Reconstructing and understanding deglacial Antarctic Ice Sheet dynamics – novel insights and implications for future sea-level rise

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Abstract

Knowledge on the response of the Antarctic Ice Sheet (AIS) to deglacial changes is very limited because most shallow marine and terrestrial sediment sequences cannot be dated adequately, reveal only the late stage of ice retreat, or resolve only local responses, leaving much room for speculation during the last two decades on the true nature and dynamics of events and their contribution to past sea-level rise. Novel findings from far-field, deep-ocean sediment records from Iceberg Alley revise our current understanding of ice-sheet dynamics. The record of iceberg-rafted debris (IBRD) in deep-ocean sediment from the Scotia Sea provides a nearly continuous, integrative history of eight AIS discharge events (AIDs) during deglaciation. The highly-resolved records indicate that these events occurred extremely rapidly - within one or a few decades, and once initiated, continued for centuries. Major AIS mass loss brackets Meltwater Pulse 1A (AID6) and 1B (AID2), between ~14.7 – 11.3 ka (Weber et al., 2014).

Independent confirmation comes from analysis of the Patriot Hills blue-ice area, indicating marked AIS draw down (in excess of 650 m) and mass loss across the Weddell Sea Embayment during the Antarctic Cold Reversal (ACR, 14.7 – 12.7 ka) (Fogwill et al., 2017). Comparing the Patriot Hills and Scotia Sea records indicates that greater AIS mass loss enhanced surface cooling in the Southern Ocean, led to higher seasonal variability in sea-ice extent, and increased ocean productivity in the sea-ice zone during the ACR, slowing the rate of atmospheric CO_2 rise and establishing a globally significant carbon sink (Fogwill et al., submitted).

Foraminiferal radiocarbon ages from shallow-marine sediment archives in the eastern Ross Sea (DeCesare et al., submitted) directly constrain discrete intervals of West Antarctic Ice Sheet grounding line retreat at 14.7 ka (30 km) and 11.5 ka (200 km), likely contributing to AID6 and AID2, respectively. These ages also constrain an ice-shelf collapse event, approximately the size of Larsen-B, at 12.3 ka, likely contributing to AID3.

Close agreement between geological and ice-core records and thermodynamic ice-sheet modelling driven by deglacial ocean temperature changes simulated in an intermediate complexity climate model (Golledge et al., 2014), confirm that the AIS was highly-dynamic during the last deglaciation. Its dynamism most likely arose from a combination of a high sensitivity to subsurface ocean warming and basal meltwater or substrate feedbacks that allowed rapid propagation of ice marginal thinning into the interior of the ice sheet.

All these recent findings are in marked contrast to previous scenarios of minor and late deglacial dynamics, and argue for a much more dynamic deglacial AIS, which is important in light of current discussions on potential AIS collapse in the near future and its impact on sea-level rise for the coming decades to centuries.

Keywords: Antarctic Ice Sheet, Antarctic Cold Reversal, Meltwater Pulse 1A, Meltwater Pulse 1B, sea-level rise, ice-sheet dynamics

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