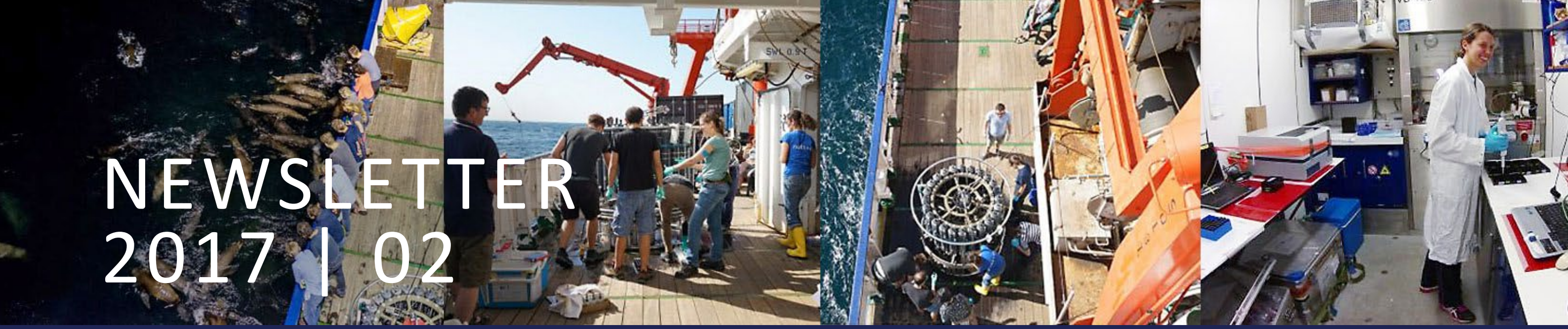

NEWSLETTER 2017 | 02

Sonderforschungsbereich 754

Climate – Biogeochemistry Interactions in the Tropical Ocean

SFB 754

Photos: Crew of Expedition M138

Publications

Niemeyer, D., T. P. Kemena, K. J. Meissner and A. Oschlies (2017) A model study of warming-induced phosphorus–oxygen feedbacks in open-ocean oxygen minimum zones on millennial timescales. Earth Syst. Dynam. 8, 357–367, doi: 10.5194/esd-8-357-2017

Observations indicate an expansion of oxygen minimum zones (OMZs) over the past 50 years, likely related to ongoing deoxygenation caused by reduced oxygen solubility, changes in stratification and circulation, and a potential acceleration of organic matter turnover in a warming climate. The overall area of ocean sediments that are in direct contact with low-oxygen bottom waters also increases with expanding OMZs. This leads to a release of phosphorus from ocean sediments. If anthropogenic carbon dioxide emissions continue unabated, higher temperatures will cause enhanced weathering on land, which, in turn, will increase the phosphorus and alkalinity fluxes into the ocean and therefore raise the ocean's phosphorus inventory even further. A higher availability of phosphorus enhances biological production, remineralisation and oxygen consumption, and might therefore lead to further expansions of OMZs, representing a positive feedback. A negative feedback arises from the enhanced productivity-induced drawdown of carbon and also increased uptake of CO_2 due to weathering-induced alkalinity input. This feedback leads to a decrease in atmospheric CO_2 and weathering rates. Here these two competing feedbacks on millennial timescales for a high CO_2 emission scenario are quantified. Using the University of Victoria (UVic) Earth System Climate Model of intermediate complexity, the model results suggest that the positive benthic phosphorus release feedback has only a minor impact on the size of OMZs in the next 1000 years. The increase in the marine phosphorus inventory under assumed business-as-usual global warming conditions originates, on millennial timescales, almost exclusively (> 80 %) from the input via terrestrial weathering and causes a 4- to 5-fold expansion of the suboxic water volume in the model.

Hahn, J., P. Brandt, S. Schmidtko and G. Krahmann (2017) Decadal oxygen change in the eastern tropical North Atlantic. Ocean Sci. Discuss. (in review), doi: 10.5194/os-2016-102

Repeat shipboard and multi-year moored observations obtained in the oxygen minimum zone (OMZ) of the eastern tropical North Atlantic (ETNA) were used to study the decadal change in oxygen for the period 2006–2015. At the depth of the deep oxycline (200–400 m), oxygen decreased with a rate of -6.2 ± 3.8 µmol kg^{-1} decade^{-1}, while below the OMZ core (400–1,000 m) oxygen increased by 4.1 ± 1.7 µmol kg^{-1} decade^{-1} on average. The inclusion of these decadal oxygen trends in the recently estimated oxygen budget for the ETNA OMZ showed a weakened ventilation of the upper 400 m, whereas the ventilation strengthened homogeneously over depth below 400 m. This resulted in a shoaling of the ETNA OMZ of -0.03 ± 0.02 kg m^{-3} decade^{-1} in density space, which was only partly compensated by a deepening of isopycnal surfaces, thus pointing to a shoaling of the OMZ in depth space as well. Shipboard, float and satellite observations of velocity and hydrography indicate different regional as well as remote changes in the circulation pattern to be responsible for the change in the ventilation of the ETNA. The reduced ventilation in the upper 400 m may have been induced by a southward shift of the wind-driven circulation or by a change of the composition of South Atlantic Central Water. There are hints that below 400 m, latitudinally alternating zonal jets have strengthened, thus contributing to the increased ventilation. Nevertheless, temporal changes in isopycnal eddy supply or diapycnal supply (diapycnal mixing as well as diapycnal advection) cannot be excluded in having contributed to the observed oxygen change.

Arevalo-Martinez, D. L., A. Kock, T. Steinhoff, P. Brandt, M. Dengler, T. Fischer, A. Körtzinger and H. W. Bange (2017) Nitrous oxide during the onset of the Atlantic Cold Tongue. J. Geophys. Res. Oceans 122(1), 171-184, doi: 10.1002/2016JC012238

The tropical Atlantic exerts a major influence in climate variability through strong air-sea interactions. Within this region, the eastern side of the equatorial band is characterized by strong seasonality, whereby the most prominent feature is the annual development of the Atlantic cold tongue (ACT). This band of low sea surface temperatures (~22–23°C) is typically associated with upwelling-driven enhancement of surface nutrient concentrations and primary production. Based on a detailed investigation of the distribution and sea-to-air fluxes of N_2O in the eastern equatorial Atlantic (EEA) it could be observed that the onset and seasonal development of the ACT can be clearly identified in surface N_2O concentrations, which increase progressively as the cooling in the equatorial region proceeds during spring-summer. The surface currents of the EEA influenced strongly the N_2O distribution, such that "high" and "low" concentration regimes could be distinguished. These regimes were spatially delimited by the extent of the warm eastward-flowing North Equatorial Countercurrent and the cold westward-flowing South Equatorial Current. Estimated sea-to-air fluxes of N_2O from the ACT (mean 5.18 ± 2.59 µmol m^{-2}d^{-1}) suggest that in May–July 2011 this cold-water band doubled the N_2O efflux to the atmosphere with respect to the adjacent regions, highlighting its relevance for marine tropical emissions of N_2O.

Somes, C. J., A. Schmittner, J. Muglia and A. Oschlies (2017) A three-dimensional model of the marine nitrogen cycle during the Last Glacial Maximum constrained by sedimentary isotopes. Front. Mar. Sci. 4:108, doi: 10.3389/fmars.2017.00108

Nitrogen is a key limiting nutrient that influences marine productivity and carbon sequestration in the ocean via the biological pump. In this study, the first estimates of nitrogen cycling in a coupled 3D ocean-biogeochemistry-isotope model forced with realistic boundary conditions from the Last Glacial Maximum (LGM) ~21,000 years before present constrained by nitrogen isotopes is presented. The model predicts a large decrease in nitrogen loss rates due to higher oxygen concentrations in the thermocline and sea level drop, and, as a response, reduced nitrogen fixation. Model experiments are performed to evaluate effects of hypothesized increases of atmospheric iron fluxes and oceanic phosphorus inventory relative to present-day conditions. Enhanced atmospheric iron deposition, which is required to reproduce observations, fuels export production in the Southern Ocean causing increased deep ocean nutrient storage. This reduces transport of preformed nutrients to the tropics via mode waters, thereby decreasing productivity, oxygen deficient zones, and water column N-loss there. A larger global phosphorus inventory up to 15% cannot be excluded from the currently available nitrogen isotope data. It stimulates additional nitrogen fixation that increases the global oceanic nitrogen inventory, productivity, and water column N-loss. Among the sensitivity simulations, the best agreements with nitrogen isotope data from LGM sediments indicate that water column and sedimentary N-loss were reduced by 17–62% and 35–69%, respectively, relative to preindustrial values. The model demonstrates that multiple processes alter the nitrogen isotopic signal in most locations, which creates large uncertainties when quantitatively constraining individual nitrogen cycling processes. One key uncertainty is nitrogen fixation, which decreases by 25–65% in the model during the LGM mainly in response to reduced N-loss, due to the lack of observations in the open ocean most notably in the tropical and subtropical southern hemisphere. Nevertheless, the model estimated large increase to the global nitrate inventory of 6.5–22% suggests it may play an important role enhancing the biological carbon pump that contributes to lower atmospheric CO_2 during the LGM.

Bourbonnais, A., R. T. Letscher, H. W. Bange, V. Échevin, J. Larkum, J. Mohn, N. Yoshida and M. A. Altabet (2017) N_2O production and consumption from stable isotopic and concentration data in the Peruvian coastal upwelling system. Global Biogeochem. Cycles 31(4), 678–698, doi: 10.1002/2016GB005567

The ocean is an important source of nitrous oxide (N_2O) to the atmosphere, yet the factors controlling N_2O production and consumption in oceanic environments are still not understood nor constrained. N_2O concentrations and isotopomer ratios, as well as O_2, nutrient and biogenic N_2 concentrations, and the isotopic compositions of nitrate and nitrite at several coastal stations during two cruises off the Peru coast (~5–16°S, 75–81°W) in December 2012 and January 2013 were measured. N_2O concentrations varied from below equilibrium values in the oxygen deficient zone (ODZ) to up to 190 nmol L^{-1} in surface waters. A 3-D-reaction-advection-diffusion model was used to evaluate the rates and modes of N_2O production in oxic waters and rates of N_2O consumption versus production by denitrification in the ODZ. Intramolecular site preference in N_2O isotopomer was relatively low in surface waters (generally −3 to 14‰) and together with modeling results, confirmed the dominance of nitrifier-denitrification or incomplete denitrifier-denitrification, corresponding to an efflux of up to 0.6 Tg N yr^{-1} off the Peru coast. Other evidence, e.g., the absence of a relationship between ΔN_2O and apparent O_2 utilization and significant relationships between nitrate, a substrate during denitrification, and N_2O isotopes, suggest that N_2O production by incomplete denitrification or nitrifier-denitrification decoupled from aerobic organic matter remineralization are likely pathways for extreme N_2O accumulation in newly upwelled surface waters. Imbalances between N_2O production and consumption in the ODZ, with the modeled proportion of N_2O consumption relative to production generally increasing with biogenic N_2 were observed. However, N_2O production appeared to occur even where there was high N loss at the shallowest stations.

Jose, Y. S., H. Dietze and A. Oschlies (2017) Linking diverse nutrient patterns to different water masses within anticyclonic eddies in the upwelling system off Peru. Biogeosciences 14, 1349-1364, doi: 10.5194/bg-14-1349-2017

Ocean eddies can both trigger mixing (during their formation and decay) and effectively shield water encompassed from being exchanged with ambient water (throughout their lifetimes). These antagonistic effects of eddies complicate the interpretation of synoptic snapshots typically obtained by ship-based oceanographic measurement campaigns. This study is based on a coupled physical–biogeochemical model and explores the biogeochemical dynamics within anticyclonic eddies in the eastern tropical South Pacific Ocean. The goal is to understand the diverse biogeochemical patterns that have been observed at the subsurface layers of the anticyclonic eddies in this region. The model results suggest that the diverse subsurface nutrient patterns within eddies are associated with the presence of water masses of different origins at different depths.

Conferences

GOLDSCHMIDT 2017
13 – 18 August, Paris (France)

5TH INT. CONFERENCE ON OCEANOGRAPHY & MARINE BIOLOGY
18 – 20 October 2017, Seoul (South Korea)

PIRATA-PREFACE-TAV MEETING
05 – 10 November 2017, Fortaleza (Brazil)

AGU FALL MEETING 2017
11 – 15 December 2017, New Orleans (USA)

2018 OCEAN SCIENCES MEETING
11 – 16 February 2018, Portland, Oregon (USA)

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

Sessions: Biogeochemical feedbacks • Coastal systems • Impacts on ecosystems • Impacts on fisheries / socioeconomics • Major upwelling systems • Oxygen consumption / microbiology • Paleo perspective • Physiological effects & multiple stressors • Prediction & monitoring • Ventilation / oxygen supply

SFB 754 Cruise

METEOR M138
Eastern Pacific, Jun. 06 - Jul. 07, 2017
Chief scientist: Hermann Bange