NEWSLETTER 2018 | 02

Sonderforschungsbereich 754

Climate – Biogeochemistry Interactions in the Tropical Ocean

SFB 754

Ocean Deoxygenation Conference 2018

Thanks everyone for a very successful conference. With all your contributions and enthusiasm we together created an important momentum to carry science and collaboration forward! The **Kiel Declaration on Ocean Deoxygenation** has been a major conclusion of the conference that we will further employ to stress the alarming implications of ocean deoxygenation for marine and climate protection (you can find the Kiel Declaration here: **https://www.ocean-oxygen.org/de/declaration**).

Publications

Schlosser, C., P. Streu, M. Frank, G. Lavik, P. L. Croot, M. Dengler. E. P. Achterberg (2018) H_2S events in the Peruvian oxygen minimum zone facilitate enhanced dissolved Fe concentrations. Scientific Reports 2018; 8: 12642, doi: 10.1038/s41598-018-30580-w

Dissolved iron (DFe) concentrations in oxygen minimum zones (OMZs) of Eastern Boundary Upwelling Systems are enhanced as a result of high supply rates from anoxic sediments. However, pronounced variations in DFe concentrations in anoxic coastal waters of the Peruvian OMZ indicate that there are factors in addition to dissolved oxygen concentrations (O_2) that control Fe cycling. This study demonstrates that sediment-derived reduced Fe (Fe(II)) forms the main DFe fraction in the anoxic/euxinic water column off Peru, which is responsible for DFe accumulations of up to 200 nmol L^{-1}. Lowest DFe values were observed in anoxic shelf waters in the presence of nitrate and nitrite. This reflects oxidation of sediment-sourced Fe(II) associated with nitrate/nitrite reduction and subsequent removal as particulate Fe(III) oxyhydroxides. Unexpectedly, the highest DFe levels were observed in waters with elevated concentrations of hydrogen sulfide (up to 4 µmol L^{-1}) and correspondingly depleted nitrate/nitrite concentrations (<0.18 µmol L^{-1}). Under these conditions, Fe removal was reduced through stabilization of Fe(II) as aqueous iron sulfide (FeS_{aqu}) which comprises complexes (e.g., $FeSH^+$) and clusters (e.g., $Fe_2S_2|4H_2O$). Sulfidic events on the Peruvian shelf consequently enhance Fe availability, and may increase in frequency in future due to projected expansion and intensification of OMZs.

Scholz, F. (2018) Identifying oxygen minimum zone-type biogeochemical cycling in Earth history using inorganic geochemical proxies. Earth-Science Reviews 184, 29-45, doi: 10.1016/j.earscirev.2018.08.002

Because of anthropogenic global warming, the world ocean is currently losing oxygen. This trend called ocean deoxygenation is particularly pronounced in low-latitude upwelling-related oxygen minimum zones (OMZs). In these areas, the temperature-related oxygen drawdown is additionally modulated by biogeochemical feedback mechanisms between sedimentary iron (Fe) and phosphorus release, water column nitrogen cycling and primary productivity. Similar feedbacks were likely active during past periods of global warming and ocean deoxygenation. However, their integrated role in amplifying or mitigating climate change-driven ocean anoxia has not been evaluated in a systematic fashion. In this review, the current state of knowledge on biogeochemical processes in the water column and sediments of OMZs is summarized. Nitrate-reducing (i.e., nitrogenous) to weakly sulfidic conditions in the water column and Fe-reducing (i.e., ferruginous) to sulfidic conditions in the surface sediment are identified as key-features of anoxic OMZs in the modern ocean. A toolbox of paleo-redox proxies is proposed that can be used to identify OMZ-type biogeochemical cycling in the geological record. By using a generalized model of sedimentary Fe release and trapping, it is demonstrated that the extent of Fe mobilization and transport in modern OMZs is comparable to that inferred for the euxinic Black Sea and ferruginous water columns in Earth history. Based on this result, it is suggested that many sedimentary Fe enrichments in the geological record are broadly consistent with OMZ-type redox conditions in the water column and surface sediment. Future studies on paleo-(de) oxygenation events with a combined focus on Fe, sulfur and nitrogen cycling may reveal that OMZ-type redox conditions were an important feature of the ocean through Earth's history.

Oschlies, A., P. Brandt, L. Stramma and S. Schmidtko (2018) Drivers and mechanisms of ocean deoxygenation. Nature Geoscience 11, 467-473, doi: 10.1038/s41561-018-0152-2

Direct observations indicate that the global ocean oxygen inventory is decreasing. Climate models consistently confirm this decline and predict continuing and accelerating ocean deoxygenation. However, current models (1) do not reproduce observed patterns for oxygen changes in the ocean's thermocline; (2) underestimate the temporal variability of oxygen concentrations and air–sea fluxes inferred from time-series observations; and (3) generally simulate only about half the oceanic oxygen loss inferred from observations. This article reviews current knowledge about the mechanisms and drivers of oxygen changes and their variation with region and depth over the world's oceans. Warming is considered a major driver: in part directly, via solubility effects, and in part indirectly, via changes in circulation, mixing and oxygen respiration. While solubility effects have been quantified and found to dominate deoxygenation near the surface, a quantitative understanding of contributions from other mechanisms is still lacking. Current models may underestimate deoxygenation because of unresolved transport processes, unaccounted for variations in respiratory oxygen demand, or missing biogeochemical feedbacks. Dedicated observational programmes are required to better constrain biological and physical processes and their representation in models to improve the understanding and predictions of patterns and intensity of future oxygen change.

Woehle, C., A. Roy, N. Glock, T. Wein, J. Weissenbach, P. Rosenstiel, C. Hiebenthal, J. Michels, J. Schönfeld, T. Dagan (2018) A Novel Eukaryotic Denitrification Pathway in Foraminifera. Current Biology 28 (16), 2536-2543, doi: 10.1016/j.cub.2018.06.027

Benthic foraminifera are unicellular eukaryotes inhabiting sediments of aquatic environments. Several species were shown to store and use nitrate for complete denitrification, a unique energy metabolism among eukaryotes. The population of benthic foraminifera reaches high densities in oxygen-depleted marine habitats, where they play a key role in the marine nitrogen cycle. However, the mechanisms of denitrification in foraminifera are still unknown, and the possibility of a contribution of associated bacteria is debated. Here, the evidence for a novel eukaryotic denitrification pathway that is encoded in foraminiferal genomes is presented. Large-scale genome and transcriptomes analyses reveal the presence of a denitrification pathway in foraminifera species of the genus Globobulimina. This includes the enzymes nitrite reductase (NirK) and nitric oxide reductase (Nor) as well as a wide range of nitrate transporters (Nrt). A phylogenetic reconstruction of the enzymes' evolutionary history uncovers evidence for an ancient acquisition of the foraminiferal denitrification pathway from prokaryotes. A model for denitrification in foraminifera, where a common electron transport chain is used for anaerobic and aerobic respiration is proposed. The evolution of hybrid respiration in foraminifera likely contributed to their ecological success, which is well documented in palaeontological records since the Cambrian period.

Kolodziejczyk N., P. Testor, A. Lazar, V. Échevin, G. Krahmann, A. Chaigneau, C. Gourcuff, M. Wade, S. Faye ,P. Estrade, X. Capet, L. Mortier, P. Brehmer, F. Schütte and J. Karstensen (2018) Subsurface Fine-Scale Patterns in an Anticyclonic Eddy Off Cap-Vert Peninsula Observed From Glider Measurements. Ocean Sci., 14, 731-750, doi: 10.1029/2018JC014135

Glider measurements acquired along four transects between Cap-Vert Peninsula and the Cape Verde archipelago in the eastern tropical North Atlantic during March–April 2014 were used to investigate fine-scale stirring in an anticyclonic eddy. The anticyclone was formed near 12°N off the continental shelf and propagated northwest toward the Cape Verde islands. At depth, between 100 and – 400 m, the isolated anticyclone core contained relatively oxygenated, low-salinity South Atlantic Central Water, while the surrounding water masses were saltier and poorly oxygenated. The dynamical and thermohaline subsurface environment favored the generation of fine-scale horizontal and vertical temperature and salinity structures in and around the core of the anticyclone. These features exhibited horizontal scales of O(10–30 km) relatively small with respect to the eddy radius of O(150 km). The vertical scales of O(5–100 m) were associated to density-compensated gradient. Spectra of salinity and oxygen along isopycnals revealed a slope of around k^{-2} in the 10- to 100-km horizontal scale range. Further analyses suggest that the fine-scale structures are likely related to tracer stirring processes. Such mesoscale anticyclonic eddies and the embedded fine-scale tracers in and around them could play a major role in the transport of South Atlantic Central Water masses and ventilation of the North Atlantic Oxygen Minimum Zone.

Scholz, F., M. Baum, C. Siebert, S. Eroglu, A. W. Dale, M. Naumann, S. Sommer (2018) Sedimentary molybdenum cycling in the aftermath of seawater inflow to the intermittently euxinic Gotland Deep, Central Baltic Sea. Chemical Geology 491 (2018) 27–38, doi: 10.1016/j.chemgeo.2018.04.031

Molybdenum (Mo) concentrations and isotope compositions in sediments and shales are commonly used as proxies for anoxic and sulfidic (i.e., euxinic) conditions in the water column of paleo-marine systems. A basic assumption underlying this practice is that the proxy signal extracted from the geological record is controlled by long-term (order of decades to millennia) Mo scavenging in the euxinic water column rather than Mo deposition during brief episodes or events (order of weeks to months). To test whether this assumption is viable the biogeochemical cycling of Mo and its isotopes in sediments of the intermittently euxinic Gotland Deep in the central Baltic Sea is studied. Here, multiannual to decadal periods of euxinia are occasionally interrupted by inflow events during which well–oxygenated water from the North Sea penetrates into the basin. During these events manganese (Mn) (oxyhydr)oxide minerals are precipitated in the water column, which are known to scavenge Mo. Sediment and pore water Mo and Mo isotope data for sediment cores which were taken before and after a series of inflow events between 2014 and 2016 are presented. After seawater inflow, pore water Mo concentrations in anoxic surface sediments exceed the salinity-normalized concentration by more than two orders of magnitude and coincide with transient peaks of dissolved Mn. A fraction of the Mo liberated into the pore water is transported by diffusion in a downward direction and sequestered by organic matter within the sulfidic zone of the sediment. Diffusive flux calculations as well as a mass balance that is based on the sedimentary Mo isotope composition suggest that about equal proportions of the Mo accumulating in the basin are delivered by Mn (oxyhydr)oxide minerals during inflow events and Mo scavenging with hydrogen sulfide during euxinic periods. Based on the observations in the Gotland Deep, short-term redox fluctuations need to be considered when interpreting Mo-based paleo-records.

News

Under the lead of **Clarissa Karthäuser** (B4) the SFB 754 has published a popular scientific article on oxygen in the ocean in the "Spektrum der Wissenschaft" magazine.
https://www.spektrum.de/news/dem-ozean-geht-die-luft-aus/1603974

Conferences

AGU FALL MEETING
10-14 December 2018, Washington DC (USA)

SFB 754 ANNUAL RETREAT
14-15 March 2019

OCEANS 2019
17-20 June 2019, Marseille (France)

IMBER OPEN SCIENCE
17-21 June 2019, Brest (France)

IUGG 27
08-19 July 2019, Montreal (Canada)

GOLDSCHMIDT
18-23 August 2019, Barcelona (Spain)

OCEAN OBS'19
16 –20 September 2019, Honolulu, Hawaii (USA)

EDITORIAL
Dr. Chris Schelten
Phone 0431/600-4242
cschelten@geomar.de