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Synergic role of frontal migration and silicic acid concentration in driving diatom productivity in the Indian sector of the Southern Ocean over the past 350 ka

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ABSTRACT

The glacial-interglacial siliceous productivity in the Sub-Antarctic Zone (SAZ) of the Southern Ocean (SO) has been proposed to respond to higher dust-bearing iron fluxes and/or basin-wide increased nutrient supply to surface waters. However, long records of diatom productivity are mainly obtained from the Atlantic and Pacific sectors of the SO. We present a new diatom productivity record from the SAZ of the western Indian sector of the SO, where the Antarctic Circumpolar Current strongly interacts with bottom topography to create a productivity hotspot, during the last four glacial-interglacial cycles. Our results show that regional changes in diatom productivity did not follow a glacial-interglacial pattern. It was highest during the Marine Isotope stage (MIS) 6 and MIS4, lowest during MIS10-MIS8 and MIS3-MIS1, whereas intermediate diatom productivity was found during MIS7 and MIS5. Multi-millennial events of high diatom productivity were scattered throughout both the glacial and interglacial periods. Both long-term and rapid diatom productivity changes in the region were disconnected from dust flux changes, but might relate to frontal migrations and SO upwelling intensity changes which have both mediated the silica and iron availability for diatoms. Importantly, our data suggest that front migrations were not homogenous in the SO, especially where these fronts interact with bottom topography. The peculiarity of these productivity hotspots must be considered when drawing SO-wide carbon balance in the past.

1. Introduction

As the most abundant primary producers in the Southern Ocean (SO), diatoms are the main contributors of biogenic silica to the deep-sea sediments, making the SO the world's largest biogenic silica accumulation site (Tréguer, 2014; Tréguer and Rocha, 2013; Tréguer et al., 2021). They are also efficient exporters of organic carbon to the deep ocean, thereby lowering atmospheric CO_2 (Buesseler, 1998; Krause and Lomas, 2020; Smetacek et al., 2012; Zúñiga et al., 2021). In this vein, it is believed that increased diatom abundances in the Polar Front Zone (PFZ) and Sub-Antarctic Zone (SAZ), at the expense of carbonate phytoplankton, have contributed to the reduction of CO_2 during glacial periods (Matsumoto et al., 2002).

Previous studies on SO phytoplankton suggest that the growth of diatoms is strongly co-limited by iron concentration and light in the PFZ, and by iron and silicic acid concentration in the SAZ (Boyd et al., 2001; Lannuzel et al., 2011). At the SO scale, the repartition of the nutrient stocks itself depends on the ocean circulation, essentially the intensity of the SO upwelling and the location of the hydrological fronts. However, in the Indian Ocean sector of the SO, the Antarctic Circumpolar Current (ACC) interacts strongly with the bottom topography (Chapman et al., 2020; Klocker, 2018; Langlais et al., 2017; Llort et al., 2018; Park et al., 2014; Rintoul, 2018; Sokolov and Rintoul, 2009; Tamsitt et al., 2017) creating regional hot spots of phytoplankton productivity (Blain et al., 2007; Pollard et al., 2009). More specifically, in the southwest Indian sector of the SO, the SAF flows anti-cyclonically in between the Del Caño Rise (DCR) and the Crozet Plateau, forming an S-bend regulated by the regional bathymetry (Pollard and Read, 2001; Pollard et al., 2007). As a result, the SAF flows south of DCR but north of Crozet Islands. A weak circulation develops between the Crozet Plateau and the SAF, which allows the accumulation of macro- and micro-nutrients sourced from the Crozet Islands in surface waters north and east of the Crozet Plateau

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