Project GENUS: Organic matter cycling in the Benguela Upwelling System

Insights from amino acid biogeochemistry

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GENUS Website

Introduction and Overview

The Benguela Upwelling System off southwest Africa is one of the four major eastern boundary upwelling systems and one of the most biologically productive areas in the global ocean[1]. It is also a very particle-rich environment over the shelf. Subproject 3 of the international research project GENUS (Geochemistry and Ecology of the Namibian Upwelling System) aims to identify sources, transportation patterns and organic matter decomposition of total suspended matter (TSM) under various physical and chemical conditions (Kunene River: 17.25°S, Walvis Bay: 23°S, Orange River: 28.4°S – see Fig. 1). TSM is sourced by fresh biological material in the shallow euphotic zone, by advection of suspended matter with upwelling intermediate water masses[2] (SACW and ESACW – Fig.1b) across the shelf break and by sediment resuspension induced by internal waves (energy dissipation) from mud deposits that are partly located in the oxygen minimum zone off central Namibia (Fig. 1c). Our data are based on ship expeditions with RVs Meteor M 76/2 (May 2008), Maria S. Merian MSM 17-3 (Feb. 2011) and M 103/1 (Jan. 2014).

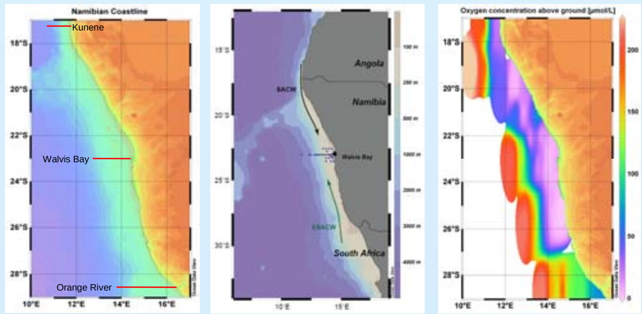
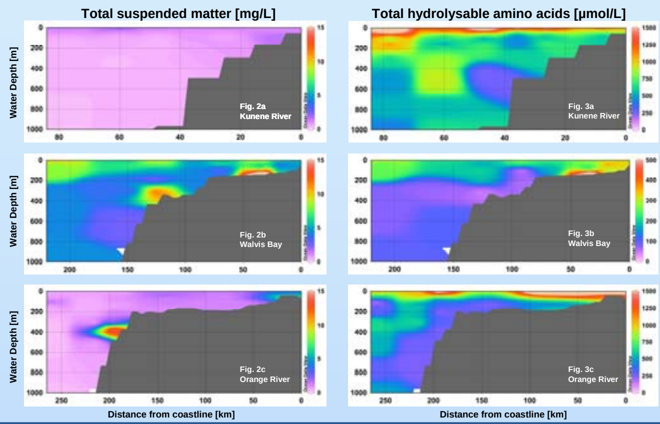


Fig. 1a: Transects across the Namibian shelf. **Fig. 1b**: South Atlantic water masses SACW and ESACW meet and mix in the Walvis Bay region. **Fig. 1c**: Extension of the oxygen minimum zone along the Namibian shelf in January 2014.

Total Suspended Matter (TSM)

The TSM concentration of about 0.8 mg/L in the Kunene area (Fig. 2a) is very homogeneously distributed across the entire shelf which is very steep at this site (please note the different distance scaling). In comparison to the northern part, TSM is much higher (average 6.8 mg/L) along the broad shelf at the Walvis Bay transect (Fig. 2b) with pronounced elevations on the inner shelf and shelf break at 400 m water depth. In the south (Fig. 2c) TSM concentrations are comparable to the Kunene transect with two distinct exceptions very close to the coast line and at the shelf break. Amino acid concentrations (Figs. 3a-c) reveal that fresh and organic rich matter mainly derives from primary production in the photic zone in the Kunene and Orange River areas, respectively, where highest concentrations between 1000 and 2000 mmol/g sediment occur. Our data also show that the elevated TSM concentrations at the shelf break of the Orange River transect do not correspond with higher amino acids concentrations. In the Walvis Bay region, however, amino acid concentrations are significantly decreased (different scaling!) with highest concentrations found slightly above the ground on the inner shelf. This could be an indication for resuspension of labile organic matter in the core of the oxygen minimum zone.



Insights from Amino Acid Biogeochemistry at 23°S

The Degradation Index (DI)[3] indicates the freshness of organic matter with higher values pointing to more fresh organic matter. The DI is commonly used for organic matter interpretation of sedimentary material. In our study we see that relatively fresh organic matter with DI values close to +1 is deposited in the core of the oxygen minimum zone off Walvis Bay (Fig. 4). The DI quickly drops to values close to 0 outside from suboxic conditions. Although resuspension occurs at the inner shelf, DI values do not indicate a direct connection between sedimentary and suspended material (Fig. 5a). However, the DI is questionable for TSM interpretation[4]. Nonetheless, if TSM was mainly sourced by resuspended material then the Reactivity Index (RI)[5] should indicate a link between these two pools. This is not the case at the Walvis Bay line (Fig. 5b) as lower values (=more degraded organic matter) prevail at the shelf edge and on the inner shelf itself. Moreover, diatomaceous sediment deposits are always significantly enriched in Glycine (Gly)[6] because Gly is needed to build opaline frustules. Again, although Gly is enriched in the sediments in the oxygen minimum zone (data not shown), there is no indication for increased Gly concentrations in the lower water column on the shelf (Fig. 5c).

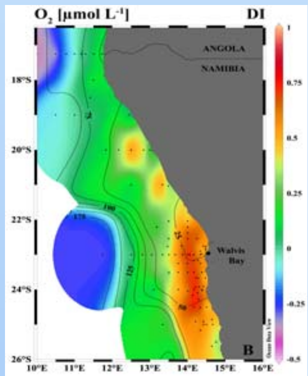


Fig. 4: Organic matter reactivity in surface sediments (0-1 cm) derived by DI values in comparison to oxygen concentrations in the bottom water[7].

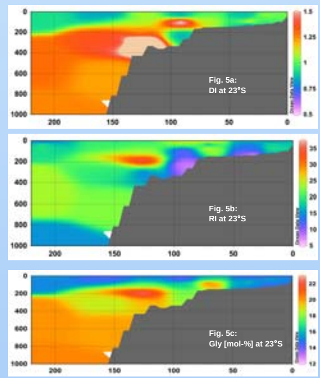


Fig. 5: Amino acid indices Degradation Index (DI), Reactivity Index (RI) and Glycine (Gly) in Total Suspended Matter at 23°S (Walvis Bay).

Conclusions

Organic matter resuspension from surface sediments is a common feature of the Benguela Upwelling System. However, surface sediments are by no means homogeneous in terms of cycling and composition. In our study, organic matter reactivity ("freshness") derived from DI values of surface sediments seems to be dependent on oxygen concentration in the water column and/or water depth (Fig. 6). Amino acid results from Nagel et al.[7] also clearly indicate that the pools of particulate matter can be subdivided according to their origin and decomposition history (Fig. 7). The principal component analysis at 23°S illustrates distinctly different amino acids compositions and limited exchange between these particle pools. The particulate organic matter preservation and reactivity thus are controlled by a complex interplay of shelf bathymetry, sediment composition, current regime and oxygen dynamics – and in turn determine the rates of remineralisation and organic matter degradation.

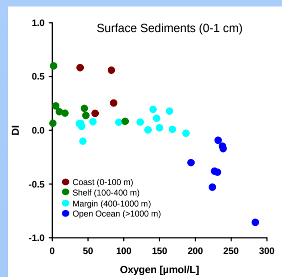


Fig. 6: DI values in surface sediments as a function of oxygen concentration and water depth.

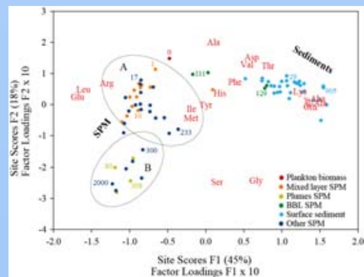


Fig. 7: Particle pool classification derived by a principal component analysis based on amino acid compositions (Nagel et al.)[7].

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