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Photos: Kirsten Isensee

Sonderforschungsbereich 754

Climate – Biogeochemistry Interactions in the Tropical Ocean

SFB 754

Publications

Arteaga, A. L., M. Pahlow, S. M. Bushinsky and J. L. Sarmiento (2019) Nutrient Controls on Export Production in the Southern Ocean. Global Biogeochemical Cycles 33, doi: 10.1029/2019GB006236

Observations from novel biogeochemical profiling floats deployed by the Southern Ocean Carbon and Climate Observations and Modeling program were used to estimate annual net community production (ANCP; associated with carbon export) from the seasonal drawdown of mesopelagic oxygen and surface nitrate in the Southern Ocean. The estimates agree with previous observations with elevated ANCP near the polar front (~3 mol C m^{-2} y^{-1}), compared to lower rates in the subtropical zone (≤ 1 mol C m^{-2} y^{-1}) and the seasonal ice zone (<2 mol C m^{-2} y^{-1}). Paradoxically, the increase in ANCP south of the subtropical front is associated with elevated surface nitrate and silicate concentrations, but decreasing surface iron. This study hypothesizes that iron limitation promotes silicification in diatoms, which is evidenced by the low silicate to nitrate ratio of surface waters around the Antarctic polar front. High diatom silicification increases the ballasting effect of particulate organic carbon and overall ANCP in this region.

Glock, N., V. Liebetrau, A. Vogts and A. Eisenhauer (2019) Organic Heterogeneities in Foraminiferal Calcite Traced Through the Distribution of N, S, and I Measured With NanoSIMS: A New Challenge for Element-Ratio-Based Paleoproxies?. Frontiers in Earth Science 7 (175), doi: 10.3389/feart.2019.00175

Oceanic oxygen decline due to anthropogenic climate change is a matter of growing concern. A quantitative oxygen proxy is highly desirable in order to identify and monitor recent dynamics as well as to reconstruct pre-Anthropocene changes in amplitude and extension of oxygen depletion. Geochemical proxies like foraminiferal I/Ca ratios seem to be promising redox proxies. Nevertheless, recent studies revealed a possible association of iodine with organic accumulations within the test. Here, a new study is presented on the micro-distribution of nitrogen, sulfur, and iodine within the test walls of *Uvigerina striata* from the Peruvian OMZ measured with Nano-SIMS. Additionally, uncleaned specimens were compared with specimens that have been treated with an oxidative cleaning procedure. Both nitrogen and sulfur, which are used as tracer for organic matter, show a patchy distribution within the test walls of the uncleaned specimens and a statistically significant correlation with the iodine distribution. This patchy organic-rich phase has a different geochemical signature than the pristine calcitic parts of the test and another phase that shows a banding-like structure and that is characterized by a strong sulfur enrichment. All three elements, sulfur, nitrogen, and iodine, are strongly depleted in the cleaned specimens, even within the massive parts of the test walls that lack the connection with the test pores. These results indicate that the organic parts of the test walls are located inside a microporous framework within the foraminiferal calcite. This has to be considered in the interpretation of geochemical proxies on foraminiferal calcite, especially for microanalytical methods, since the chemical signature of these organic parts likely alters some element-to-calcium ratios within the foraminiferal test.

Doering, K., C. Ehlert, P. Martinez, M. Frank and R. Schneider (2019) Latitudinal variations in δ^{30}Si and δ^{15}N signatures along the Peruvian shelf: quantifying the effects of nutrient utilization versus denitrification over the past 600 years. Biogeosciences, 16, 2163-2180, doi: 10.5194/bg-16-2163-2019

The stable sedimentary nitrogen isotope compositions of bulk organic matter ($\delta^{15}N_{bulk}$) and the silicon isotope composition of diatoms ($\delta^{30}Si_{BSi}$) both reflect the degree of past nutrient utilization However, in ocean areas where anoxic conditions prevail, the $\delta^{15}N_{bulk}$ signal is also influenced by water column denitrification, causing an increase in the subsurface δ^{15}N signature of dissolved nitrate ($\delta^{15}NO^-_3$). Such conditions are found in the oxygen minimum zone off Peru, where an increase in subsurface $\delta^{15}NO^-_3$ along the shelf is observed due to denitrification within the poleward-flowing subsurface waters, while the δ^{30}Si signature of silicic acid remains unchanged. Here, three new $\delta^{30}Si_{BSi}$ records between 11 and 15∘S are combined with published $\delta^{30}Si_{BSi}$ and $\delta^{15}N_{bulk}$ records covering the past 600 years. This study presents a new approach to calculate past subsurface $\delta^{15}NO^-_3$ signatures based on the direct comparison of $\delta^{30}Si_{BSi}$ and $\delta^{15}N_{bulk}$ signatures at a latitudinal resolution. The results show that, during the Current Warm Period (CWP, since 1800 CE) source water $\delta^{15}NO^-_3$ compositions have been close to modern values, increasing southward from 7 to 10 ‰. In contrast, during the Little Ice Age (LIA) low $\delta^{15}NO^-_3$ values between 6 ‰ and 7.5 ‰ were calculated. Furthermore, the direct $\delta^{30}Si_{BSi}$ versus $\delta^{15}N_{bulk}$ comparison permits to relate short-term variability to changes in the ratio of nutrients (NO^-_3:$Si(OH)_4$) taken up by different dominating phytoplankton groups (diatoms and non-siliceous phytoplankton). Accordingly, this study estimates a shift from a 1:1 (or 1:2) ratio during the CWP to a 2:1 (up to 15:1) ratio during the LIA, associated with a shift from high nutrient utilization to NO^-_3-dominated (and thus non-siliceous phytoplankton) utilization.

Niemeyer, D., I. Kriest and A. Oschlies (2019) The effect of marine aggregate parameterisations on nutrients and oxygen minimum zones in a global biogeochemical model. Biogeosciences, 16, 3095–3111, doi: 10.5194/bg-16-3095-2019

Particle aggregation determines the particle flux length scale and affects the marine oxygen concentration and thus the volume of oxygen minimum zones (OMZs) that have been found to expand faster than can be explained by current state-of-the-art models. To investigate the impact of particle aggregation on global model performance, a sensitivity study with different parameterisations of marine aggregates and two different model resolutions was carried out. Model performance was investigated with respect to global nutrient and oxygen concentrations, as well as extent and location of OMZs. Results show that including an aggregation model improves the representation of OMZs. Moreover, it was found that besides a fine spatial resolution of the model grid, the consideration of porous particles, an intermediate-to-high particle sinking speed and a moderate-to-high stickiness improve the model fit to both global distributions of dissolved inorganic tracers and regional patterns of OMZs, compared to a model without aggregation. The model results therefore suggest that improvements not only in the model physics but also in the description of particle aggregation processes can play a substantial role in improving the representation of dissolved inorganic tracers and OMZs on a global scale.

Kemena, T. P., A. Landolfi, A. Oschlies, K. Wallmann and A. W. Dale (2019) Ocean phosphorus inventory: large uncertainties in future projections on millennial timescales and their consequences for ocean deoxygenation. Earth Syst. Dynam. 10, 539.553, doi: 10.5194/esd-10-539-2019

Previous studies have suggested that enhanced weathering and benthic phosphorus (P) fluxes, triggered by climate warming, can increase the oceanic P inventory on millennial timescales, promoting ocean productivity and deoxygenation. In this study, the major uncertainties in projected P inventories and their imprint on ocean deoxygenation using an Earth system model of intermediate complexity was assessed. The set of model experiments under the same climate scenarios but differing in their biogeochemical P parameterizations suggest a large spread in the simulated oceanic P inventory due to uncertainties in (1) assumptions for weathering parameters, (2) the representation of bathymetry on slopes and shelves in the model bathymetry, (3) the parametrization of benthic P fluxes and (4) the representation of sediment P inventories. Considering the weathering parameters closest to the present day, a limited P reservoir and prescribed anthropogenic P fluxes, a +30 % increase in the total global ocean P inventory by the year 5000 relative to pre-industrial levels was found, caused by global warming. Weathering, benthic and anthropogenic fluxes of P contributed +25 %, +3 % and +2 %, respectively. Suboxic volumes were up to 5 times larger than in a model simulation with a constant oceanic P inventory. In the model, nitrogen fixation was not able to adjust the oceanic nitrogen inventory to the increasing P levels or to compensate for the nitrogen loss due to increased denitrification. It is suggested that uncertainties in P weathering, nitrogen fixation and benthic P feedbacks need to be reduced to achieve more reliable projections of oceanic deoxygenation on millennial timescales.

Wallmann, K., S. Flögel, F. Scholz, A. W. Dale, T. P. Kemena, S. Steinig and W. Kuhnt (2019) Periodic changes in the Cretaceous ocean and climate caused by marine redox see-saw. Nature Geosciencevolume 12, 456–461, doi: 10.1038/s41561-019-0359-x

Periodic changes in sediment composition are usually ascribed to insolation forcing controlled by Earth's orbital parameters. During the Cretaceous Thermal Maximum at 97–91 Myr ago (Ma), a 37–50-kyr-long cycle that is generally believed to reflect obliquity forcing dominates the sediment record. Here, a numerical ocean model is employed to show that a cycle of this length can be generated by marine biogeochemical processes without applying orbital forcing. According to this model, the restricted proto-North Atlantic and Tethys basins were poorly ventilated and oscillated between iron-rich and sulfidic (euxinic) states. The Panthalassa Basin was fertilized by dissolved iron originating from the proto-North Atlantic. Hence, it was less oxygenated while the proto-North Atlantic was in an iron-rich state and better oxygenated during euxinic periods in the proto-North Atlantic. This redox see-saw was strong enough to create significant changes in atmospheric pCO_2. This study concludes that most of the variability in the mid-Cretaceous ocean–atmosphere system can be ascribed to the internal redox see-saw and its response to external orbital forcing.

Salvatecci, R., D. Gutierrez, D. Field, A. Sifeddine, L. Ortlieb, S. Caquineau, T. Baumgartner, V. Ferreira and A. Bertrand (2019) Fish debris in sediments from the last 25 kyr in the Humboldt Current reveal the role of productivity and oxygen on small pelagic fishes. Progress in Oceanography, 176, 102-114, doi: 10.1016/j.pocean.2019.05.006

Upwelling of cold, nutrient-rich water from the oxygen minimum zone (OMZ) off Peru sustains the world's highest production of forage fish, mostly composed of anchovy (*Engraulis ringens*). However, the potential impacts of climate change on upwelling dynamics and thus fish productivity are uncertain. Here, past changes in fish populations during the last 25,000 years were reconstructed, using fish debris deposited in laminated sediments, to unravel their response to changes in OMZ intensity and productivity. The records span the Last Glacial Maximum to the recent Holocene and thus encompass a variety of combinations of productivity, oxygen, and global temperature. The results reveal that productivity appears to be the main factor controlling small pelagic fish abundance, while sub-surface oxygenation affects mainly anchovy and likely sardine populations. Lower productivity and higher oxygen concentrations during the glacial resulted in lower total fish productivity, whereas higher productivity and a stronger OMZ in some time intervals during the Holocene resulted in higher fish abundances. Anchovy have been the predominant small pelagic fish throughout the record, at least over centennial to millennial timescales. Its abundance reached a maximum during the Current Warm Period, an era characterized by high productivity and intense OMZ conditions. Thus, industrial fisheries developed during a period of exceptional productivity in relation to that of the last 25 kyr. The records reveal that dramatic decreases in pelagic fish abundances have occurred in response to past large-scale climate changes than those observed in the instrumental period, which suggests that future climate change may result in substantial changes in ecosystem structure.

Conferences

OCEAN SCIENCES MEETING

16-21 February 2020, San Diego (USA)
Sessions:
OB010 - Feedbacks of the biological pump to atmosphere in past, present and future changing climates
OB016 - Marine deoxygenation in a changing climate: drivers, detection, and ecosystem impacts
OB020 - New Tools and Approaches to Constrain the Marine Nitrogen Cycle: From the Surface to the Sediments
OB029 - The role of plankton physiology and ecology for ocean biogeochemistry

EGU

03-08 May 2020, Vienna (Austria)

GOLDSCHMIDT

21-26 June 2020, Honululu, Hawaii (USA)

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