Response of South Atlantic surface circulation to African monsoon variability: Evidence from Late Quaternary records of geochemical tracers for sea-surface temperatures and productivity

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Paleoclimate reconstructions and results from atmospheric general circulation models have revealed that during the Late Quaternary the zonal strength of trade winds over the South Atlantic has significantly responded to precessional variations of boreal summer insolation because zonality of trades is tightly coupled to African Monsoon intensity. The most prominent indicator for this trade-wind response to precessional forcing via the monsoon system is the corresponding predominance of periodic 19 to 23-kyr variations between paleorecords of proxies for continental climate and those for sea-surface temperatures (SST) and biological productivity in equatorial Atlantic surface waters (Pokras & Mix, 1985; Prell & Kutzbach, 1987; McIntyre *et al.* 1989; De Menocal *et al.* 1993).

In order to reconstruct Late Quaternary surface circulation in the eastern South Atlantic (10°W to 10°E, 0 to 20°S) we evaluated SST and paleoproductivity changes for the last 200,000 years. For this purpose records of alkenone, organic carbon and opal fluxes, as well as time series of planktonic foraminifera and organic carbon $\delta^{13}C$ were produced from Guinea and Angola Basin and Walvis Ridge sediments (Schneider 1991; Müller *et al.*, 1994; Schneider *et al.*, 1993; Schneider *et al.*, 1994). Comparable to the results from the equatorial Atlantic mentioned before, all these records of geochemical tracers for productivity and SST are characterized by a significant 23-kyr periodicity which is coherent to precessional forcing. But phase relationships of periodic 23 kyr variations in SST and productivity estimates from the eastern South Atlantic with respect to boreal summer insolation changes document that surface waters north and south of about 15°S have responded in different way to precessional insolation changes. Generally, periods of warm SST's and low productivity co-occured with intervals of increased North African insolation, but there is a distinct phase lag of maximum SST and minimum productivity between the two areas. While periodic SST and paleoproductivity changes related to the 23 kyr frequency band from the central equatorial divergence zone and from the Walvis Ridge are in phase with changes in July insolation at 10°N, those from the African continental margin in the Angola Basin lag insolation changes by about 4 kyr and are in fairly phase with SST changes in the Cape Basin.

Since the equatorial upwelling and the Walvis Ridge area are located beneath the centre of the modern zonal trade-wind field, we suggest from the phase pattern described above that surface water oceanography under the field of northwest-directed trades was predominantly driven by monsoonal modulation of their zonal intensity. Low productivity and warm surface waters within this zone are in phase with July insolation maxima which indicates direct reponse to orbital forcing and maximum monsoon strength at periods of minimum Earth–Sun distance during boreal summer. The 4 kyr lag of precessional SST and paleoproductivity changes in the eastern Angola Basin suggests that this part of the surface waters in the South Atlantic was not directly effected by trade-wind variations and that the zonal-directed trade-wind zone in the southern hemisphere did not migrate northward by several degrees of latidude during glacials. Instead, the close correspondence of Angola Basin SST and productivity phasing with that from the Cape Basin SST's can be taken as evidence that surface water oceanography in the most eastern part of the South Atlantic was additionally influenced by periodic 23 kyr changes in the advection of cold surface waters from the Southern Ocean.

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