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Pan-Southern Ocean Compilation of Foraminiferal $\delta^{13}C$ Reveals Regional Heterogeneity in the Pace and Timing of Deglacial Deep Sea Ventilation

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Changes in interior ocean circulation and wind-driven upwelling in the Southern Ocean play a critical role in the release of carbon dioxide (CO_2) from the deep ocean to the atmosphere across the last deglaciation ~11,000 – 18,000 years ago (~11 – 18 ka). High-resolution records from the south Atlantic and Pacific have revealed that the pace and timing of this ventilation was not consistent across the Southern Ocean. This inconsistency suggests that the dynamics that initiate ventilation may be distinct between the separate sectors of the Southern Ocean. Here, we present a compilation of 23 highly-resolved benthic stable carbon isotope records ($\delta^{13}C$) from sediment cores bathed by deep waters (~2.5 – 4 km depth) throughout the Southern Ocean, including three new records from the Indian Ocean collected as part of the Coring to Reconstruct Ocean Circulation and Carbon dioxide Across 2 Seas (CROCCA-2S) expedition in Fall 2018. We combine these records by sector and generate $\delta^{13}C$ "stacks" to reveal the underlying basin-wide ventilation signal. We then apply piecewise regression techniques to identify the onset of ventilation in each stack and quantify its pace across the last deglaciation. Our results reveal distinctly different ventilation signals among the three sectors. In the Pacific, ventilation begins earliest (20.8 ± 1.9 ka) and proceeds gradually throughout the deglacial period until the mid-to-late Holocene (~7 ka). The Atlantic, in contrast, begins later in the deglaciation (15.3 ± 1.4 ka) and ventilates rapidly, reaching modern-day values by the beginning of the Holocene (~10 ka). The Indian begins ventilation within error of the Pacific's onset (18.7 ± 0.9 ka) but rapidly reaches modern values like the Atlantic. Altogether, the Atlantic sector has a significantly later and more rapid onset of ventilation than the Indo-Pacific. Co-occurring changes in deep Atlantic circulation strength and water mass provenance suggests a resumption of deep-water production initiated Atlantic ventilation. The earlier signals in the Indo-Pacific must therefore be related to circulation and air-sea dynamics in the Southern Ocean. Taken together, our data suggest northern- and southern-hemisphere forcings played regionally-distinct roles in the ventilation of the Southern Ocean.