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Seawater Pb isotopes record early Miocene to modern circulation dynamics in the Pacific sector of the Southern Ocean

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The Antarctic Circumpolar Current (ACC) is the largest current on Earth in terms of volume transport and plays a critical role in the global distribution of heat, salt and gases. Strengthening of the ACC has long been suggested to have caused Cenozoic ice sheet expansion in Antarctica by preventing poleward heat transport from low latitudes. The final transition of Earth’s climate into the present ‘icehouse’ state occurred after the Middle Miocene Climate Transition (MMCT, ~14 Ma) and was accompanied by significant ice-sheet growth on the Antarctic continent. Due to the scarcity of Southern Ocean (SO) circulation reconstructions, the role of ACC strength in the waxing and waning of the Antarctic ice sheet since the Miocene is still unclear.

Seawater-derived lead (Pb) isotopes are excellent recorders of regional deep water mass sourcing and mixing. We employed a laser ablation multiple-collector inductively coupled plasma mass spectrometry (LA-MC-ICPMS) technique to generate continuous high-resolution (<40 kyr) seawater Pb isotope records for the past 20 Ma from Fe-Mn crust PS75/247-2 dredged on the Marie Byrd Seamounts in the Pacific sector of the SO. Because this Fe-Mn crust is located between the SO’s two key passages, i.e. Drake Passage and Tasman Gateway, it has sensitively recorded past changes in ACC circulation and water mass mixing. We use the Kiel Climate Model (KCM) to examine the potential triggers of ACC changes found in our records.

Our seawater Pb isotope records resolve five relatively stable and (multi-)million-year-long circulation states. Our results show that the southward shift of the ACC and enhanced poleward export of Pacific Deep Water (PDW) coincided with the substantial Antarctic ice sheet retreat during the Middle Miocene Climate Optimum (MMCO, approx. 17–14 Ma) and the following MMCT was accompanied by enhanced export of Antarctic Bottom Water (AABW) and a northward shift of the ACC. We attribute these circulation changes to changes in tectonics rather than reflecting the response to the decline of pCO_2. We also suggest that the modern ACC in the study area was established at about 5 Ma as a consequence of the closure of the Panama Seaway.