ACCELERATING GREENLAND AND ANTARCTIC ICE SHEET MELTING AND SEA LEVEL RISE

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The Greenland ice sheet is a relic of the last ice age. Most of the ice formed during the ice age between 188,000 to 130,000 years ago and expanded during the final Pleistocene glacial advance until about 24,000 years ago, when it covered an area 40 percent larger than its current extent.

The accumulated ice sheet is as much as 3.2km thick, but as the world warms, the ice sheet is shrinking, and as it shrinks, its decreasing elevation causes a positive melting feedback loop because the air is warmer at lower elevations.

The Greenland and Antarctic ice sheets, which hold almost all of the world's freshwater ice, are melting at an alarmingly high rate, according to Otosaka et al. (2023). This international team of scientists from the Ice Sheet Mass Balance Inter-comparison Exercise (IMBIE) combined data from 50 satellite surveys of Antarctica and Greenland spanning the years 1992 to 2020.

By tracking changes in the ice sheets' volume and ice flow and the Earth's gravity field, they found that ice sheet melting has increased six-fold over the past 29 years (Figure 1) due to increasing global temperatures. The seven years of largest polar ice sheet melting all occurred during the past decade.

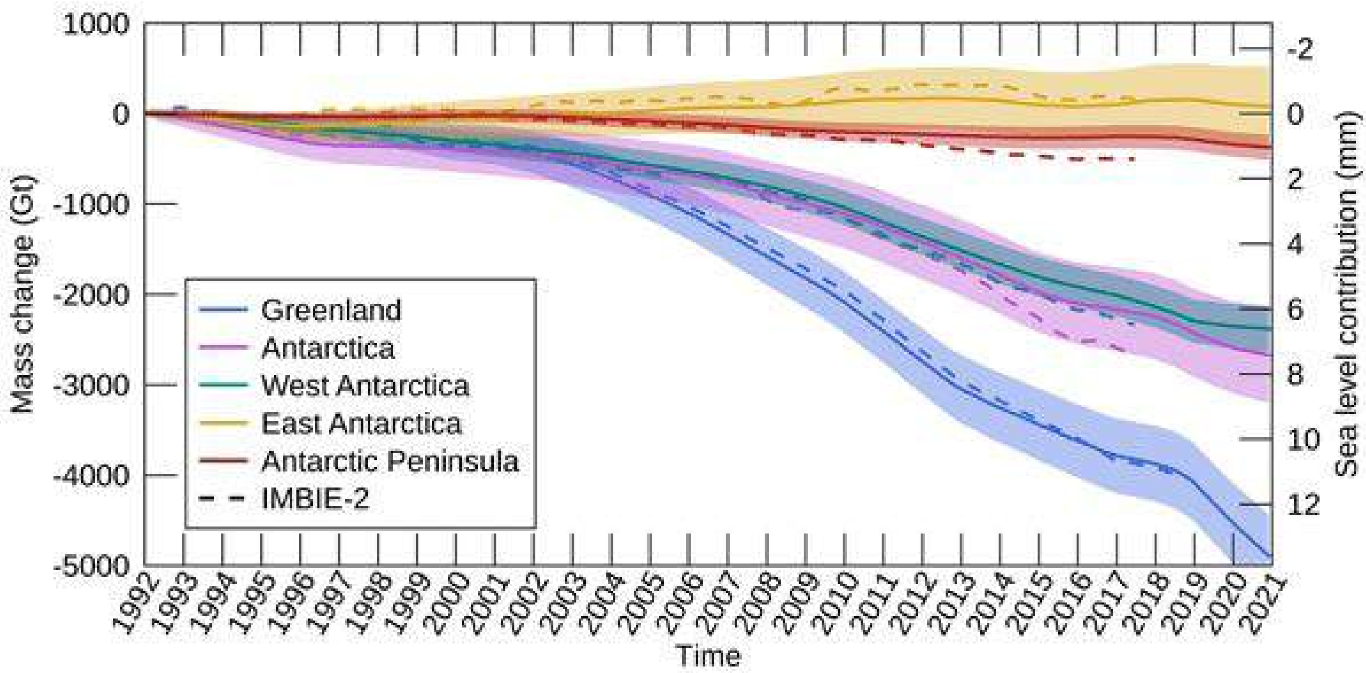

Figure 1. Cumulative ice sheet mass changes, with shadings representing uncertainties. The dashed lines show the results from the previous assessments (IMBIE-2). Source: Otosaka et al. (2023).

Between 1992 and 2020, the ice sheets contributed 21 mm to global mean sea level rise. Other factors contributing to sea level rise include thermal expansion of seawater and changes in ocean circulation to a lesser extent. Ice sheet melting now accounts for a quarter of all sea level rise, which is a fivefold increase since the 1990s, and is causing major impacts because 40% of the global population lives in coastal areas.

In Greenland, there are large inter-annual variations in mass balance and the melting occurs in varying amounts in places conditioned by intra-annual weather patterns. In Antarctica however, ice losses continue to be dominated by mass loss from West Antarctica, and, to a lesser extent, from the Antarctic Peninsula (Figure 2). The rate at which the Antarctic ice sheet is melting has slowed but remains much faster than in the 1990s (Figure 1).

Moreover, West Antarctica is the location of the unstable Thwaites Glacier, whose breakup has the potential to generate very rapid sea level rise (Risk Frontiers Briefing Note, 2022a). East Antarctica remains close to a state of balance but is the most uncertain component of Antarctica's mass balance.

Exceeding certain global warming thresholds could trigger important and potentially irreversible positive feedback mechanisms. Scientists at IMBIE are now able to continuously update their assessments of ice sheet mass balance, and plan to update their assessment every year to facilitate response to the accelerating increase in global ice sheet melting.

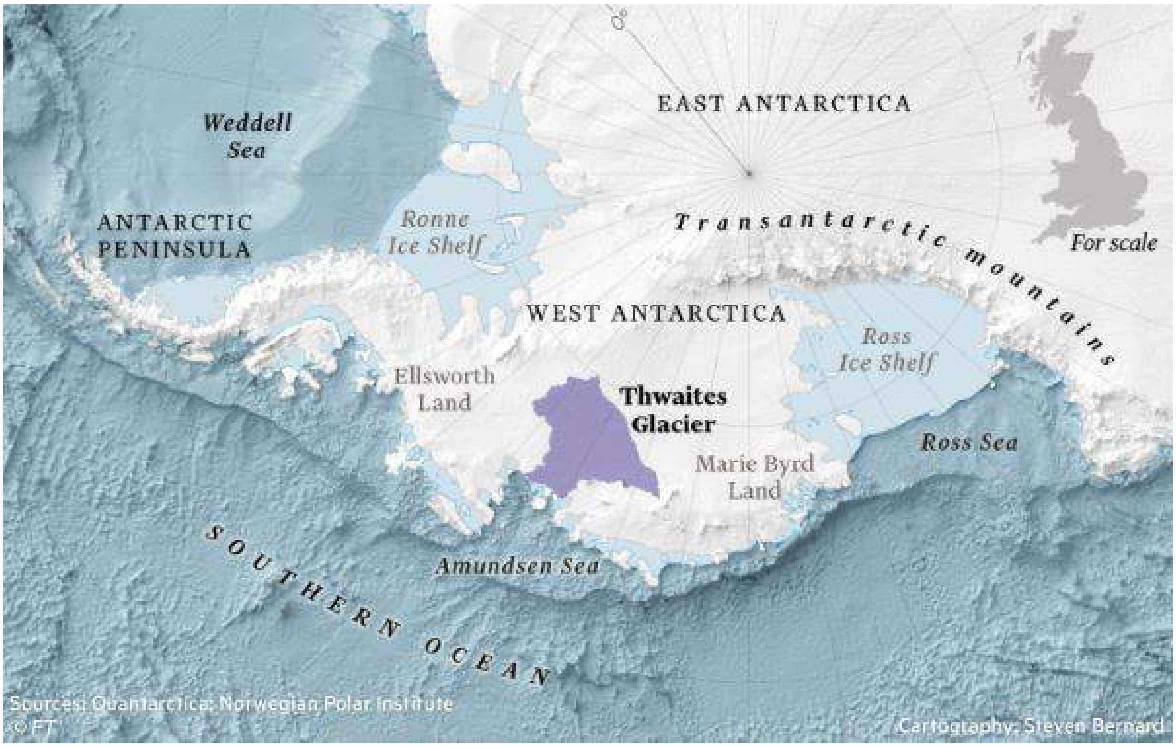

Figure 2. Location of the Thwaites Glacier, which forms a plug between the West Antarctica Ice Sheet and the Amundsen Sea. Sources: Quantarctica; Norwegian Polar Institute.

SLOWING OF THE GLOBAL ABYSSAL CIRCULATION

The melting of polar ice caps in Greenland and Antarctica is discharging massive amounts of freshwater into the oceans, making water more buoyant and reducing the amount of deep-water formation at high latitudes. Deep-water formation is the key mechanism driving vertical circulation of ocean water masses such as the Atlantic Meridional Overturning Circulation and the Antarctic Abyssal Overturning Circulation.

There has been extensive research showing the slowdown of the Atlantic meridional overturning circulation during the past two decades in part due to accelerated freshwater input from melting icecaps (England et al., 2022; Orihuela-Pinto et al., 2022). This could dramatically modulate the European Climate, Arctic sea-ice extent and have far-reaching consequences across the globe, including in Australia (Risk Frontiers, 2022b).

Although the Antarctic abyssal overturning circulation has remained steady in the past few decades, recent research suggests that the deep-water transport could halve by 2050 as a result of accelerated Antarctic ice melt (Li et al., 2023). The global decrease of deep-water formation would slow down the re-circulation of heat in the oceans resulting in accelerated warming.

This would also deplete deep-waters' oxygen accumulated in cold surface water and starve the upper ocean of the upwelling of nutrients provided when deep waters resurface from the ocean abyss. The implications for marine ecosystems would be profound. In Australia, this would manifest as a persistent La Nina state with increased wet conditions, multiplying the likelihood of record-breaking floods such as the ones observed in 2022.

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Paul is Chief Geoscientist at Risk Frontiers. He has a PhD in Geophysics, and has 45 years experience as an engineering seismologist, including 15 years with Risk Frontiers. He has had first hand experience of damaging earthquakes in California, Japan, Taiwan and New Zealand. He works on the development of QuakeAUS and QuakeNZ.

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