Environmental controls on N₂ fixation by *Trichodesmium* in the tropical eastern North Atlantic

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A model of nitrogen fixation at TENATSO

The low surface nitrate concentration and high atmospheric iron input in the tropical eastern North Atlantic provide beneficial conditions for N₂ fixation. Different abundances of diazotrophs have been observed and an N₂-P-colimitation of N₂ fixation was reported in this ocean region. It is however unclear how different limiting factors control the temporal variability of N₂ fixation and what the role of Fe-limitation is in a region with high fluxes of dust deposition.

To study the environmental controls on N₂ fixation, a one-dimensional ecosystem model is coupled with a physical model (General Ocean Turbulence Model) for the Tropical Eastern North Atlantic Time-series Station (TENATSO), north of the Cape Verde Islands.

**Components of the ecosystem model**

![Diagram of ecosystem model](image)

A NPZD-type ecosystem model is extended by including:
- one diazotrophic (Tri) and one non-diazotrophic (Phy) phytoplankton;
- four nutrient pools: dissolved inorganic nitrogen (DIN), biodegradable iron (FeL), dissolved inorganic (DIP) and organic phosphorus (DOP).

The model describes diazotrophy according to the physiology of *Trichodesmium*, taking into account a growth dependence on light, temperature, iron and phosphorus. Tri takes up DIN and meets its N demand additionally by N₂ fixation. Both Phy and Tri can take up DIP, whereas DOP is only accessible to Tri, based on the ability of *Trichodesmium* to exploit organic P (Dyhrman et al., 2006). All ecosystem variables have flexible N:P:Fe quotas which regulate both growth and nutrient uptake. Fe speciation and removal processes are described explicitly, based on Ye et al. (2009), for a better analysis of the impact of dust deposition on biology.

**Modelled temporal and vertical distribution of *Trichodesmium***

![Graph of modelled distribution of *Trichodesmium*](image)

The modelled *Trichodesmium* grows mainly in the upper 40 m and displays a strong seasonality with negligibly low concentrations in spring and summer and high concentrations in autumn and early winter. The highest concentrations (0.02 - 0.35 mg Chl m⁻³) occur between September and November.

One year data (from Dec 2007 to Nov 2008) of cyanobacterial Chl a concentration was retrieved at ± 2° latitude and longitude around TENATSO, using the PhytoDOAS method (Bracher et al., 2009) combined with HPLC measurements. A similar seasonality of surface Chl a is demonstrated in both satellite (red) and model data (green).

**Modelled growth limitation factors**

The seasonality of Tri is predominantly determined by temperature. Within the upper 20 m water layer, Tri growth is co-limited by Fe (yellow) and P (red), with more Fe-controlled at the beginning of its bloom and increasingly P-controlled during its bloom. Below the upper water layer, Tri growth is mainly limited by light (green). No significant growth (blue) occurs further below.

**Competitive as well as mutually beneficial interactions**

The modelled diazotrophs and non-diazotrophic phytoplankton bloom temporally differently (Fig. A).

**Impact of dust deposition and diazotrophy on prim. prod.**

Dust deposition provides a high amount of bioavailable Fe for all phytoplankton incl. *Trichodesmium* and enhances primary production significantly (black & green). A simple relationship between dust fluxes and the magnitude of N₂ fixation is however not found.

N₂ fixation, providing new fixed N for further primary production, is only seasonally important (up to 25%) (black & red), because we only considered *Trichodesmium* as diazotroph in the model and its high abundance occurs in autumn. Introducing other diazotrophs into the model may change this picture.

**Outlook**

We will further compare modelled interannual variability of Chl a with satellite-derived data.

The model description of N₂ fixation will be implemented in one 3D biogeochemical model, to study environmental controls on the distribution and magnitude of N₂ fixation in the Atlantic and in the global scale.

**References**


