sliding. This leads to further thinning, floatation, rapid calving and increased glacier recession[33]. The retreat rate will be controlled to a large extent by fjord depth and geometry, and over deepened basins resulting in particularly rapid glacier recession.

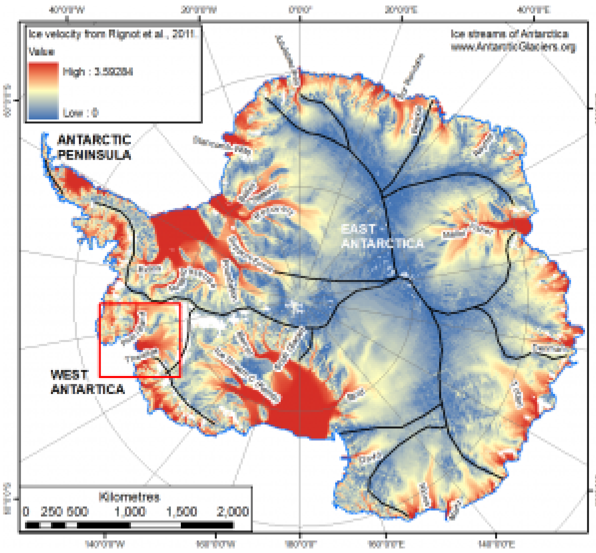
Sea level is rising



Recent sea level rise. Credit: Bruce C. Douglas (1997). "Global Sea Rise: A Redetermination". Surveys in Geophysics 18: 279–292. DOI:10.1023/A:1006544227856. Image from Global Warming art project. Wikimedia Commons

Global sea levels are currently rising at a rate of about 3 mm per year[7]. The contribution from the Antarctic Peninsula is −41.5 Gt yr^{-1} [36], although a recent study refines this to -34 Gt yr^{-1} [37]. King et al. calculate that the Antarctic Ice Sheet as a whole currently contributes about 0.19 mm±0.05 mm per year to global sea level rise, which is largely from the Antarctic Peninsula, the Amundsen Sea sector (including Pine Island Glacier), and which is partly balanced by increased ice accumulation in East Antarctica.

Most modern sea level rise, and sea level rise predicted over the next 100 years, comes from ocean expansion and the melting of small glaciers and ice caps. However, the amount that the sea level will rise in the future depends not only on temperature, glacier recession and ocean warming and expansion, but also the dynamic behaviour of the West Antarctic Ice Sheet. Marine Ice Sheet Instability may result in rapid future sea level rise, contributed to by ice-shelf collapse and the dynamic behaviour of ice streams. How much will Antarctica contribute to sea level rise in the future? You can read more about that in this blog post.



Ice streams of Antarctica with Pine Island Glacier and Thwaites glacier highlighted.

Impact of climate on glaciers

The Antarctic Peninsula is particularly vulnerable to climate change due to its small size and northerly latitude[2]. It receives high snowfall but high melt, with a large number of days above 0°C in the summer months[33]. It interrupts the Circumpolar Westerlies and is liable to be affected by small changes in these winds. Increased numbers of positive degree days [32] coincide with increased rates of thinning on Antarctic Peninsula marine-terminating glaciers, and increased meltwater ponding and hydrofracture on ice shelves. Glaciers are thinning and receding in response to warmer temperatures, and thinning glaciers are easier to float. We know that basal melting of ice shelves drives ice sheet loss[34], and we can observe the impacts of climate change around the Antarctic Peninsula today.

Further reading

- Marine Ice Sheet instability
- Ice shelves
- Sea level rise
- Glacier recession in Patagonia
- Glacier recession on the Antarctic Peninsula
- Antarctica's contribution to global sea level rise
- Antarctic Peninsula Ice Sheet evolution
- The Antarctic Peninsula Ice Sheet
- Antarctic Peninsula photographs

Go to top or jump to Glacier Recession.

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