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Sonderforschungsbereich 754

Climate – Biogeochemistry Interactions in the Tropical Ocean

SFB 754

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Publications

Thomsen, S., J. Karstensen, R. Kiko, G. Krahmann, M. Dengler and A. Engel (2019) Remote and local drivers of oxygen and nitrate variability in the shallow oxygen minimum zone off Mauritania in June 2014. Biogeosciences, 16, 979-998, doi: 10.5194/bg-16-979-2019

Upwelling systems play a key role in the global carbon and nitrogen cycles and are relevant due to their high productivity and fish resources. To understand their high spatial and temporal variability, novel measurement techniques have to be combined in an interdisciplinary manner. High-resolution glider- and ship-based observations were used to investigate the drivers of oxygen and nitrate variability off Mauritania in June 2014. High-oxygen and low-nitrate anomalies were related to water mass variability and linked to ocean transport. Low-oxygen and high-nitrate patches co-occurred with enhanced turbidity signals close to the seabed, suggesting locally high microbial respiration rates of resuspended organic matter near the sea floor. This interpretation is supported by high particle abundance and enhanced particle-based respiration rate estimates close to the seabed. Dissolved organic carbon and amino acids measurements suggest the formation of dissolved organic carbon due to particle dissolution near the seabed fueling additional microbial respiration. During June an increase in the oxygen concentration on the shelf break of about 15 µmol kg^{-1} was observed. These changes go along with meridional circulation changes but cannot be explained by typical water mass property changes. Our interdisciplinary observations highlight the complex interplay of remote and local physical–biogeochemical drivers of oxygen and nitrate variability off Mauritania.

Ji, Q., M. A. Altabet, H. W. Bange, M. I. Graco, X. Ma, D. L. Arévalo-Martínez and D. S. Grundle (2019) Investigating the effect of El Niño on nitrous oxide distribution in the eastern tropical South Pacific. Biogeosciences, 16, 2079-2093, doi: 10.5194/bg-16-2079-2019

A strong El Niño event occurred in the Peruvian coastal region in 2015–2016, during which higher sea surface temperatures co-occurred with significantly lower sea-to-air fluxes of nitrous oxide, an important greenhouse gas and ozone depletion agent. Stratified water column during El Niño retained a larger amount of nitrous oxide that was produced via multiple microbial pathways; and intense nitrous oxide effluxes could occur when normal upwelling is resumed after El Niño.

Glock, N., A.-S. Roy, D. Romero, T. Wein, J. Weissenbach, N. P. Revsbech, S. Høgslund, D. Clemens, S. Sommer and T. Dagan (2019) Metabolic preference of nitrate over oxygen as an electron acceptor in foraminifera from the Peruvian oxygen minimum zone. PNAS February 19, 116 (8), 2860-2865, doi: 10.1073/pnas.1813887116

Benthic foraminifera populate a diverse range of marine habitats. Their ability to use alternative electron acceptors—nitrate (NO_3−) or oxygen (O_2)—makes them important mediators of benthic nitrogen cycling. Nevertheless, the metabolic scaling of the two alternative respiration pathways and the environmental determinants of foraminiferal denitrification rates are yet unknown. Denitrification and O_2 respiration rates were measured for 10 benthic foraminifer species sampled in the Peruvian oxygen minimum zone (OMZ). Denitrification and O_2 respiration rates significantly scale sublinearly with the cell volume. The scaling is lower for O_2 respiration than for denitrification, indicating that NO_3− metabolism during denitrification is more efficient than O_2 metabolism during aerobic respiration in foraminifera from the Peruvian OMZ. The negative correlation of the O_2 respiration rate with the surface/volume ratio is steeper than for the denitrification rate. This is likely explained by the presence of an intracellular NO_3− storage in denitrifying foraminifera. Based on these findings, a mathematical formulation of foraminiferal cell volume as a predictor of respiration and denitrification rates was developed, which can further constrain foraminiferal biogeochemical cycling in biogeochemical models. The results of this study show that NO_3− is the preferred electron acceptor in foraminifera from the OMZ, where the foraminiferal contribution to denitrification is governed by the ratio between NO_3− and O_2.

Burmeister, K., J. F. Lübbecke, P. Brandt and O. Duteil (2019) Interannual Variability of the Atlantic North Equatorial Undercurrent and Its Impact on Oxygen. Journal of Geophysical Research: Oceans, doi: 10.1029/2018JC014760

The North Equatorial Undercurrent (NEUC) has been suggested to act as an important oxygen supply route toward the oxygen minimum zone in the eastern tropical North Atlantic. Observational estimates of the mean NEUC strength are uncertain due to the presence of elevated mesoscale activities, and models have difficulties in simulating a realistic NEUC. The interannual variability of the NEUC and its impact onto oxygen is investigated based on the output of a high-resolution Ocean General Circulation Model (OGCM). The results are contrasted with an unique data set of 21 ship sections along 23°W and a conceptual model. In the OGCM the interannual variability of the NEUC is related to the Atlantic meridional mode with a stronger and more northward NEUC during negative Atlantic meridional mode phases. Discrepancies between the OGCM and observations suggest a different role of the NEUC in setting the regional oxygen distribution. In the OGCM, a stronger NEUC is associated with a weaker oxygen supply toward the east which is attributed to a too strong simulated recirculation between the NEUC and the northern branch of the South Equatorial Current (nSEC). Idealized experiments with the conceptual model support the idea that the impact of NEUC variability on oxygen depends on the source water pathway. A strengthening of the NEUC supplied out of the western boundary acts to increase oxygen levels within the NEUC. A strengthening of the recirculations between NEUC and nSEC results in a reduction of oxygen levels within the NEUC.

Cisternas-Novoa, C., F. A. C. Le Moigne and A. Engel (2019) Composition and vertical flux of particulate organic matter to the oxygen minimum zone of the central Baltic Sea: impact of a sporadic North Sea inflow. Biogeosciences, 16, 927-947, doi: 10.5194/bg-16-927-2019

Particle sinking is a major form of carbon transport to below the euphotic zone via the biological carbon pump (BCP). O_2 depletion may improve the efficiency of the BCP but the mechanisms are not well understood. Here, we investigate the composition and vertical fluxes of POM in two deep basins of the Baltic Sea (GB: Gotland Basin and LD: Landsort Deep). The two basins showed different O_2 regimes resulting from the intrusion of oxygen-rich water. In June 2015, we deployed surface-tethered drifting sediment traps in oxic surface waters, within the oxygen minimum zone (OMZ) and at recently oxygenated waters by the North Sea inflow. The composition and vertical fluxes of sinking particles were different in GB and L with respect to fluxes of particulate organic carbon, particulate nitrogen and Coomassie stainable particles. Fluxes of particulate organic phosphorus, biogenic silicate, chlorophyll a and transparent exopolymeric particles peaked in the OMZ core coinciding with the presence of manganese oxide-like (MnOx-like) particles aggregated with organic matter. Our results suggest that aggregates with MnOx-like particles formed after the inflow of oxygen-rich water and the formation of those MnOx–OM-rich particles may alter the composition and vertical flux of POM, potentially contributing to a higher transfer efficiency of POC in GB. This idea is consistent with observations of fresher and less degraded organic matter in deep waters of GB than LD.

Scholz, F., S. Beil, S. Flögel, M. F. Lehmann, A. Holbourn, K. Wallmann and W. Kuhnt (2019) Oxygen minimum zone-type biogeochemical cycling in the Cenomanian-Turonian Proto-North Atlantic across Oceanic Anoxic Event 2. Earth and Planetary Science Letters 517, 50-60, doi: 10.1016/j.epsl.2019.04.008

Oceanic Anoxic Events (OAEs) in Earth's history are regarded as analogues for current and future ocean deoxygenation, potentially providing information on its pacing and internal dynamics. Here, proxy records for iron (Fe), sulfur and nitrogen cycling in the Tarfaya upwelling system in the Cretaceous Proto-North Atlantic before, during and after OAE2 (~93 Ma) are reported. A novel quantitative approach to sedimentary Fe speciation was applied, which takes into account the influence of terrigenous weathering and sedimentation as well as authigenic Fe (non-terrigenous, precipitated onsite) rain rates on Fe-based paleo-redox proxies. Generally elevated ratios of reactive Fe (i.e., bound to oxide, carbonate and sulfide minerals) to total Fe (Fe_{HR}/Fe_T) throughout the 5 million year record are attributed to transport-limited chemical weathering under greenhouse climate conditions. Trace metal and nitrogen isotope systematics indicate a step-wise transition from oxic to nitrogenous to euxinic conditions over several million years prior to OAE2. Taking into consideration the low terrigenous sedimentation rates in the Tarfaya Basin, it is demonstrated that highly elevated Fe_{HR}/Fe_T from the mid-Cenomanian through OAE2 were generated with a relatively small flux of additional authigenic Fe. Evaluation of mass accumulation rates of reactive Fe in conjunction with the extent of pyritization of reactive Fe reveals that authigenic Fe and sulfide precipitation rates in the Tarfaya Basin were similar to those in modern upwelling systems. Because of a smaller seawater nitrate inventory, however, chemolithoautotrophic sulfide oxidation with nitrate was less efficient in preventing hydrogen sulfide release into the water column.

Loginova, A. N., S. Thomsen, M. Dengler, J. Lüdke and A. Engel (2019) Diapycnal dissolved organic matter supply into the upper Peruvian oxycline. Biogeosciences, 16, 2033-2047, doi: 10.5194/bg-16-2033-2019

This study reports the first estimates of diapycnal fluxes and supply of O_2, dissolved organic carbon (DOC), dissolved organic nitrogen, dissolved hydrolysable amino acids (DHAA) and dissolved combined carbohydrates (DCCHO) for the ETSP off Peru. Diapycnal flux and supply estimates were obtained by combining measured vertical diffusivities and solute concentration gradients. They were analysed together with the molecular composition of DCCHO and DHAA to infer the transport of labile DOM into the upper OMZ and the potential role of DOM utilization for the attenuation of the diapycnal O_2 flux that ventilates the OMZ. The observed diapycnal O_2 flux (50 mmol O_2 m^{-2} d^{-1} at maximum) was limited to the upper 80 m of the water column; the O_2 supply of ~1 µmol kg^{-1} d^{-1} was comparable to previously published O_2 consumption rates for the North and South Pacific OMZs. The diapycnal DOM flux (31 mmol C m^{-2} d^{-1} at maximum) was limited to ~30 m water depth, suggesting that the labile DOM is extensively consumed within the upper part of the shallow oxycline off Peru. The analyses of DCCHO and DHAA composition support this finding, suggesting that DOM undergoes comprehensive remineralization within the upper part of the oxycline, as the DOM within the core of the OMZ was found to be largely altered. Estimated by a simple equation for carbon combustion, aerobic respiration of DCCHO and DHAA, supplied by diapycnal mixing (0.46 µmol kg^{-1} d^{-1} at maximum), could account for up to 38 % of the diapycnal O_2 supply in the upper oxycline, which suggests that DOM utilization plays a significant role for shaping the upper oxycline in the ETSP.

Conferences

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