CRYOSPHERE: Antarctic ice growth and retreat

Antarctic Ice Sheet change during the last glacial cycle is unclear. The timing of moraine development in the Ross basin suggests that the ice sheet reached maximum thickness under the warming temperatures of the last termination.

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The Antarctic Ice Sheet (AIS) is undergoing change in response to changing climate and oceanic conditions, with implications for global sea level[1–4]. During the colder climates of the last glacial cycle, the AIS had a greater mass and extent, expanding to cover the continental shelf. The growing database of radiocarbon and cosmogenic dates was used in a recent reconstruction of the AIS for the period 20,000 to 5,000 years ago by the RAISED consortium[5–8]. However, there are still few precise and reliable ages for the exact timing of maximum extent of the ice sheet and the onset of retreat, particularly in the Ross Sea region. This data gap hinders attempts to link ice sheet dynamics with the relevant forcing mechanisms reconstructed from palaeoproxy records. Writing in Nature Geoscience, Hall and co-authors[9] outline the timing of ice sheet expansion and decay in the Ross drainage system, which is fed by the West and East AIS, and unravel the relative importance of the factors leading to instability during the warming of the last glacial termination.

The dynamics of the AIS are sensitive to the balance between two main factors. Ice mass is gained through the accumulation of snow across the colder, higher-elevation interior of the ice sheet. Mass is primarily lost where the ice sheet meets the ocean. This occurs through iceberg-calving and ice-melt both at the marine grounding line and the underside of fringing ice shelves. At the ice–ocean interface the ice sheet is stabilized where its grounding-lines are anchored on pinning points such as sills and islands, as well as by the buttressing effect of ice-shelves.

Increased ice melt can induce ice shelf thinning, recession of the grounding line and uncoupling from pinning points. These changes lead to acceleration in ice stream flow and rapid retreat across the ice shelf. Such an effect has been noticed in the Amundsen Sea region of the AIS as a result of atmospheric warming and greater inflow of relatively warm Circumpolar Deep Water through cross-shelf bathymetric troughs to the grounding line, which has resulted in ice melt and the ice lifting from pinning points[10–13]. This rapid melting has prompted concerns that continued climate and oceanic change could ultimately lead to collapse of the West AIS[10–13]. Ice sheet behaviour in the past provides a long-term context for the significance of current change and indicates whether increased ocean forcing has any precedent in previous ice sheet retreat.

To assess the factors that control the retreat of the AIS following the Last Glacial Maximum, Hall and colleagues[9] built a unique, well-dated chronology for the timing of maximum ice-sheet extent in the Ross drainage system. They studied a moraine system that formed at the margin of the Ross drainage system, located in the coastal region of the Transantarctic Mountains (Fig. 1). Hall et al. determined the timing of moraine construction from radiocarbon dating of the remains of blue-green algae that were trapped in the deposits. The resulting chronology — which is unrivalled in the region and Antarctica more generally — shows that the moraine system formed continuously between 18,700 and 12,800 years ago. This suggests that ice thickness, and by implication, extent, reached a maximum well after the global glacial maximum about 20,000 years ago.

The growth of the ice sheet during the last deglaciation coincides with more ice accumulation during a period of increased atmospheric temperatures during the last deglaciation as recorded by an ice core from the West Antarctic Ice Sheet divide. However, during this time, ocean temperatures were warming, and rising sea level would have also promoted ice melt from marine grounding lines and fringing ice shelves. The fact that the ice sheet remained at its maximum extent in this region implies that mass gain outpaced ice-loss from ocean forcing.

Accumulation has remained high, and glaciers that terminate on land have continued to expand in the Ross drainage system and are at their maximum extent today. However, the marine sector of the ice sheet in the Ross Sea began to retreat around 12,800 years ago. Hall and colleagues suggest that after this time, the loss caused by ocean forcing was greater than the mass gained through accumulation. This imbalance caused the retreat of the ice sheet grounding line and a drawdown of ice in the interior of the ice sheet throughout large parts of the Ross drainage system. Similar dynamics might explain the reconstructed timing of ice sheet retreat in the Weddell Sea sector of the AIS[5–8], which has proven controversial. If ocean forcing has driven significant mass loss in the past, then thinning and recession of ice in the

Amundsen Sea today in response to an inflow of relatively warm seawater could perhaps lead to a decline in the West AIS and even its eventual collapse[10–13].

Hall and colleagues[9] have provided an important step forward in our understanding of the timing of the ice sheet maximum in the Ross drainage system during deglaciation, subsequent AIS retreat, and relevant mechanisms. How these mechanisms may play out in the face of future climate warming remains to be investigated.

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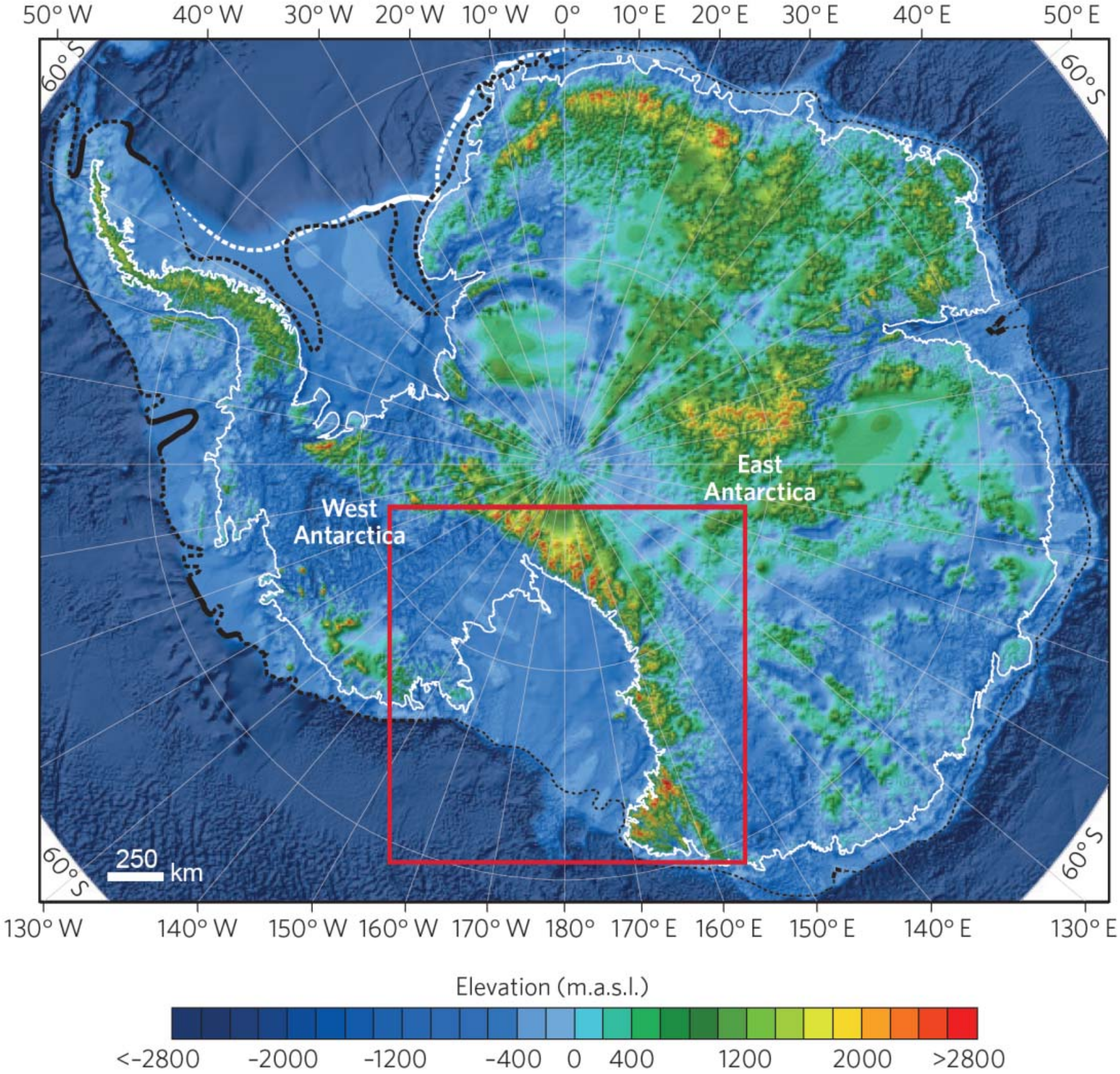
Figure 1. The Antarctic Ice Sheet 20 ka and now. Geomorphologic evidence suggests that the AIS was larger than at present at some point during the previous glacial cycle (varying scenarios in black and white solid and dashed lines). Hall and colleagues[9] show that the ice sheet in the Ross drainage system (red outline) reached its maximum extent between 18,700 and 12,800 years ago, as a result of increased accumulation during the deglaciation following the Last Glacial Maximum. The ice sheet in the Ross drainage system only retreated when the mass loss at the ice–ocean interface exceeded the mass gain from accumulation. Ground elevation in colour shading. Figure adapted from ref. 5.



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