Carbon pumps in the Benguela upwelling system

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Introduction

- The biological carbon pump influences the flux of carbon dioxide (CO_2) between the ocean and the atmosphere by the photosynthesis of organic carbon (C_{org}) and the precipitation of calcium carbonate (C_{CaCO3}). Since these processes have counteracting effects, the CO_2 uptake efficiency of the biological pump depends on the relative importance of these two processes to each other.
- The Benguela upwelling system (BUS) off the southwest African coast is one of the ocean's most productive regions. Contrary to the adjacent South Atlantic where the export of organic carbon is dominated by calcifying plankton[1], most of the northern BUS (NBUS) shelf is almost free of carbonate deposits[2] (Fig. 1) and only little is known about particle fluxes on the NBUS shelf.
- To assess whether the $CaCO_3$-depleted surface sediments on the shelf are caused by low carbonate production in the surface and/or the dissolution of carbonates in the water column we investigated the spatial and temporal variability of the carbonate system (A_T, DIC, fCO_2, Ω_{Cal}), the distribution of coccolithophorids, and the annual particle flux on the shelf (HydroBios sediment trap) in 2010.

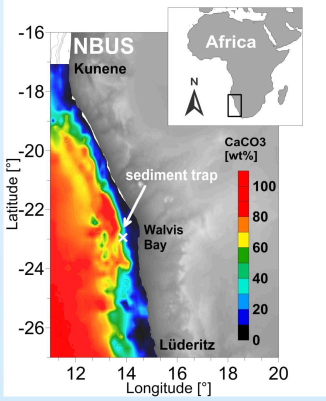

Fig. 1: Map of NBUS showing the $CaCO_3$ content of surface sediment and the location of the sediment trap (cross).

Results

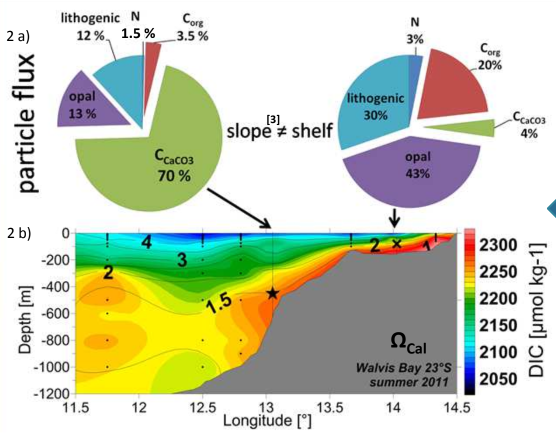

Fig. 2: a) Particle fluxes measured on the continental margin[3] and on the shelf (black star and cross in Fig. 2 b); b) vertical distribution of DIC (color coded) and Ω_{Cal} (black line) measured off Walvis Bay.

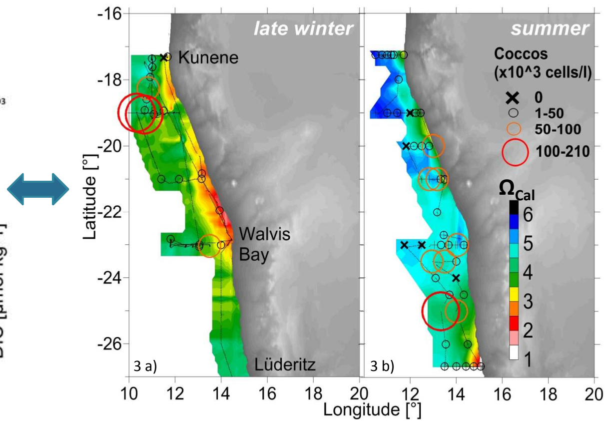

Fig. 3.: Spatial distribution of Ω_{Cal} (color coded) and abundance of coccolithophorids (circles) observed during a) late austral winter and b) austral summer.

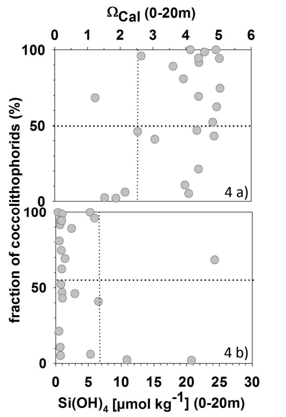

Fig. 4: Relative abundance of coccolithophorids and diatoms vs. a) Ω_{Cal} and b) $Si(OH)_4$ in 0-20 m water depth.

Water column

- The C_{org} flux on the shelf is dominated by diatoms in contrast to previous studies conducted along the continental margin where the C_{org} flux is dominated by calcifying plankton[3] (Fig. 2 a).
- The decomposition of diatomaceous organic matter controls the distribution of O_2 and DIC in the water column and lowers Ω_{Cal} in the ascending sub-thermocline waters to minimum values of Ω_{Cal} = 1.2 (Fig. 2 b).

Surface

- The Ω_{Cal} ranges between 1.5 – 5 in coastal surface water with overall lower values occurring during the upwelling season in austral winter (Fig. 3).
- Coccolithophorids dominate over diatoms at Ω_{Cal} > 2.5 associated with silicate concentrations $Si(OH)_4$ < 7 µmol kg^{-1} (Fig. 4).

- The results suggest that the low Ω_{Cal} and high $Si(OH)_4$ concentrations in coastal surface water favor diatoms rather than coccolithophorids which is reflected in low C_{CaCO3} fluxes on the shelf and explains why most of the shelf area is almost free of carbonate deposits.

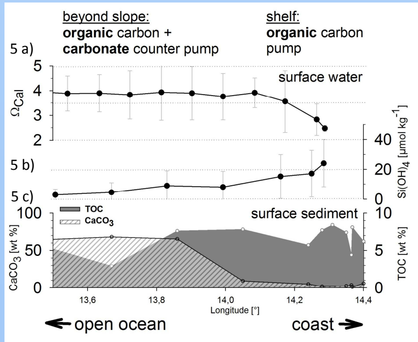

Fig. 5: Mean a) Ω_{Cal}, b) $Si(OH)_4$ in the surface (0-10 m) and c) TOC and $CaCO_3$ content of the surface sediment[2] off Walvis Bay.

Conclusions

- **The decomposition of organic matter which originates from high, diatom dominated organic carbon fluxes sustains low Ω_{Cal} in ascending sub-thermocline waters.**
- **The low Ω_{Cal} in upwelled coastal surface water reduces the carbonate production relative to the high formation and export of organic carbon on the Namibian shelf.**
- **The low carbonate formation indicates an efficient upwelling-driven CO_2 uptake by the coastal biological pump.**

References:
[1] Romero et al. (2002). Seasonal productivity dynamics in the pelagic central Benguela System inferred from the flux of carbonate and silicate organisms, Journal of Marine Systems, 37, 259-278; [2] Inthorn et al. (2006). Compilation of organic carbon distribution and sedimentology in the surface sediments on the continental margin offshore southwestern Africa. DOI: 10.1130/G22153.1, 10.1594/PANGAEA.351146; [3] Giraudeau et al. (2000). A high-resolution time-series analyses of particle fluxes in the Northern Benguela coastal upwelling system: carbonate record of changes in biogenic production and particle transfer processes. Deep-Sea Research II 47, 1999-2028.

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