Geophysical Research Abstracts,
Vol. 11, EGU2009-1628-1, 2009
EGU General Assembly 2009

Productivity paradox in the NW African upwelling area during the last glaciation related to changes in nutricline depth and Saharan humid episodes

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The Sahara is the largest desert of the world. However, during the early Holocene the Saharan realm was nearly completely vegetated within the “African humid period”. This period has been attributed to a strengthening and northward extension of the summer monsoon. Our reconstructions of marine productivity and terrigenous input from a sediment core off NW Africa provide a detailed record of subtropical climate from 45,000 to 3,000 years BP. We show that abrupt climatic changes modulated the precessionally forced paleoproductivity-signal off NW Africa. Cold periods with increased upwelling intensity show low productivity due to a deepening of the nutricline depth during the winter bloom. Although the glacial in NW Africa is believed to be a dry and cold period, our data indicate wet phases during the insolation maximum in marine isotopic stage 3. These glacial “Saharan humid episodes” would have offered ecological conditions almost resembling those of the early Holocene.

Core GeoB 5546 was retrieved at 27°32‘N, 13°44‘W at 1070 m water-depth off Cape Yubi. The average sedimentation rate of 20 cm /1000 years is caused by the combined influence of high regional surface ocean productivity and high supply of terrigenous material, partly windblown African mineral dust and partly wadi/river transported material. Along with fourteen 14C-datings, the 18O-values of the planktonic foraminifera G. bulloides were used for stratigraphy.

At present, productivity in the Eastern Boundary Current region of the NE Atlantic is seasonal and closely linked to two major processes, that is, coastal upwelling in summer and deep mixing with an associated bloom in winter. High TOC contents of up to 1.5 % occur during interstadials, whereas lower values (0.6-0.9 %) prevail during stadials. If wind-driven coastal upwelling was the major process that controls the paleoproductivity in the Eastern Boundary Current, this finding would contradict modelling results which indicate strengthened NE trade winds during North Atlantic cold events. Enhanced trade winds during Heinrich Events are documented at this site by highest Zr/K-ratios as well as high giant quartz-grain abundances (Figure 2), both typical indicators for wind speed. Obviously the trade winds and the associated upwelling were not sufficient to enhance the annual mean productivity in the Eastern Boundary Current. This paradox can be explained by significant reduction of the winter bloom productivity during Heinrich Events and Dansgaard-Oeschger stadials. This interpretation is supported by a climate model experiment, which indicates that the deep winter mixing for an idealized Heinrich Event is reduced in the Canary Islands region due to northern North Atlantic meltwater input.

An additional process has to explain the occurrence of high-productivity events especially during insolation maxima. This process is likely related to the terrigenous input of nutrients in the near coastal area. Silicon is a proxy for terrestrial material in core GeoB 5546, since biogenic opal contributes less than 0.6 % to the bulk sediment. From our record three periods of enhanced silicon contents are obvious, one in MIS 3 within the interstadials 8, 7 and 6, another shortly after a major sea level change at 25 kyrs in MIS 2 and the most pronounced within the early Holocene. Although the fluvial import of terrigenous particles is negligible in recent times near Cape Yubi, hydrological conditions during the early Holocene were completely different to those of the late Holocene.

Wind-driven upwelling of nutrient-rich water masses as the classical forcing mechanism for an enhancement of productivity off NW Africa is accompanied by strong winter bloom processes. The observed productivity paradox off NW Africa reflecting low productivity in times of enhanced upwelling (e.g. the Heinrich events) can be explained by a temporal deepening of the nutricline that prevents nutrients from being uplifted to the mixed layer, which reduces the winter bloom. Climatic changes within Africa played a crucial role in the development of human society. Presently only the Holocene humid period is discussed as the time in which ancestors of the modern northern African populations migrated into the Sahara (e.g. Kuper and Kröpelin, 2006). The Saharan humid episodes described here would offer episodic ecological conditions within the glacial similar to that of the Holocene African humid period, but more than 20 kyrs earlier. The data of core GeoB 5546 indicate that interstadial periods during the glacial should also be considered as opportunities for the establishment of savanna-type ecosystems in NW Saharan Africa.