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Spatiotemporal variability of the Antarctic Circumpolar Current strength over the past million years

SHUZHUANG WU[1,2], ALAIN MAZAUD[3], ELISABETH MICHEL[4], MICHAEL P. ERB[5], THOMAS F. STOCKER[6], HELEN ERI AMSLER[6,7], PERIG LE-TALLEC-CARADO[2,8], FRANK LAMY[9,10] AND SAMUEL L. JACCARD[6,7,11]

[1]Institute of Deep-sea Science and Engineering, Chinese Academy of Sciences
[2]Institute of Earth Sciences, University of Lausanne
[3]Laboratoire des Sciences du Climat et de l'Environnement
[4]LSCE Laboratoire des Sciences du Climat et de l'Environnement, CEA-CNRS-UVSQ, Université Paris-Saclay
[5]School of Earth Science and Environmental Sustainability, Northern Arizona University
[6]Oeschger Centre for Climate Change Research, University of Bern
[7]Institute of Geological Sciences, University of Bern
[8]University of Bordeaux
[9]Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research
[10]MARUM–Center for Marine Environmental Sciences
[11]University of Lausanne

The Antarctic Circumpolar Current (ACC) links the Atlantic, Indian, and Pacific basins, regulating global ocean circulation, Antarctic Ice Sheet mass balance, and marine carbon storage. Although many studies have assumed uniform ACC variability across the Southern Ocean during Pleistocene, emerging proxy evidence indicates sector-specific differences on orbital timescales. In this study, we reconstruct the spatiotemporal variability of ACC strength over the past one million years using sortable silt mean grain size from a transect of six sediment cores in the South Indian Ocean, complemented by a synthesis of existing records from all Southern Ocean sectors. We find persistent zonal asymmetry in ACC strength on both glacial-interglacial and obliquity timescales. The ACC strength variability exhibited anti-phased changes in the Indian and Pacific sectors: during glacial and low-obliquity intervals, the ACC strengthened in the Indian sector while weakening in the Pacific sector; the reverse pattern prevailed during interglacials and high-obliquity periods. Integration of proxy data with climate model simulations suggests that this asymmetry arises from sector-specific responses to the jet-stream configuration in the Southern Hemisphere westerly winds, bathymetric steering, sea-ice extent and meridional density gradients. These findings provide geological evidence for persistent zonal asymmetric changes in ACC flow, with implications for interbasin exchange, ice-sheet stability, and the Southern Ocean's role in regulating atmospheric CO_2 in the past and future climate.