Linking up the Sun and Indian summer monsoon rain through ocean sediments

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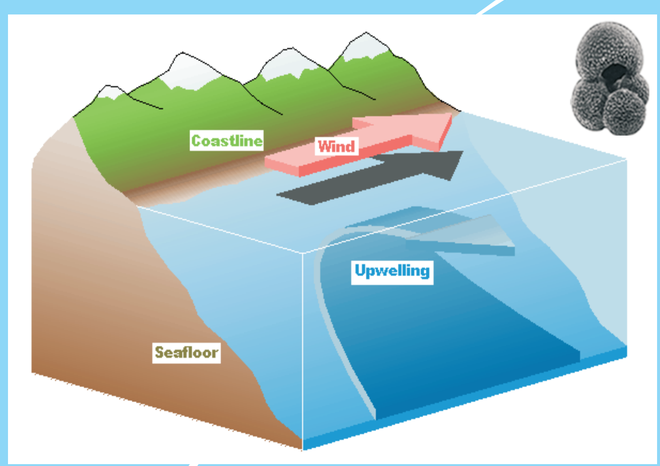
Abstract

The population study of planktic foraminifer *Globigerina bulloides* from the deep-sea sediments of the Arabian Sea is used to decipher the variations in the monsoon intensity. The strength of the Indian summer monsoon and the North Atlantic climate change have been found closely related during the last glacial period as well as the present interglacial. There is good resemblance between *G. bulloides* record of monsoon variability and the percentage of haematite stained grains from the North Atlantic through out the Holocene. The production rates of cosmogenic nuclides (^{14}C and ^{10}Be), reflecting changes in solar activity, are closely tied to the Bond cycles in the Holocene. Recent studies document that the summer monsoon intensity has been positively related to changes in solar insolation not only at orbital scale but also in centennial and decadal scales.

Comparison of a recently published record of Holocene sunspot activity with our high-resolution record of the Indian summer monsoon winds from rapidly accumulating and minimally bioturbated sediments of the northwest Arabian Sea reveals intervals of summer monsoon minima during the time of less sunspot numbers (decreased solar activity). Our results suggest that small changes in solar irradiance can bring significant changes in the tropical monsoon at multidecadal time scales.

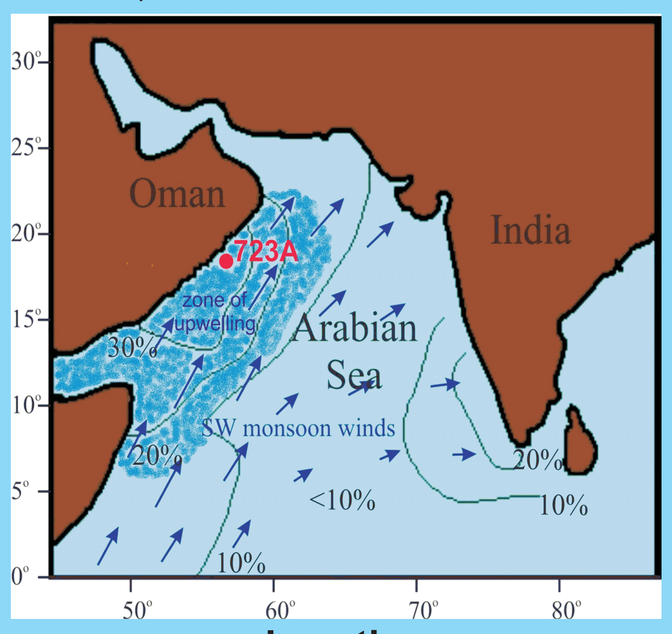
Coastal upwelling

The seasonal reversal of the wind direction and associated circulation pattern has a direct bearing on the biological productivity in the Arabian Sea. The SW monsoon winds, blowing parallel to the Oman coast, drive the surface layer of water almost 90° to the right due to Ekman transport. Removal of the surface layer causes thermocline water, which is usually cold and nutrient-rich, to upwell along the coast.
This coastal upwelling takes place along the Oman margin during the summer, causing sea surface cooling and promoting the bloom of distinct flora and fauna.



Distribution of *Globigerina bulloides*

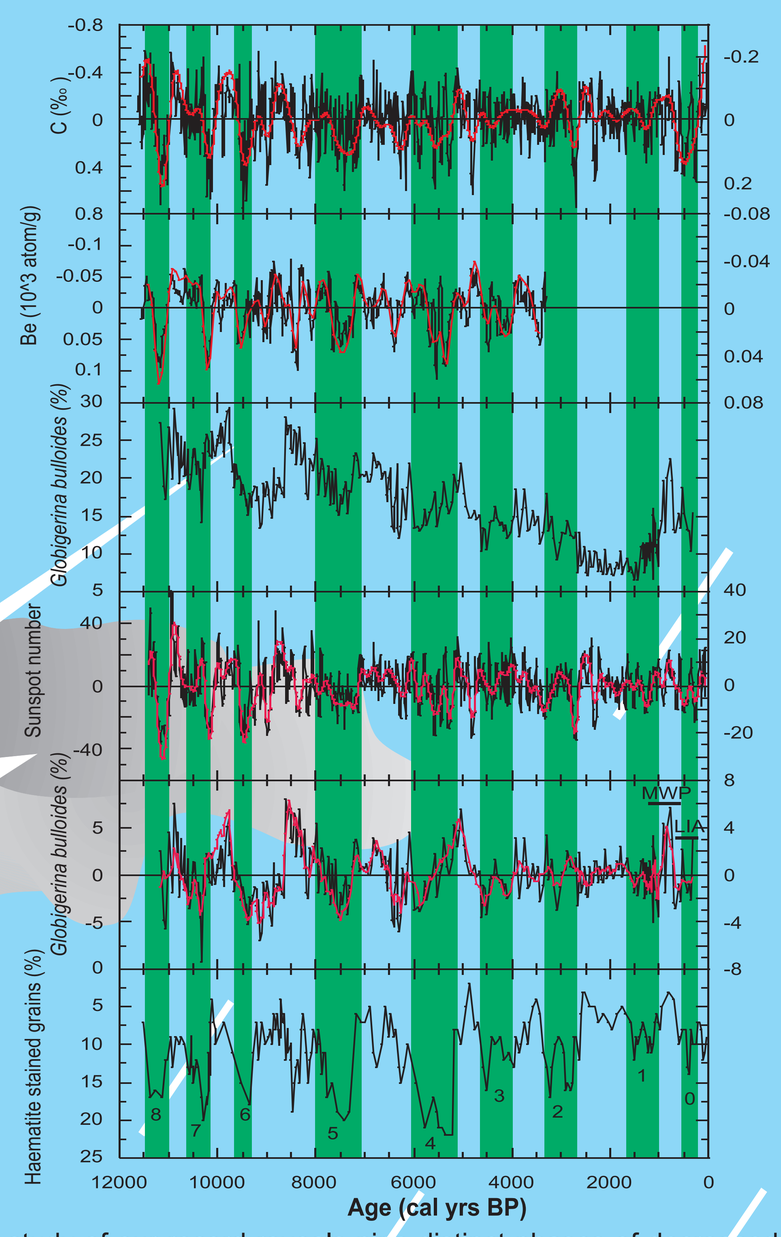
Planktic foraminifer, *Globigerina bulloides*, a sub polar species, has an unique association with the summer monsoon as it thrives in the cool upwelling waters in the tropics. Therefore the biological response to the monsoonal activity in the surface water column is preserved as increased abundance of *G. bulloides*.



Location

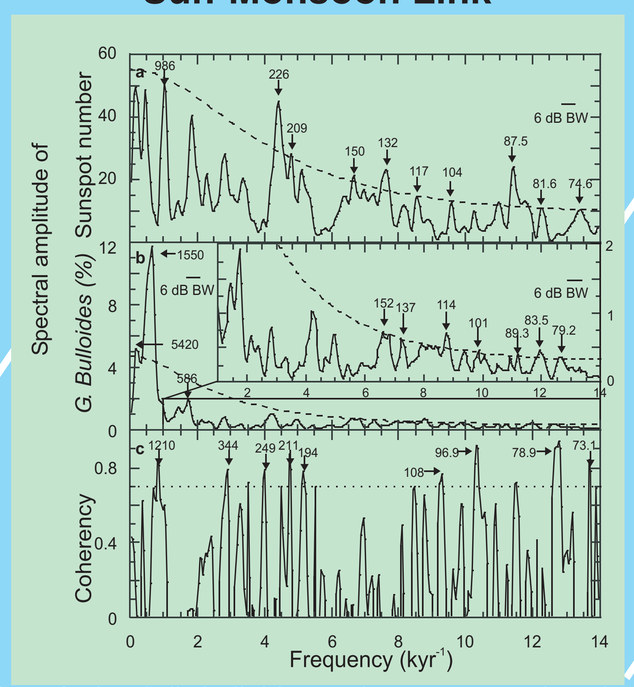
The study area, Ocean Drilling Program (ODP) Site 723, Hole A, Leg 117 is located off the Oman Margin, northwestern Arabian Sea at 18°03.079'N latitude and 57°36.561'E longitude at a water depth of 807.8 m. The hole lies in an upwelling zone caused by strong SW (summer) monsoon winds where the population abundance of *Globigerina bulloides* is maximum, and is thus ideal for studying the planktic foraminiferal record. The intense monsoon driven upwelling causes high surface biological production leading to high biogenic sediment record and intense Oxygen Minimum Zone (OMZ). The effect of bioturbation is either absent or minimal because of the intense OMZ.

Indian summer monsoon-North Atlantic climate relation



Close study of our record reveals nine distinct phases of decreased SW monsoon strength throughout Holocene to be closely aligned with abrupt ocean surfaces cooling in the North Atlantic (Bond et al., 2001)(green bars coinciding with the Bond events 0-8). The abrupt changes in the Asian SW monsoon has been documented to be linked to the cold spells of North Atlantic region (Gupta et al., 2003). The detrended and smoothened *G. bulloides* time series is compared with the average changes in the cosmogenic nuclides (^{14}C and ^{10}Be) production rates (Finkel and Nishiizumi, 1997; Stuiver et al., 1998; Yiou et al., 1997) and the change in sunspot numbers around the mean (Solanki et al., 2004).

Sun-Monsoon Link



Cross spectral analysis of *G. bulloides* and sunspot number time series shows matching peaks at 152, 137, 114, 101, 89, 83 and 79 years indicating multidecadal to centennial scale coherency of the sun-monsoon connection. Therefore it is evident that the intensity of the SW monsoon winds varies coherently with the sunspot numbers, which are a direct tracer of solar activity (Solanki et al., 2004).
The SW monsoon shifts (*G. bulloides* record) are also found to be associated to sub-orbital "1,500-year" cycle as the North Atlantic drift-ice events (Bond et al., 2001) and may be related to variations in solar irradiance (Denton and Karlén, 1973).Thus the response of the Indian summer monsoon and North Atlantic climate to the sun was direct and synchronous. It can be concluded that the solar variability principally drives changes in the atmospheric circulation pattern both in the tropics as well as higher northern latitudes.

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