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Strong Carbon Isotopic Fingerprint of Sea-ice on the Glacial Southern Ocean

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The Southern Ocean is a major site of upwelling of carbon and nutrient rich deep waters and net outgassing of carbon from the ocean to the atmosphere. Processes which act to stem this CO_2 leak are thought to play a central role in lowering atmospheric CO_2 during glacial cycles.

From examining nutrient-based proxies, previous studies have shown that an increase in the efficiency of the Southern Ocean's biological pump occurred during the last glacial maximum, and so have hypothesised this to be one of the dominant processes involved. These proxies however are unable to record changes in carbon stored by the disequilibrium carbon pump, most importantly via an increase in sea ice.

Carbon isotopes in planktonic foraminifera have the potential to help resolve the importance of the different carbon drawdown mechanisms, being sensitive to both changes in the biological and disequilibrium carbon pumps. Here, we show that the glacial Southern Ocean was marked by a widespread reduction in $\delta^{13}C$ and pCO_2. This reduction is significantly greater than would be predicted by the whole ocean change in $\delta^{13}C$ or due to vital effects. In addition, it has the wrong sense to be explained by the biological carbon pump, which should drive an increase in surface water $\delta^{13}C$.

Using a carbon cycle model, we show that changes in physical processes, most importantly an increase in sea-ice cover, are required to create this signature. Concomitant reduction in the delivery of carbon and nutrient-rich deep waters to the surface Southern Ocean explains the lower surface water pCO_2. This highlights the importance of the physical processes and the disequilibrium carbon pump in dictating changes in Southern Ocean carbon cycling during the last glacial period.