IFM-GEOMAR

Leibniz-Institut für Meereswissenschaften
an der Universität Kiel

IFM-GEOMAR Report 2002-2004

From the Seafloor to the Atmosphere

- Marine Sciences at IFM-GEOMAR Kiel -

June 2005

Preface

For the first time, the Leibniz Institute of Marine Sciences (IFM-GEOMAR) presents a joint report of its research activities and developments in the years 2002-2004. In January 2004 the institute was founded through a merger of the former Institute for Marine Research (IfM) and the GEOMAR Research Center for Marine Geosciences. This report addresses friends and partners in science, politics and private enterprises. It gives an insight into the scientific achievements of IFM-GEOMAR and its predecessor institutes during the last three years.

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3.8 Dust Fertilization of the Tropical North Atlantic stimulates Nitrogen Fixation

Phytoplankton productivity is an important sink for atmospheric CO_2 and has been suggested to alter global CO_2 concentrations. Given that the nutrient availability exerts a strong control on the productivity of phytoplankton populations it is of great importance to understand which nutrients limit productivity. Alternate views exists: Biological oceanographers argue that supply of bound nitrogen (N) limits phytoplankton productivity and biomass, while geochemists assert that over geological timescales nitrogen fixation should provide the fixed N necessary for primary production and that availability of biologically utilizable phosphorus compounds (P) control primary productivity.

It has been shown that iron is a very important limiting nutrient for phytoplankton growth in the Pacific and southern ocean. There in situ iron fertilization of nutrient rich surface waters result in phytoplankton blooms. Iron has also been suggested as a potential nutrient limiting nitrogen fixation due to the iron rich nitrogen fixing enzyme nitrogenase. The oligotrophic tropical North Atlantic is considered a hot spot for nitrogen fixation. Satellite images regularly show spectacular dust clouds entering the tropical North Atlantic from the Sahara and Sahel zone that can provide iron and also P to the surface ocean (Fig. 1). This region is subjected to some of the highest mineral dust deposition rates in the world, and has high dissolved iron concentrations in surface waters relative to other oceanic basins. As such, the tropical North Atlantic is a region where the phytoplankton community is least likely to be iron limited. Therefore, surface waters have been assumed to be replete in iron with respect to nitrogen fixation.

During the *METEOR* 55 and 60 cruises (October - November 2002, and March April 2004 respectively) to the tropical North Atlantic we have attempted to determine the role of the nutrients N, P and Fe in controlling primary productivity and nitrogen fixation using a nutrient addition bioassay approach. Additions of Saharan dust were also made to investigate whether this aeolian input could provide limiting nutrients. Our results showed that at all sites phytoplankton biomass and primary production were limited by N (Fig. 2). After relief of N limitation, further stimulation was seen with the addition of P and then iron. The finding of N limitation of the phytoplankton community stresses the importance for nitrogen fixing organisms, diazotrophs, in this system. At all sites tested during *METEOR* 55 we detected nitrogen fixation, and the addition of P and Fe together stimulated nitrogen fixation (Fig. 2). Conversely, additions of inorganic N (added as NO_3^- and NH_4^+) inhibited diazotrophic activity. Saharan dust additions also resulted in enhanced primary productivity, bacterial production, and nitrogen fixation, though not at all stations tested, indicating that the dust supplies microbial populations with the nutrients that at times limit different processes.

Given the high atmospheric loading of iron to the eastern tropical North Atlantic we were surprised to find that iron addition stimulated diazotrophy. It is generally argued that iron concentrations in our study area are in excess of diazotroph iron requirements, but our findings suggest that total dissolved iron concentration is a poor index of bioavailability, perhaps due to temporal variation in the chemical speciation of dissolved iron. It is also possible that the level of iron required to saturate diazotroph growth has been underestimated. The important role of iron in our study region implies that the control of nitrogen fixation by

Figure 1: Dust storm over the subtropical and tropical North Atlantic from the African continent observed by SeaWiFS satellite images on February 26th, 2000.

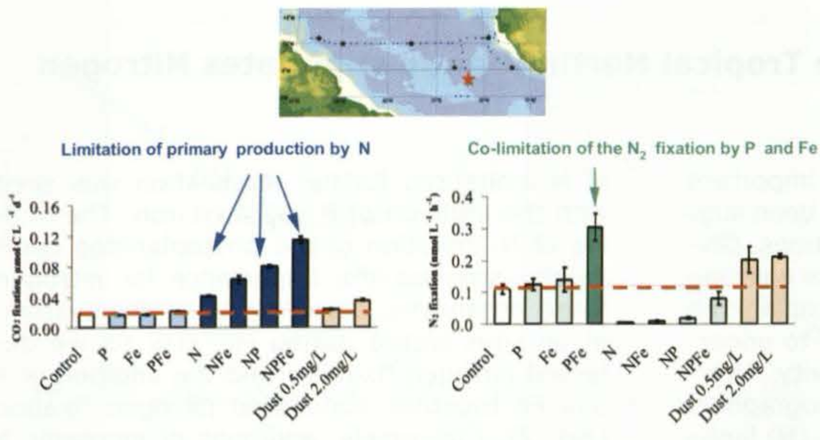

Figure 2: Effects of nutrient (N, P, Fe) additions on primary production (= CO_2 fixation) and nitrogen fixation (= N_2 fixation) in natural plankton communities of the tropical Atlantic. The map at the top shows the cruise track and the location of the bioassay experiments. Results shown are indicated by red star and red line indicates control response.

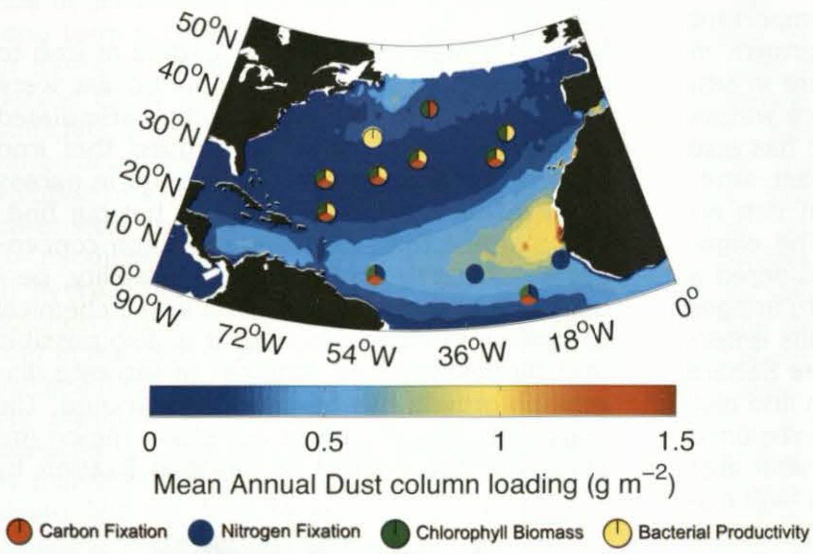

Figure 3: Mean annual dust column loading to the North Atlantic calculated using MODIS aerosol optical thickness data from April 200 - March 2004. Overlayed on the map are the sites of the nutrient enrichment bioassay experiments with colors indicating the presence of a stimulation of CO_2 fixation (red), N_2 fixation (blue), chlorophyll biomass (green), and bacterial productivity (yellow) by dust. Note: Sample analysis for N_2 fixation have been completed for sites south of 20°N.

iron should be even greater in other oceanic regions that receive less dust deposition.

Our results have important implications for understanding controls on marine microbial productivity and how it relates to CO_2 fixation in the North Atlantic. First, contrary to recent suggestions, our experiments demonstrate that the total primary productivity of the natural plankton community in the tropical/sub -tropical Atlantic is N-limited. Second, they demonstrate that nitrogen fixation is co-limited by iron and P in a region where mineral dust deposition is high and iron should be in excess. Further studies are required to determine whether this co-limitation is widespread. Finally, our results suggest that dust, when supplied at high levels locally, can relieve N limitation of primary production, iron and P co-limitation of diazotrophy, and N and P co-limitation of bacterial production.

The tropical North Atlantic is a region of high dust deposition. It is also considered one of the most important areas globally for nitrogen fixation. Dust deposition is highly episodic, and has varied widely on geological timescales. If dust deposition can to some extent relieve nutrient limitation of marine microbial communities as our results demonstrate (Fig. 3), the postulated link between changes in dust deposition as seen between glacial and interglacial periods and changes of elemental cycles in the ocean by plankton may be even stronger than initially suggested.

IFM-GEOMAR Contributions

Mills, M.M., Ridame, C., Davey, M., LaRoche, J., and Geider, R.J., 2004: Iron and phosphorus co-limit nitrogen fixation in the Eastern Tropical North Atlantic. *Nature*, **429**, 292-294.

LaRoche, J., and Breitbarth, E., 2005: The importance of Trichodesmium in the global nitrogen cycle. *Journal of Sea Research*, **53**, 67-91.

Matthew Mills and Julie LaRoche