NEWSLETTER 2018 | 01

Sonderforschungsbereich 754

Climate – Biogeochemistry Interactions in the Tropical Ocean

SFB 754

Publications

Bianchi, D., T.S. Weber, R. Kiko and C. Deutsch (2018) Global niche of marine anaerobic metabolisms expanded by particle microenvironments. Nature Geoscience 2018, doi: 10.1038/s41561-018-0081-0

In ocean waters, anaerobic microbial respiration should be confined to the anoxic waters found in coastal regions and tropical oxygen minimum zones, where it is energetically favourable. However, recent molecular and geochemical evidence has pointed to a much broader distribution of denitrifying and sulfate-reducing microbes. Anaerobic metabolisms are thought to thrive in microenvironments that develop inside sinking organic aggregates, but the global distribution and geochemical significance of these microenvironments is poorly understood. Here, a new size-resolved particle model to predict anaerobic respiration from aggregate properties and seawater chemistry was developed. Constrained by observations of the size spectrum of sinking particles, the model predicts that denitrification and sulfate reduction can be sustained throughout vast, hypoxic expanses of the ocean. Globally, the expansion of the anaerobic niche due to particle microenvironments doubles the rate of water column denitrification compared with estimates based on anoxic zones alone.

Breitburg, D., L. A Levin, A. Oschlies, M. Grégoire, F.P. Chavez, D.J. Conley, V. Garçon, D. Gilbert, D. Gutiérrez, K. Isensee, K. Jacinto, G. S. Limburg, K. E. Montes, I. Naqvi, S. W. A. Pitcher, G. C. Rabalais, N. N. Roman, M. R. Rose, K. A. Seibel, B. A. Telszewski, M. Yasuhara and J. Zhang (2018) Declining oxygen in the global ocean and coastal waters Deep. Science 359 (6371), doi: 10.1126/science.aam7240

As plastic waste pollutes the oceans and fish stocks decline, unseen below the surface another problem grows: deoxygenation. Breitburg et al. review the evidence for the downward trajectory of oxygen levels in increasing areas of the open ocean and coastal waters. Rising nutrient loads coupled with climate change—each resulting from human activities—are changing ocean biogeochemistry and increasing oxygen consumption. This results in destabilization of sediments and fundamental shifts in the availability of key nutrients. In the short term, some compensatory effects may result in improvements in local fisheries, such as in cases where stocks are squeezed between the surface and elevated oxygen minimum zones. In the longer term, these conditions are unsustainable and may result in ecosystem collapses, which ultimately will cause societal and economic harm.

Segschneider, J., B. Schneider and V. Khon (2018) Climate and marine biogeochemistry during the Holocene from transient model simulations. Biogeosciences Discussions, 1-52, doi: 10.5194/bg-2017-554

Climate and marine biogeochemistry changes over the Holocene are investigated based on transient global climate and biogeochemistry model simulations over the last 9,500 yr. The simulations are forced by accelerated and non-accelerated orbital parameters, respectively, and atmospheric pCO_2, CH_4, and N_2O. The analysis focusses on key climatic parameters, the processes that determine the strength of the marine carbon pumps, and on the oxygen minimum zones (OMZs) in the world ocean. The most pronounced changes occur in the eastern equatorial Pacific (EEP) OMZ, where a substantial increase in volume of the OMZ in the EEP continuing into the late Holocene was found in the non-accelerated simulation. The concurrent increase of age of the water mass within the EEP OMZ suggests that this growth is driven by a slow down of the circulation in the interior of the deep Pacific. This results in large scale deoxygenation in the deeper Pacific and hence the source regions of the EEP OMZ waters from mid-to-late Holocene. The simulated expansion of the OMZ in the late Holocene raises the question whether the currently observed deoxygenation is a continuation of the orbitally driven decline in oxygen, or a result of climate change from anthropogenic forcing as widely assumed. An additional explanation would be that the anthropogenic forcing amplifies the natural forcing.

Lutterbeck, H. E., D. L. Arevalo-Martinez, C.R. Löscher, and H.W. Bange (2018) Nitric oxide (NO) in the oxygen minimum zone off Peru. Deep Sea Research Part II: Topical Studies in Oceanography , doi: 10.1016/j.dsr2.2017.12.023

Nitric oxide (NO) is a short-lived compound of the marine nitrogen cycle. However, measurements of NO in seawater are analytically challenging and our knowledge about its oceanic distribution is, therefore, rudimentary. NO was measured in the oxygen minimum zone (OMZ) of the eastern tropical South Pacific Ocean (ETSP) off Peru during R/V Meteor cruise M93 in February/March 2013. NO concentrations ranged from close to or below the detection limit (0.5 nmol L^{-1}) in the surface layer to 9.5 nmol L^{-1} in the OMZ. NO concentrations increased significantly when oxygen (O_2) concentrations dropped below 1–2 µmol L^{-1}. Positive correlations between NO and NO_2^- as well as between NO and the abundance of archaeal amoA, a marker gene for archaeal nitrifiers, were found. No trends between NO and nirS and hzo, marker genes for canonical denitrification and anammox, respectively, were found. Thus, it can be concluded that NO off Peru was mainly produced by archaeal nitrifier-denitrification at low O_2 concentrations in the OMZ.

Su, B., M. Pahlow and A.E.F. Prowe (2018) The role of microzooplankton trophic interactions in modelling a suite of mesocosm ecosystems. Ecological Modelling 368, 169-179, doi: 10.1016/j.ecolmodel.2017.11.013

The zooplankton components in biogeochemical models drive top-down control of primary production and remineralisation, and thereby exert a strong impact on model performance. Who eats whom in oceanic plankton ecosystem models is often largely determined by body size. However, zooplankton of similar size can have different prey-size spectra. Thus, models with solely size-structured trophic interactions may not capture the full diversity of feeding interactions and miss important parts of zooplankton behavior. An optimality-based plankton ecosystem model is applied to analyse trophic interactions in a suite of mesocosm experiments in the Peruvian upwelling region. Sensitivity analyses reveal a dominant role of trophic structure for model performance, which cannot be compensated by parameter optimisation. The single most important aspect governing model performance is the trophic linking between dinoflagellates and ciliates. Only with a bidirectional link, i.e., both groups can prey on each other, is the model able to reproduce the differential development of the microzooplankton communities in the mesocosms. Thus, a solely size-based trophic structure may not be appropriate to represent the most important trophic interactions in plankton ecosystems. The diversity of feeding interactions needs to be adequately represented to capture community dynamics.

Frenger, I., D. Bianchi, C. Stührenberg, A. Oschlies, J. Dunne, C. Deutsch, E. Galbraith, and F. Schütte (2018) Biogeochemical role of subsurface coherent eddies in the ocean: Tracer cannonballs, hypoxic storms, and microbial stewpots? Global Biogeochemical Cycles 32, 226-249, doi: 10.1002/2017GB005743

Subsurface eddies are known features of ocean circulation, but the sparsity of observations prevents an assessment of their importance for biogeochemistry. A global eddying ocean-biogeochemical model was used to carry out a census of subsurface coherent eddies originating from eastern boundary upwelling systems (EBUS). A small fraction of long-lived eddies propagates over distances greater than 1,000 km, carrying the oxygen-poor and nutrient-rich signature of EBUS into the gyre interiors. In the Pacific, transport by subsurface coherent eddies accounts for roughly 10% of the offshore transport of oxygen and nutrients in pycnocline waters. This "leakage" of subsurface waters can be a significant fraction of the transport by nutrient-rich poleward undercurrents and may contribute to the well-known reduction of productivity by eddies in EBUS. Finally, eddies represent low-oxygen extreme events in otherwise oxygenated waters, increasing the area of hypoxic waters by several percent and producing dramatic short-term changes that may play an important ecological role. Capturing these nonlocal effects in global climate models, which typically include noneddying oceans, would require dedicated parameterizations.

Gier, J., C. Löscher, A.W. Dale, S. Sommer, U. Lomnitz and T. Treude (2017) Benthic Dinitrogen Fixation Traversing the Oxygen Minimum Zone Off Mauritania (NW Africa). Front. Mar. Sci. 4390, doi: 10.3389/fmars.2017.00390

Despite its potential to provide new nitrogen (N) to the environment, knowledge on benthic dinitrogen (N_2) fixation remains relatively sparse, and its contribution to the marine N budget is regarded as minor. In the present study, benthic N_2 fixation together with sulfate reduction and other heterotrophic metabolisms were investigated in the Mauritanian oxygen minimum zone (OMZ). Bottom water oxygen concentrations ranged between 30 and 138 µM. Benthic N_2 fixation determined was detected at all stations with highest rates (0.15 mmol m^{-2} d^{-1}) on the shelf and lowest rates (0.08 mmol m^{-2} d^{-1}) below 412 m water depth. The biogeochemical data suggest that part of the N_2 fixation could be linked to sulfate- and iron-reducing bacteria. Molecular analysis of the key functional marker gene for N_2 fixation, nifH, confirmed the presence of sulfate- and iron-reducing diazotrophs. High N_2 fixation further coincided with bioirrigation activity caused by burrowing macrofauna, both of which showed high rates at the shelf sites and low rates in deeper waters. However, statistical analyses proved that none of these processes and environmental variables were significantly correlated with benthic diazotrophy, which lead to the conclusion that either the key parameter controlling benthic N_2 fixation in Mauritanian sediments remains unidentified or that a more complex interaction of control mechanisms exists.

Beil, S., Kuhnt, W., Holbourn, A. E., Aquit, M., Flögel, S., Chellai, E. H. and Jabour, H. New insights into Cenomanian paleoceanography and climate evolution from the Tarfaya Basin, southern Morocco. Cretaceous Research, 84 . pp. 451-473. doi: 10.1016/j.cretres.2017.11.006

A 325 m long continuous succession of uppermost Albian to lower Turonian pelagic (outer shelf) deposits was recovered from a new drill site in the central part of the Tarfaya Basin (southern Morocco). This exceptional sediment archive allows to identify orbitally driven cyclic sedimentation patterns and to evaluate the pacing of climatic events and regional environmental change across the Albian-Cenomanian boundary (ACB), the mid-Cenomanian Event (MCE) and Oceanic Anoxic Event 2 (OAE2) in the latest Cenomanian. The deposition of organic-rich sediments in the Tarfaya Basin, likely driven by upwelling of nutrient-rich water masses, started during the latest Albian and intensified in two major steps following the MCE and the onset of OAE2. The duration and structure of the MCE and OAE2 carbon isotope excursions exhibit striking similarities, suggesting common driving mechanisms and climate-carbon cycle feedbacks. Both events were also associated with eustatic sea level falls, expressed as prominent sequence boundaries in the Tarfaya Basin. Based on the 405 kyr signal imprinted on the Natural Gamma Ray (NGR) and XRF-scanner derived Log(Zr/Rb) records, the duration of the Cenomanian Stage was estimated to be 4.8 ± 0.2 Myr.

News

FLORIAN SCHÜTTE

Congratulations to Dr. Florian Schütte (A5), who received the Annette-Barthels-Award 2018 for his PhD thesis „Characteristics and impact of mesoscale eddies in the eastern tropical North Atlantic".

Conferences

EGU GENERAL ASSEMBLY
8 - 13 April 2018, Vienna (Austria)

PICES 4TH INTERNATIONAL SYMPOSIUM
4 – 8 June 2018, Washington DC (USA)

GOLDSCHMIDT 2018
12 – 17 August 2018, Boston (USA)

SFB 754 INTERNATIONAL CONFERENCE
3 – 7 September 2018, Kiel (Germany)

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