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Deep Ocean Circulation Variability in the High-Latitude South Pacific for the Last Six Glacial Terminations Using ε_{Nd} Isotopic Signatures

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The late Pleistocene climate shows glacial-interglacial "sawtooth" patterns that are hard to explain by orbital forcing alone, necessitating other amplifiers in the climate system, including the carbon cycle and ocean circulation. The Southern Ocean (SO) is thought to have stored and released carbon on glacial-interglacial timescales, and the water masses of the deep South Pacific may have served as a carbon reservoir during glacial intervals. In this study, we investigate the role of deep SO water mass mixing in late Pleistocene climate evolution using a 600 kyr long high-resolution (one sample/3 kyr) Nd isotope (ε_{Nd}) record from Integrated Ocean Discovery Program (IODP) Site U1540 (55°08.467′S, 114°50.515′W, 3580 m).

Nd isotopes are a well-recognized water mass tracer; in the modern deep ocean, dissolved ε_{Nd} can be largely explained by conservative endmember mixing, with a present-day ε_{Nd} value of ~ -8 at Site U1540. However, over the last 600 kyr at Site U1540, only MIS1, 7, 11, and 15 reach the present-day ε_{Nd} value, while MIS 3, 5, 9, and 13 exhibit more radiogenic Nd isotopic compositions (i.e., higher ε_{Nd} values). Concurrently, the most radiogenic ε_{Nd} value of ~ -5.5 is only observed during MIS 6 and 12. The mean glacial and interglacial ε_{Nd} values are ~ -6.62 and -7.23, indicating the increased prevalence of Pacific- and Atlantic-type waters during glacial and interglacial periods, respectively. Broadly, Site U1540 ε_{Nd} exhibits remarkable coherence with glacial-interglacial fluctuations observed in the deep ocean $\delta^{18}O_{sw}$ from ODP Site 1123, suggesting a close coupling between global ice volume, water mass mixing in the deep South Pacific, and glacial-interglacial climate change. However, while Site U1540 ε_{Nd} generally rapidly decreases across glacial terminations, we also observe two notable deviations at terminations IV and VI where unradiogenic, glacial-like ε_{Nd} persists for ~ 10 kyr into interglacials MIS 9 and 13. We attribute these deviations to changes in water geometry in the South Pacific. Based on these new ε_{Nd} data, we hypothesize that both global and regional changes in water mass mixing were instrumental in controlling the carbon cycling in the South Pacific.