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Biomarkers reveal that high-latitude Southern Ocean carbon sink enhanced by seasonal sea-ice feedbacks during the Antarctic Cold Reversal

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The Southern Ocean plays a fundamental role in regulating global atmospheric CO_2 levels, yet the underlying processes and feedbacks that control the carbon cycle during climate transitions remain unclear. Following the Last Glacial Termination (LGT), the rapid rise in atmospheric CO_2 was interrupted by an enigmatic 1,900-year plateau during a period of pronounced mid- to high-latitude Southern Hemisphere cooling called the Antarctic Cold Reversal (ACR, 14,600-12,700 years ago or 14.6-12.7 kyr BP. Figure 1). Here we report the first biomarker and ancient DNA analysis of a highly-resolved Antarctic ‘horizontal’ ice core, which combined with marine sediment records reveals a coherent signal of marine productivity and microbial diversity changes across the South Atlantic sector of the Southern Ocean during the LGT.

Our study develops four important new approaches in the analysis of biomarkers captured within a new and highly resolved Antarctic ice core record (Imaging Flow Cytometery (ImageSteam®), florescence biomarker, DNA and liquid chromatographic carbon detection), to reconstruct high-latitude Southern Ocean surface productivity through the LGT. We identify marked variations in biomarker signals through the LGT derived from precipitation delivered by low-pressure systems tracking across the South Atlantic sector of the Southern Ocean. We record high concentrations during the period defined by the ACR, reflecting a marked increase in marine bacteria and algae (including picoplankton and larger nanoplankton), and a increase in marine species diversity . Each measure (proxy) is independent, yet mutually supportive, with remarkable coherence through this period of abrupt and extreme change

Together, these data provides direct evidence that during the ACR feedbacks enhanced the Southern Ocean biological pump at high-latitudes, whilst at mid-latitudes wind induced ventilation reduced it. To understand the mechanisms driving this signal we use available proxy reconstructions and transient climate modelling to demonstrate that this period of enhanced marine productivity coincides with the largest seasonal viability in sea-ice extent. We suggest triggered seasonally high productivity in the high-latitude Southern Ocean, contrasting with the records further north. Transient climate modelling shows this period coincided with the maximum seasonal variability in sea-ice extent, suggesting sea-ice feedbacks enhanced CO_2 sequestration, making the high-latitude Southern Ocean a significant carbon sink that contributed to the sustained plateau in CO_2 levels during the ACR.