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Links between the Antarctic Circumpolar Current, intermediate ocean ventilation, and deglacial CO2 changes

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Understanding the source of glacial-interglacial changes in atmospheric CO2 is important in predicting future atmospheric CO2 levels and climate. Southern Ocean stratification is proposed as a mechanism for isolating the deep ocean from the atmosphere during the glacial state, thereby lowering the atmospheric CO2 content. Southward shifts in the Southern Westerly Winds (SWW) during deglaciation are hypothesized to have broken down the Southern Ocean stratification, drawing old abyssal water to the surface and allowing CO2 to escape to the atmosphere. While deglacial spikes in Southern Ocean productivity (Anderson et al., 2009) and in North Pacific reservoir ages (Marchitto et al., 2007) support a sudden release of old abyssal water, constraints on the actual Southern Ocean dynamics thought to drive stratification changes are lacking. Modeling studies suggest that altering the position or strength of the SWW and the Antarctic Circumpolar Current (ACC) could play a central role in driving observed glacial-interglacial CO2 changes.

Here we present new high-resolution benthic and planktonic foraminiferal and records from a sediment core (MD07-3128) recovered just west of southern Chile (52°39.57'S 075°33.97'W, 1032 m) during the PACHIDERME cruise onboard the R/V Marion Dufresne of IPEV. Together with existing Southern Ocean cores, the new records allow us to portray changes in the position of water masses and frontal systems relative to Drake Passage and Southern Chile. Specifically, planktonic (N. pachyderma, sinistral) values are lower and more variable during the glacial period (relative to the Holocene). The lowest values occur in two pulses, the first during the peak of the Last Glacial Maximum (LGM), and the second at the beginning of the last termination. Likewise, LGM benthic (C. wuellerstorfi) values are also low (<0‰ and increase rapidly to Holocene levels (>1‰ during deglaciation, suggesting a shift in the fronts and water masses bathing our core site.

Taken together, our results suggest that the boundary between intermediate water (relatively high values) and circumpolar deep water (relatively low values) was shifted northward (and/or shoaled) during the glacial period associated with a northward shift of the SWW. The low LGM values, indicating higher nutrient levels, point toward particularly strong isolation/stratification of Antarctic water masses (and increased carbon storage) just prior to deglacial warming. This work confirms that Southern Ocean dynamics are actively involved in deglaciation as previously hypothesized. In addition, we propose that the inferred LGM increase in Southern Ocean CO2 may be an important prerequisite for terminations and helps explain the rapidly rising atmospheric CO2 at the initial warming following the LGM.