

ACHIEVEMENTS

# Southern Ocean Intermediate Waters Held the Key to Earth's CO<sub>2</sub> Past

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For decades, oceanographers considered the deep ocean to be the primary natural reservoir for storing atmospheric carbon dioxide (CO<sub>2</sub>). However, a new international study led by Dr. Raúl Tapia and Associate Professor Sze-Ling Ho of the Institute of Oceanography at National Taiwan University challenges this long-standing assumption. By reconstructing 600,000 years of ocean history, the research team discovered that the oft-overlooked “Antarctic Intermediate Water” (AAIW), located 500–1,500 meters below the ocean surface, has played a critical role in regulating atmospheric CO<sub>2</sub> over the past several glacial cycles. The study findings were published in *Science Advances*.

The study concentrated on the “Mid-Brunhes Event” (MBE), a major climate transition that occurred around 424,000 years ago. Earth’s climate naturally alternates between glacial and interglacial periods, accompanied by ~100 parts per million (ppm) glacial–interglacial CO<sub>2</sub> swings. During the MBE, however, interglacial CO<sub>2</sub> concentrations unexpectedly rose by an additional ~35 ppm compared with the preceding cycle. Previous theories mainly attributed this shift to changes in deep Southern Ocean circulation, but climate models have struggled to fully account for the phenomenon.

Examining sediment cores collected in the South Pacific—one of the least-sampled ocean regions in the world—the researchers reconstructed long-term temperature and salinity changes in AAIW. Their results revealed a major contrast before and after the MBE.

Before the MBE, AAIW was colder and fresher. Colder water has a greater capacity to dissolve CO<sub>2</sub>, boosting ocean uptake from the atmosphere. Once absorbed, strong stratification acted as a barrier, locking that carbon away in deeper waters for long periods.

After the MBE, AAIW became warmer and saltier, reducing its capacity to dissolve CO<sub>2</sub>. At the same time, weaker ocean stratification allowed more carbon to escape back into the atmosphere, consistent with the observed rise in atmospheric CO<sub>2</sub>.

The researchers linked these changes to the Antarctic Circumpolar Current (ACC) and Antarctic icebergs. Prior to the MBE, Antarctica discharged more icebergs than today. A stronger ACC transported more Antarctic icebergs northward,

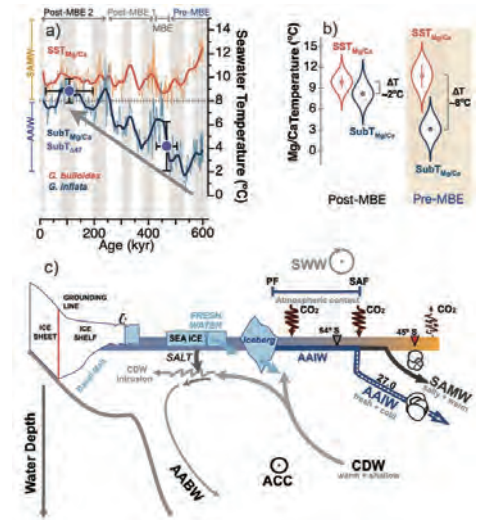


Figure 1. (a) Since the MBE, thermocline temperatures (blue) have steadily increased. (b) Vertical stratification weakened fourfold after the MBE. Because colder water dissolve more CO<sub>2</sub>, and stratification determines how long that carbon remains sequestered at depth, cooler and more stratified pre-MBE conditions favored greater intermediate-depth CO<sub>2</sub> storage. (c) Antarctic iceberg meltwater freshened surface waters, shifting AAIW formation northward and expanding its exposure to the atmosphere, thereby enhancing CO<sub>2</sub> uptake.



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supplying cold freshwater to intermediate-water formation zones. After the MBE, a southward shift in Southern Hemisphere westerly winds reduced iceberg transport and freshwater input, leading to warmer intermediate waters.

The findings highlight the previously underestimated role of intermediate ocean waters in Earth's carbon cycle and suggest that ongoing Antarctic ice loss today could weaken the ocean's ability to store carbon, potentially accelerating future global warming.

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