Nitrogen cycling in the Benguela Upwelling System (SW-Africa)

An isotopic perspective

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Introduction

Upwelling of nutrient-rich deep water stimulates enormous primary production which induces nutrient draw-down in coastal surface water due to nitrate and ammonium assimlation (Fig. 1). Phosphate release from sediments and denitrification in anoxic zones generate a nitrogen deficit: heterotrophic denitrification and anaerobic ammonium oxidation (anammox) produce N_2 that escapes from the ocean to the atmosphere (Fig. 1). Upwelling transfers the nitrogen deficit to the adjacent surface ocean but nitrate/phosphate ratios are restored back to 16 as upwelled water is advected offshore. This requires a source of dissolved inorganic nitrogen on the way.

In order to identify N-cycling processes and N-sources we measured nutrient concentrations and stable N and O isotopes of nitrate ($\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$) and $\delta^{15}N$ of suspended matter ($\delta^{15}N_{PN}$) on the 23°S transect offshore Namibia normal to the coast (Fig. 2).

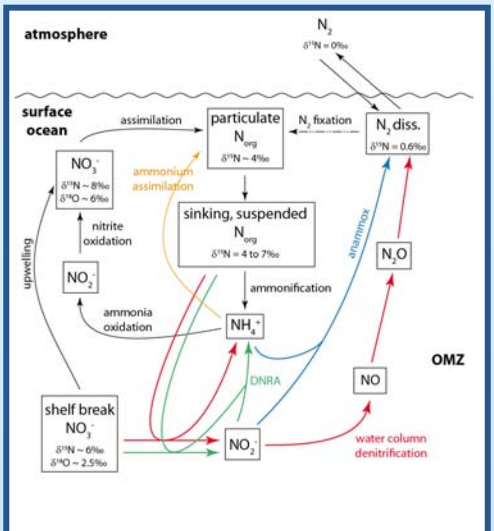

Fig. 1: Nitrogen cycle on the Namibian Shelf with isotope ratios typically found within the reservoirs

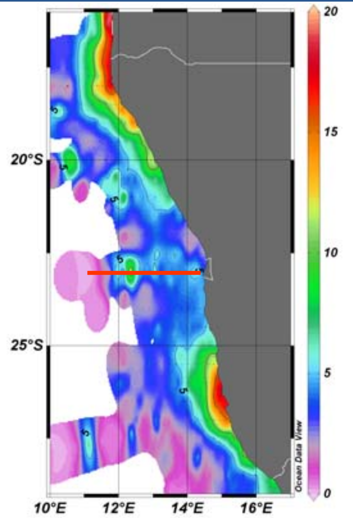

Fig. 2: Nitrate concentrations in surface water. Red line indicates 23 °S transect where water column sampling was carried out in May/June 2008.

Results

- O_2 concentrations on the inner shelf are below the threshold for anammox and denitrification (Fig. 3).
- $\delta^{15}N_{NO3}$ ratios increase as nitrate is consumed by denitrification/anammox in bottom water and by nitrate assimilation in surface water (Fig.4).
- Δ(15,18) shows the decoupling of $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ relative to the source nitrate and negative values identify nitrate added from nitrification (mainly on the shelf), and N_2 fixation that occurs in the surface layer of the hemipelagic ocean (Fig. 5).
- High suspended matter content (SPM, Fig. 6) is found:

a) within the bottom nepheloid layer where particles are kept in suspension due to high current energy

b) in coastal surface water with high primary production rates

c) in surface water above the shelf break indicating high productivity due to shelf break upwelling

d) at the most offshore station due to N_2 fixation.

- $\delta^{15}N_{PN}$ ratios do not correlate with $\delta^{15}N_{NO3}$ ratios indicating high remineralisation rates on the inner shelf and N_2 fixation at the most offshore station.
- N* is an expression for the nitrate deficit that is high in coastal waters as a result of denitrification and anammox, phosphate release and further assimilation under Redfield conditions

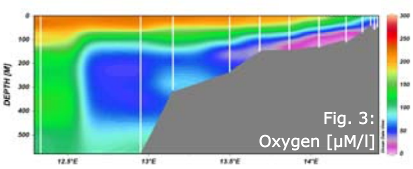

Fig. 3: Oxygen [μM/l]

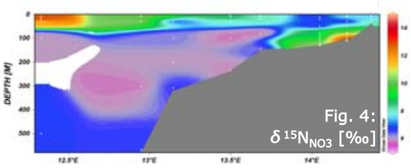

Fig. 4: $\delta^{15}N_{NO3}$ [‰]

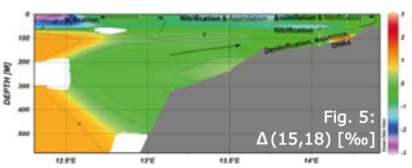

Fig. 5: Δ(15,18) [‰]

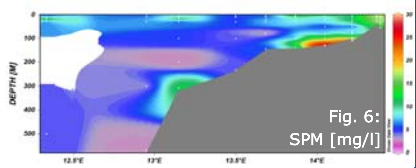

Fig. 6: SPM [mg/l]

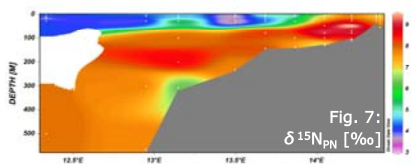

Fig. 7: $\delta^{15}N_{PN}$ [‰]

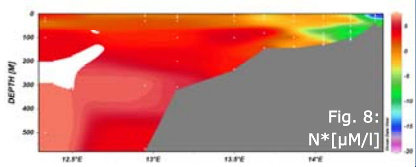

Fig. 8: N*[μM/l]

Conclusions

- shelf break upwelling (episodically) fuels productivity above the shelf break.
- N:P ratios are restored back to 16 by nitrification, shelf break upwelling and N_2 fixation.
- although the Benguela Upwelling System is nitrate-driven N_2 fixation can occur under oceanic conditions possibly owing to higher surface water temperatures.

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