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Enhanced Carbonate Counter Pump efficiency during interglacials of the past 800 000 years in the Indian sector of the Southern Ocean and its impact on the carbon cycle

Margaux Brandon[1,2], Stéphanie Duchamp-Alphonse[1], Elisabeth Michel[2], Amaëlle Landais[2], Gulay Isguder[2], Nicolas Pige[3], Franck Bassinot[2], Samuel Jaccard[4], Sylvain Pont[5], and Annachiara Bartolini[6]

[1]Université Paris-Saclay, CNRS GEOPS, Orsay Cedex, France (margaux.brandon@universite-paris-saclay.fr)
[2]Université Paris-Saclay, CNRS, CEA, UVSQ, Laboratoire des sciences du climat et de l'environnement, 91191 Gif-sur-Yvette, France
[3]Univ. Lyon, Université Claude Bernard Lyon 1, ENS de Lyon, CNRS, UMR 5276 LGL-TPE, F-69622, Villeurbanne, France
[4]Institute of Earth Sciences, University of Lausanne, 1015 Lausanne, Switzerland
[5]IMPMC, Sorbonne Université, MNHN, UPMC Paris 06, UMR CNRS 7590, 75005 Paris, France
[6]Muséum National d'Histoire Naturelle, Département Origines & Evolution, CR2P MNHN, CNRS, Sorbonne Université, 8 rue Buffon CP38, 75005, Paris, France

The Southern Ocean (SO) is a key region for ocean-atmosphere CO_2 exchanges, as it witnesses significant changes in physical and biological pump dynamics. While numerous studies have highlighted the central role of reinvigorated SO upwelling behind rapid increases in atmospheric CO_2 during glacial terminations, a very few studies have yet focused on the impact of the Biological Carbon Pump and more specifically of the Carbonate Counter Pump (CCP) that, contrary to the Soft Tissue Pump, participates to increase the concentration of dissolved CO_2 in oceanic surface waters and thus, in the atmosphere.

Amongst the last 9 interglacials, Marine Isotope Stage (MIS) 11 (~ 400 ka) is the longest interglacial of the past 800,000 years, characterised by a ~30 ka-long plateau with atmospheric CO_2 hovering around 280 ppm. Reconstructions of past global biosphere productivity based on $\Delta^{17}O$ of O_2 measurements on air bubbles trapped in ice cores, show that MIS 11 registers the strongest global biosphere productivity (~ 20% higher) compared to the other 8 interglacials (Brandon et al., 2020; Yang et al., EGU21) Meanwhile, marine sedimentary records suggest strong carbonate production and export. Studying the detailed variations of the CCP during this specific period can therefore be useful to better understand its relationship with biospheric productivity changes and to better constraint its impacts on atmospheric CO_2.

As calcifying organisms, coccolithophores and planktonic foraminifera represent the major producers of $CaCO_3$ in pelagic environments and are therefore useful tools to reconstruct past variations in the CCP strength. Here, we calibrate Ca_{XRF} and $CaCO_3$ signals from marine core MD04-2718 located in the Indian sector of the SO (48°53 S; 65°57 E) in terms of coccolith and planktonic carbonate production and export signals over the last 800 ka, with a focus on the interval MIS 12 to MIS 10. We compare our results with published micropaleontological and

geochemical records from the subantarctic zone (SAZ) in order to reconstruct past changes in CCP efficiency and circulation at the SO scale and understand their relationships with atmospheric CO_2 patterns.

We show an increase in CCP efficiency during interglacial periods, with an exceptional high carbonate export production during MIS 11. We demonstrate that enhanced CCP efficiency at the beginning of MIS 11 is likely the consequence of both higher SST conditions and nutrient contents in the upper water column of the SAZ, that increase coccolithophore and planktonic foraminifera productions, thanks to the southward migration of SO fronts and the reinvigoration of southern upwelling. While the sharp increase in atmospheric CO_2 during Termination V seems correlated with the reinvigoration of the SO upwelling, enhanced CCP at the beginning of MIS 11 might have greatly reduced the efficiency of the biological pump, impacting the CO_2 flux from the ocean to the atmosphere. The strong global biological productivity registered during this interval might have permitted to sustain the 30 ka-long plateau of atmospheric CO_2 that characterize this time interval.