Sediments oxidation by seagrasses: influence on the S cycle in *Posidonia oceanica* (L.) Delile intermattes dynamic

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The Mediterranean seagrass *Posidonia oceanica* forms meadows and develops a complex of rhizomes, roots and sediment which is called "matte". *P. oceanica* meadows show discontinuity patterns in the form of sand or dead matte (matte without living shoots) patches, called "intermattes", which can have natural or anthropogenic origins. Mechanical processes (e. g. currents, anchoring) can initiate intermattes formation but their dynamic after creation seems to be linked with the sediment chemistry, especially with S cycle. *P. oceanica* plays an important role in controlling coastal belowground biogeochemistry, in particular by oxidizing sediments through the release of O_2 by roots. This process allows creating more suitable condition for plant growth and colonization. The lack of H_2S oxidation in ${SO_4}^{2-}$ can lead to limitation of the plant development or its regression.

In order to investigate the effect of oxidation condition in sediments on intermattes dynamic and the neighboring meadow, we initiate, in December 2013, a study on six intermattes (three natural, three anthropogenic) at different depths in Calvi Bay, in Corsica (France). We hypothesize that redox potential and H_2S concentration in sediments play an important role in the regression of *P. oceanica* meadows, particularly after a mechanical anthropic impact like anchoring. It also may be possible that two different kinds of processes are involved for each type of intermatte. Regular samplings throughout two years are planed with the aim of evaluating the seasonal variations of physicochemical parameters.

Impact of low oxygen concentrations on scallop culture in the upwelling-influenced Bay of Paracas, Peru

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Paracas bay is a traditional cultivation area of the Peruvian scallop (*Argopecten purpuratus*) where coastal upwelling favor high primary productivity and subsequent growth of this filter-feeding bivalve. However in recent years, numerous high/total scallop mortality events were recorded accompanied by a phenomenon of milky turquoise waters locally called "aguas blancas" that affect the local economy. In order to better understand the dynamics of these events, a joint monitoring of oceanographic variables (hourly recorded) and growth, reproduction and survival (weekely measurements) of bottom and suspended cultured scallops was performed over six months. The data indicates that oceanographic conditions are more stable during the austral winter than in summer where temperatures varies between 22.5°C and 14.7°C. During this period oxygen saturations (Sat.) are also highly variable ranging from over saturation to anoxia in the course of a day as well as a considerable increase in turbidity (>10 NTU) was also observed. During both winter and summer hypoxic conditions (Sat. <30%) were recorded, however hypoxic events were more prolonged in summer reaching anoxia in conjunction with 2-4 days milky turquoise waters occurance. These events were always preceded by an abrupt decreases in water temperature (~-3.75 °C/h). Oceanographic variables showed evidence of two water masses entering into the bay during the summer: upwelling cold waters and oceanic warm waters. Critical oxygen conditions are commonly seen in the upwelled water mass. During summer, prolonged low oxygen have dramatic consequences on cultived scallops: significant somatic weight losses, reproductive cycle interruption and high mortality rates. These effects were worst in bottom culture (68% of monitored period under hypoxia) reaching 100% of cumulative mortality at the end of six months monitoring, compared to suspended culture (36% of monitored period under hypoxia) where cumulative mortality was 43%. High instantaneous mortality rates were observed during the presence of milky turquoise waters. The scallops growing in suspension reached a somatic weight and gonado-somatic index significantly ($p < 0.001$) higher than in bottom. A principal component analysis shows that the saturation was more favorable in suspended culture also that highest turbidity values was correlated to bottom culture. Despite the high rates of mortality during anoxia *A. purpuratus* shown to have a considerable tolerance to hypoxic conditions. A rapid recovery on growth and reproduction was obseved when oxygen saturation conditions improve. There are indications that upwelled water that enters into the Bay in summer contains significant levels of hydrogen sulphide that would come from anaerobic degradation of organic matter due to sulphate reducing bacteria (Widdel, 1988), in addition to low oxygen content. The former would affect negatively *A. purpuratus* physiology, thus reduce productivity and increasing the risk of culture losses. The milky turquoise coloration on water of the "aguas blancas" may be due to the formation of microgranules of elemental sulphur that can occur from the oxidation of hydrogen sulphyde under certain oceanographic conditions (Dohnalek and FitzPatrick, 1983; Millero et al., 1987). This study emphasized the need for monitoring and modeling the Bay hydrodynamics to assess/predict hypoxic/anoxic events, and performing carrying capacity studies.

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HYPOXIA IN THE CENTRAL ARABIAN GULF (EEZ OF QATAR)

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Hypoxia, or oxygen minimum zone, has been observed for the first time in the deeper (>50 m) waters of the mid Arabian Gulf. Not only low oxygen levels were recorded but also stagnation, nutrient rich, low chlorophyll, low temperature water body as well as a region of remineralization of organic matter were observed in the hypoxic waters. The condition occurs naturally during summer season and caused by an interaction between physical, chemical and biological factors, which drive the system towards hypoxia.

The strong Arabian Sea - south-westerly winds (the SW monsoon up-welling's) (summer; June and September) drives relatively low-salinity nutrient-rich surface water from the Arabian Sea (Gulf of Oman) through the Strait of Hormuz into central Arabian Gulf. Thus the penetration of surface inflow makes the deep off-shore Qatari marine environment (central Arabian Gulf) highly fertile especially during summer. Consequently, the ranges of dissolved inorganic nitrogen (NH4+, NO2- and NO3-), PO43-, SiO42- (all in μM), and chlorophyll-a (μg 1-1) concentrations for summer were: below detection limit (BDL) – 7.49; BDL – 1.02; 0.37 – 14.69; 0.10 – 4.11, and winter: BDL – 4.93; BDL – 0.48; 0.13 – 4.36; 0.00 – 2.16, respectively. Furthermore, strong stratification (seasonal thermocline and pycnocline) develops during summer, when the deep water temperature (20.88oC) in the central Arabian Gulf is about 11oC colder than at the surface (31.94oC). This leads to the existence of a two-layer system in the central Arabian Gulf. Oxygen concentrations in the surface layer were generally uniform and super-saturated (>100-130%) while very low dissolved oxygen was found close to the sea bottom ($\geq$ 50 m) in the deep parts of the north and northeast EEZ of Qatar; 0.86 ml L-1 (17.3% saturation) observed at about 69 m depth below the summer thermocline. This was the lowest oxygen value ever recorded within central Arabian Gulf. The calculated OMZ area is around 7,220 km square. The Total Organic Matter (TOM) of the underlying sediments lied between 6.5 and 9.9% with an average of 8.4% compared to less than 1% along the EEZ of Qatar. The benthic infauna within the OMZ area exhibited a low level of invertebrate diversity and very low biomass, with a total of 138 individuals. The N:P and Si:P ratios in the OMZ are 0.17:1 and 6.23:1 compared to 15.52:1 and 15.7:1, respectively, for the water overlying the OMZ.. These "optimum" ratios are coupled with stratification and hence high water column stability, and high intensity of incident solar radiation during this period, altogether give rise to conditions that are optimal for maximum primary production (chlorophyll-a) within the euphotic zone (above 50 m depth) of the central Arabian Gulf during summer.

Impact of Low Oxygen Layers on Phytoplankton Composition and Fish Kill.

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Biological characteristics of the ecosystem of the Sea of Oman are influenced by the hydrodynamics of the area driven mostly by monsoonal winds and by inflow and outflow of waters from the Arabian Gulf and the Arabian Sea. Nevertheless, in recent years, this ecosystem has been showing signs of rapid and profound changes due to climate change and increasing anthropogenic nutrient loading.

The most evident changes in the Sea of Oman ecosystem are the rise in phytoplankton blooms outbreak and fish kill. For instance, Noctiluca scintillans is the dominant widely spread species in the coastal water of Oman and most HABs related fish kill events have been attributed to this species through dissolved oxygen depletion. In 2008, Cochlodinium polykrikoides bloom occurred in the coastal water of Oman and was broad causing massive fish kill especially in fish cages. Low dissolved oxygen is considered as one of the major factors that cause massive fish kill every year in the coastal water of Oman. The diversity and spatial-temporal variations of phytoplankton communities succession, their contribution to changes in dissolved oxygen concentrations and their link with environmental changes will be presented.

Wave driven devices for the oxygenation of bottom layers: a numerical analysis of their hydrodynamic behavior

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The early ideas to pump water vertically in the ocean date back to 1950, when Stommel made his first study on the perpetual salt fountain [*Stommel*, 1956]. His concept was based on the fact that both temperature and salinity affect the density of seawater and the constraint that heat can be conducted through a metal pipe whereas salt cannot. Stommel's idea was extended to a wave powered pump by Isaacs during the period 1974–1976 . That pump involved a buoy moving up and down on the surface, with a pipe attached to the buoy and a flapper valve that opens and closes inside the pipe [*Behrman*, 1992]. Wave pumps have been used on a small scale to generate power but recently have been considered as a means of drawing the nutrient rich deep ocean water to the surface to increase fish production, as a means of mitigating climate change [*Liu*, 1999] and the basis for reducing the intensity of hurricanes by bringing deep colder water to the ocean surface [*Blumberg*, 2012]

Ideas have also been developed to pump water downwards in the ocean to address water quality issues, like eutrophication. The term eutrophication refers to an excessive enrichment of waters in nutrients, and its associated adverse biological effects [*European Environmental Agency*, 1994]. Cultural eutrophication, which results from human activity, may negatively affect marine ecosystems, increasing the occurrence of massive benthos and fish mortality, loss of diversity, poisoning episodes which also cause human illness, and mucilage production (e.g., *Smayda*, 1990; *Viviani*, 1992; *Vollenweider*, 1992; *Degobbis*, 1995). Two recent studies using physical models of a device capable of pumping well oxygenated water from the surface to the deep layer have been completed [*Margheritini*, 2011; *Antonini*, 2012). Both of these devices have the goal of using waves overtopping the pumping device to pump water down into a tube that connects the surface to the deeper waters.

The present study analyzes numerically, by means of a CFD code through a discretization of domain by way of overset mesh, the hydrodynamic behaviour of the device studied by Antonini, in order to identify the most relevant parameters for its response under the action of the incoming waves. The device consists in a floating body, an inferior stabilizing ring and a pipe which joins the floater to the ring. The floater collects part of the incoming wave crest into the reservoir and the higher head induces water flux through the pipe in the downward direction.

The goal of this paper is to determine through the use of a numerical model of the device the best parametric configuration that would maximize the downward flow in the pipe.

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M91: Surface Ocean – Lower Atmosphere Study in the upwelling region off Peru

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The Meteor cruise M91 (Callao-Callao) took place in the coastal wates off Peru from 01 December to 26 December 2012. The overall goal of M91 was to conduct an integrated biogeochemical study on the upwelling region off Peru in order to assess its importance for the emissions of various climate-relevant atmospheric trace gases and tropospheric chemistry. The various work packages of M91 included measurements of and sampling for (1) atmospheric and dissolved trace gases, (2) aerosols, (3) nitrogen processes and isotopes in the water column, (4) dissolved organic matter in the surface microlayer, (5) upwelling velocity, and (6) exchange fluxes across the ocean/atmosphere interface. M91 is contribution to the SOLAS midterm strategy initiative "Air-sea gas fluxes at eastern boundary upwelling and oxygen minimum zones system" and was funded by the German SOLAS project SOPRAN (Surface Ocean Processes in the Anthropocene: www.sopran.pangaea.de). An overview of first results from M91 are presented.

Oxygen and the denitrification paradox: are sediments a source or a sink of N2O?

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Multiple pathways of N2O production occur in freshwater and marine sediments, but their dependence on oxygen (O2) availability and nitrogen source are poorly understood. Heterotrophic denitrification is traditionally viewed as commencing at anoxic boundaries and is widely thought as the most significant contributor to N2O fluxes from sediments. However this view may reflect erroneous assumptions, both experimental and theoretical. The role of O2 in N2O production is not straightforward and recent work has demonstrated the N2O yield from nitrification to dramatically increase in sub-oxic marine environments. Traditional experimental incubations rely on sealed chambers in which sediment redox status changes rapidly. Because O2 plays the key role in sediment N2O cycling, N2O processing rates derived in this way may vary markedly from those in situ. To overcome this we designed a semi enclosed mesocosm that maintains the headspace O2 partial pressure at preselected values, enabling the experimental manipulation of "in-situ" conditions to examine closely the role of O2 in net sediment N2O production. Early results show highest net sediment N2O production at low O2 partial pressures (0.5-2%). Under some circumstances anoxic conditions lead to N2O consumption by heterotrophic denitrifiers The implication is that processes other than denitrification may principally be responsible for sediment N2O production and that denitrification in isolation may result in net N2O consumption. We hypothesise that ammonium oxidation pathways (nitrifier nitrification; nitrifier denitrification; nitrification-coupled denitrification) are the major mechanisms of sediment N2O production, challenging the established view of anoxic heterotrophic denitrification as the principal sediment N2O source.

Oxygen minimum zones in miniature: Microbial diversity, community composition, and function in anoxic meromictic marine lakes of Palau

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Steep chemical gradients occur in aquatic ecosystems where oxygen is depleted through microbial activity, such as in oceanic oxygen minimum zones (OMZs). OMZs and other low-oxygen aquatic ecosystems are expanding and intensifying as a consequence of human activity, compressing habitat for aerobic macroorganisms and altering microbial ecology and biogeochemistry, yet our understanding of these changes is limited by a lack of comparative analyses of low-oxygen ecosystems. Marine lakes—bodies of seawater enclosed by land—are an ideal comparative system as they represent a deoxygenation gradient: from well-mixed holomictic lakes, to stratified, anoxic, meromictic lakes that vary in the depth range and intensity of anoxia. We analyzed 7 marine lakes in the Republic of Palau using next-generation sequencing of 16S rRNA genes and quantitative PCR for nitrogen- and sulfur-cycling functional genes. Microbial diversity typically increased with depth or was minimal at mid-depth in meromictic lakes, while community similarity declined sharply with increasing depth. Community similarities ranged from 9% to 86% across samples, reflecting the dominance of typical marine Cyanobacteria, SAR11, and SAR86 bacteria in the epilimnion of most lakes, and markedly different community composition in the anoxic hypolimnion. Hypolimnion bacteria included anoxygenic phototrophs, sulfate-reducing bacteria, Arcobacter, SUP05, and candidate division OD1—all of which are known to participate in the biogeochemical cycling of carbon, nitrogen, and sulfur in other anoxic aquatic habitats. Quantitative PCR showed that ammonia-oxidizers were limited to discrete depths, whereas nitrite oxidizers were present over a wide range of conditions, including anoxic and sulfidic conditions. Denitrifier nitrite reductase (nirS) genes were also detected in the sulfidic hypolimnion of all meromictic lakes, whereas anammox nirS and 16S rRNA genes were not. Collectively these data provide new insight into open ocean OMZs and provide a new model system for microbial ecology and biogeochemistry within low-oxygen marine ecosystems.

Sulfur cycling and the effects of deoxygenation on bacterial community structure in the ocean's largest oxygen minimum zone

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Oceanic oxygen minimum zones (OMZs) play a central role in ocean biogeochemical cycles and are expanding as a consequence of climate change, yet how deoxygenation will affect the microbial communities that control these cycles is unclear. Here we sample across dissolved oxygen gradients in the oceans' largest OMZ (the ETNP) and show that bacterial richness displays a unimodal pattern with decreasing dissolved oxygen, reaching maximum values on the edge of the OMZ and decreasing within it. Rare groups on the OMZ margin are abundant at lower dissolved oxygen concentrations, including sulphur-cycling Chromatiales. We demonstrate sulfate reduction within the ETNP OMZ, and sulfur oxidation on the OMZ edge, based on patterns of functional gene expression. These data provide potential thresholds for sulfur cycling in OMZs and closely mimic recent model predictions. Our microbial species distribution models (MSDMs) accurately replicate community patterns based on multivariate environmental data, demonstrate likely changes in distributions and diversity in the eastern tropical North Pacific Ocean, and highlight the sensitivity of key bacterial groups to deoxygenation. Through these mechanisms, OMZ expansion may alter microbial composition, competition, diversity and function, all of which have implications for biogeochemical cycling in OMZs.

Littoral food web in the eastern Baltic Sea lagoons with seasonal hypoxic events

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High nutrient inputs to the coastal areas of the Baltic Sea result in summer macroalgal blooms initiated by opportunistic filamentous algae (mainly Cladophora glomerata, Ulva intestinalis, Pilayella littoralis, etc.). It is known that macroalgal respiration resulted in sediment anoxia and macroalgal detritus coupled with hypoxia/anoxia enhanced the production of hydrogen sulfide. The hypoxia influenced strongly on bottom environments facilitating decreasing benthic species abundance. In the Neva estuary, the temporal hypoxia (5.4-24.5% or 0.6-2.8 mg/l) are usually recorded during 6-8 weeks of July-September when great masses of drifting algae or loose-lying mats (phytomass of 315-445 g/m2 in dry weight, concentrated in coastal areas (Berezina, 2008).

This paper studies structure of trophic webs in coastal littoral with developed macrophytes and recognizes possible adaptation of this biocenosis to low oxygen level under macroalgal blooms in the Neva Estuary and Curonian Lagoon, the most eutrophic parts in the Baltic Sea. We based our study on microscopic analysis of gut content in predaceous dominating taxa (amphipods and mysids) and the Stable Isotope analysis (C, N) of tissues in plants and animals inhabiting the littoral.

The macroinvertebrate community in the studied habitats included eurybiotic taxa of chironomids, mollusks and alien amphipods Gmelinoides fasciatus, Gammarus tigrinus, Pontogammarus robustoides, Obesogammarus crassus, and alien mysids Paramysis lacustris, Limnomysis benedeni). Dominating taxa such as amphipods and mysids belong to the bento-planktonic organisms and are the link between these types of communities in littoral area. These crustaceans are able to be tolerant to the temporal hypoxia caused by the algae decomposition until they eventually migrate to areas with more favorable conditions. This behavioral adaptation can be considered as a main mechanism facilitating these taxa dominance in the Baltic eutrophic coastal areas.

We obtained that alien amphipod and mysid species are omnivorous possessing mixed feeding strategies and acting as grazers, collector-gatherers and predators. Significant differences in food spectra and position in trophic web were recorded between species and within species between different-sized specimens (juveniles and adults). The role of amphipods and mysids in littoral food chains was assessed as important. At the same time, their impact on producer and first level consumers due to euryphages (varying percentage of plant and animal food in a diet) was very variable depending on types and oxygen conditions in habitats.

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Redoxcline sediments of haloclines associated with Deep Hypersaline Anoxic Lakes support protist and fungal populations

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One of the most extreme marine habitats known is the Mediterranean Deep Hypersaline Anoxic Basins (DHABs; water depth approximately 3500m). These DHAB brines are nearly saturated with salt, causing them to be considered uninhabitable for eukaryotes. While diverse bacterial and protistan communities are reported from DHAB water-column haloclines, the existence and activity of benthic DHAB protists have not been explored. Here, we report findings regarding protists recovered from DHAB redoxcline sediments collected with ROV Jason in 2011. Microscopic counts indicate that while populations are relatively sparse, halocline sediments are more densely populated than adjacent control sediments. Ciliates appear to dominate the halocline protistan community, although flagellates and thecate foraminifera were also observed. Furthermore, pyrosequencing analysis based on RNA indicates that metabolically active eukaryotes are present in the halocline sediments from the three DHABs sampled (Discovery, Urania, L'Atalante); most are Fungi. Benthic communities in the DHABs appear to differ, as expected, due to differing brine chemistries. A low proportion of protists appear to bear putative symbionts. Supported by NSF grants OCE-0849578 and OCE-1061391.

Mesoscale structures as barriers to mixing in the East Tropical Pacific Oxygen Minimum Zone

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The oxygen content of sea water is a major factor affecting marine fauna and biogeochemical cycles. Zones were an oxygen deficit is present in the water column represent significant portions of the total area and volume of the world's oceans and are tought to be increasing. In the Eastern Tropical Pacific an oxygen minimum zone is found, maintained primarily by biological processes and weak ventilation and where equatorial and eastern boundary current systems drive the circulation. The Eastern Tropical Pacific Oxygen Minimum Zone developed off Peru is populated by mesoscale eddies whose role on the exchange of water mass properties remains largely unknown. We study this problem from a modeling approach and a Lagrangian point of view, characterizing pathways and barriers to transport and mixing of oceanic regions with distinct concentrations of dissolved oxygen. Our results show the crucial role of mesoscale dynamics in the establishment of the Oxygen Minimum Zone frontiers, and the existence of episodic eddies coming in/out the zone with higher/lower oxygen concentrations with respect to the surrounding waters.

Oxygen minimum zones in an eddy-resolving coupled climate model

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Open-ocean oxygen minimum zones (OMZ) regulate the balance of ocean nutrients, affect the distribution of marine animals, and are predicted to expand under global warming. Many open questions remain on the physical and biogeochemical interactions that maintain OMZ and drive their variability. While broad features of OMZ are determined by the large-scale ocean circulation, oxygen deficits are replenished by vigorous mesoscale processes, including eddies and jets, that are poorly represented in current models of ocean biogeochemistry. These models, used to project oxygen changes under anthropogenic influences, are characterized by large biases in both the mean oxygen distribution (e.g. larger OMZ than observed), and their response to historical forcings. To elucidate the role of fine-scale physical processes and their variability on oceanic oxygen, we analyzed the output from GFDL eddy-resolving climate model CM2.6, coupled to a minimal-cost ocean biogeochemistry model with explicit nutrient and oxygen cycling, and run under preindustrial and anthropogenic forcing scenarios. A similar, low-resolution version of the model, with identical biogeochemistry, is run in parallel for comparison. Here we present an analysis of the oxygen distribution from the two model configurations, focusing on the physical balances that maintain OMZ patterns, the generation of oxygen anomalies by variability in circulation and climate, and the regional patterns of oxygen change.

Oxygen dynamics in the Gulf of St. Lawrence and on the Scotian Shelf

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Dissolved oxygen is crucial for marine ecosystems and deoxygenation is of particular concern in regions that support rich and diverse ecosystems and fishery resources, such as the coastal ocean. Along the margins of Eastern Canada, a long-term decrease of dissolved oxygen has been observed in the St. Lawrence estuary and overall hypoxia has been progressively intensifying in the deep waters of the Gulf of St. Lawrence. Dissolved oxygen has also decreased in the deep waters of Emerald Basin, on the Scotian Shelf. Here, we use a coupled physical-biogeochemical model based on the Regional Ocean Modelling System (ROMS) to characterize the oxygen budget in the Gulf of St. Lawrence and on the Scotian Shelf and to investigate the mechanisms leading to deoxygenation. The model allows us to evaluate the roles of physical and biological processes, both pelagic and benthic. Moreover, a suite of model experiments are used to identify the sensitivity of dissolved oxygen to changes in circulation and other environmental forcing.

Climate change promotes risk of hypoxia in coastal zones threatening zoobenthic communities and their functions

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Coastal zones are highly productive ecosystems but are facing the increasing threat of climate-driven change coupled with eutrophication. Effects, such as rising temperature, changing salinity, and decreasing oxygen concentrations, become especially pronounced in the land-locked, low-saline environment of the Baltic Sea, an area that contains about one fifth of all reported hypoxic sites worldwide. We are using a long-term data series, spanning four decades (1973-2013) around the Åland Islands, Northern Baltic Proper, to describe the development of zoobenthic communities under an increasing risk of hypoxia in coastal zones. Current climate change scenario simulations suggest a further growing trend in hypoxic areas with a general elevation in depth, resulting in habitat reduction for aerobic organisms such as zoobenthos and benthivorous fish. We show that zoobenthic biomass increased in deep waters (20-35m) of the coastal zones, while decreasing in shallower areas, during the last decades. With these two trends eventually colliding (the hypoxic zone reaching the high-biomass depths), a major reorganization of benthic habitats and communities is to be expected. Our aim is to describe the consequences of recent and potential hypoxic conditions on functional traits and production of zoobenthos, and to apply climate models to project possible future developments for benthic communities in coastal zones.

CO2, CH4 and N2O dynamics and fluxes in the brackish Lake Grevelingen (The Netherlands)

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Lake Grevelingen in the South West Netherlands is a former estuary locked off from the sea by two dikes and a brackish lake since 1971 (salinities from 29 to 33 during our sampling). It is connected with the North Sea by sluices, has a surface area of 108 km2, a mean depth of 5.3 m, a maximum depth of 48 m, and about 60% of the area the depth is less than 5 m. During summer, bottom waters of Lake Grevelingen become anoxic. From January 2012 to December 2013, a biogeochemical survey was conducted at monthly interval at a fixed station (35 m depth) at Den Osse. Here, we focus on the analysis of partial pressure of CO2 (pCO2), and concentrations of CH4 and N2O obtained throughout the water column. The water column was isothermal in winter, stratification settled in spring, was maximal in summer (August), and vertical mixing occurred in fall. Overall, salinity increased from surface to depth, ranged from 29.57 to 31.57 in surface waters and from 30.55 to 32.74 in bottom waters, and was minimal in winter and maximal in summer. pCO2 in surface waters ranged from 270 to 650 ppm, and followed a typical seasonal cycle for temperate coastal environments shifting from CO2 over-saturation in winter to spring CO2 under-saturation due to the spring phytoplankton bloom, and shifting back to over-saturation in fall. Unlike the adjacent Southern Bight of the North Sea and the adjacent Oosterschelde, CO2 under-saturation prevailed in summer in Lake Grevelingen due to a summer-time bloom, as also evidenced by O2. pCO2 was vertically virtually homogeneous in winter and fall, and showed the strongest vertical gradient during the anoxic event in August. CH4 values were minimal in winter (20 nM) and as stratification developed during spring and summer a distinct maximum of CH4 (up to 730 nM) developed at the pycnocline (5 to 10 m). N2O showed little seasonal variations and only a very faint increase with depth, except in August when bottom waters became anoxic. At this time, N2O shown a maximum (_22 nM) at the oxycline (probably related to enhanced N2O production by nitrification at low O2 concentrations), and decreased in the anoxic layer (3 nM) (probably related to denitrification).

Seasonal, inter-annual and decadal changes of oxygen (O2), carbon dioxide CO2 (CO2), methane (CH4) and nitrous oxide (N2O) in the Scheldt estuary (Belgium, The Netherlands)

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We carried out monthly cruises to study the seasonal and spatial variations of dissolved oxygen (O2), the partial pressure of carbon dioxide CO2 (pCO2), methane (CH4) and nitrous oxide (N2O) concentrations in the Scheldt estuary, an strongly human impacted system located in Belgium and the Netherlands. This survey was initiated in 2008 for pCO2, and from 2009 onwards for methane (CH4) and nitrous oxide (N2O). In the lower estuary, pCO2 strongly decreased and oxygen saturation level (%O2) strongly increased during the spring phytoplankton bloom. In the upper estuary, two yearly maxima of pCO2 coinciding with minima of %O2 occurred in spring and fall due to enhanced nitrification and/or net heterotrophy. In the upper estuary, pCO2 decreased in winter due to lower temperature (affecting solubility and inhibiting biological activity). pCO2 also decreased in summer due to increase in primary production and decrease of net heterotrophy. In the upper estuary, maxima of CH4 were observed in winter due to enhanced river inputs (high discharge) while in the lower estuary higher CH4 was observed in summer. This was probably due to inputs of CH4 from inter-tidal areas at the mouth of estuary that increased in summer due to higher temperatures and higher organic matter availability. N2O also showed higher values during winter in the upper estuary, but in summer N2O was low in the lower estuary due to decreased solubility due to higher temperature. During winter 2009, extremely high N2O values were observed in the upper estuary, up to 3257 nM (23738% saturation). This was related to the problems encountered by the Brussels North waste water treatment plant (WWTP) in late 2009. One of the collectors of the station was shut down in 25 November 2009, and by 8 December 2009, the whole WWTP was shut down and the waste-water was delivered directly to the Rupel. Extremely high N2O values were observed in the upper estuary on 7 December 2009, and abnormally high N2O values (compared to other years) persisted until April 6 2010. The comparison of present day N2O values with historical data obtained in 1993-1997 and 1978 shows a spectacular decrease of N2O levels from maximal values of about 350 nmol L-1 in the 1990's to 50 nmol L-1 in 2009-2012. This decrease reflects the collapse of NH4+ concentrations in the estuary due to the overall improvement of water quality in relation to the implementation of WWTPs, leading to a decrease of nitrification rates. The maximum of N2O concentration in 1978 was located between salinities 10-15, in the 1990's it was located between salinities 2 and 5, and nowadays it is located at salinities < 2.5. This suggests that the maximum of nitrification was migrated upstream in the estuary.

CO2, CH4 and N2O dynamics in Belgian rivers across a gradient of oxygen concentration

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Two rivers and two streams close to the city of Liège in Belgium (Meuse, Ourthe, Geer and Blanc Gravier) were sampled to describe the dynamics of CO2, CH4 and N2O (for the first time in Belgium for freshwaters). The four systems were chosen to cover a gradient of size (stream to river) and of human influence (mainly forested to mainly agricultural watersheds). The study covers the period from February 2011 to March 2013 with weekly sampling in surface waters. The variables were very contrasted in the four systems, the Geer showing a strong enrichment in nitrogen and phosphorous in relation to the other three systems. The O2 concentrations were much lower, and the concentration of CH4, N2O and pCO2 were much higher in the Geer than in other three systems. The concentrations in CH4, N2O and pCO2 were higher in the Ourthe than in the Meuse and than in the Blanc Gravier. Marked seasonal variations were observed in the 4 systems. In general the concentration of CH4, N2O and pCO2 were higher in summer than in winter. This is related on one hand to the increase of temperature in summer that stimulates bacterial activity. Also in summer, the availability of organic matter for bacterial activity is higher after the spring phytoplankton blooms and also from allochthnous inputs from the watersheds. The increase of temperature and bacterial consumption of O2 in the water column leads to a lesser O2 penetration in the sediments that could stimulate benthic anaerobic processes among which methanogenesis and denitrification, leading to an increase of CH4 and N2O in the water column. Also, the production of N2O by denitrification strongly increases at low O2. During low water, the increase of residence time of the water mass and the decrease of current (decrease of degasing) allow an accumulation of CO2, CH4 and N2O in the water column. On the contrary during high water, dilution and increase of current (increase of degasing) lead to a decrease of concentrations. The four systems were over-saturated in CH4, N2O and CO2, excepted during spring phytoplankton blooms when an under-saturation of CO2 was observed in the Ourthe. Hence, the four systems were sources of CH4, N2O and CO2 to the atmosphere.

Activity and seasonal dynamics of freshwater epsilonproteobacteria in a sulfidic redoxcline of a meromictic karstic lake

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Sulfidic redoxclines are well-defined zones in the water column of both marine and freshwater environments characterized by contrasting gradients of oxygen and sulfide. In these interphases, sulfide is readily oxidized to sulphate by different groups of microorganisms, either lithotrophic or phototrophic, actively linking C and S cycles. Among the different bacterial groups involved, Epsilonproteobacteria represent the major fraction of autotrophic sulfide-oxidizers in stratified marine environments such as anoxic basins, coastal sediments and deep-sea vents. Less information is known for freshwater habitats, where epsilonproteobacteria have only been documented in terrestrial caves and springs and glacial deposits. Here, we report the abundance, seasonal dynamics, phylogenetic identity and activity of the epsilonproteobacterial community in the sulfidic redoxcline of a meromictic basin of Lake Banyoles. Our results indicate a clear seasonality in epsilonproteobacterial abundance, with maximal values in winter ($2.45 \cdot 10^7$ cells$\cdot$ml^{-1}, ~78% of total cells). Phylogenetic analysis using massive parallel sequencing and clone libraries datasets revealed that the target community is dominated by a phylotype closely related to *Arcobacter sulfidicus*, a marine, sulfur-oxidizing, autotrophic member of the genus *Arcobacter*. "In situ" incubations using radiolabelled bicarbonate and MAR-CARD-FISH analysis revealed that this population likely assimilated CO_2 in the dark. Clone libraries for the B-subunit of the ATP citrate lyase (*aclB*) —a key enzyme in the reductive tricarboxylic acid (rTCA) pathway of CO_2 fixation— yielded sequences closely related to *aclB* gene from other autotrophic epsilonproteobacteria such as *Arcobacter sulfidicus*, *Sulfurimonas autotrophica* and *Sulfurovum lithotrophicum*. Altogether, our data support the key role of Epsilonproteobacteria in linking C and S cycles, extending their ecological significance to freshwater habitats. Our current efforts are focused on the isolation of this freshwater representative to allow further studies aimed to investigate both its versatility regarding electron donors/acceptors and its capacity to facultatively grow on organic carbon sources.

Oxygenic primary production in the hypolimnion: a main driver for biogeochemical cycling at the oxic-anoxic interface in shallow lakes?

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Many shallow lakes develop an anoxic hypolimnion during summer stratification. A typical example for such a lake is the 16m deep, prealpine Lake Rot in Switzerland. In this lake, light can penetrate below the oxycline. We hypothesized that oxygenic primary production may influence the temporal dynamics of the oxic-anoxic interface in this lake and the biogeochemical processes in its close vicinity. In order to test this hypothesis we performed a field campaign in August 2013 during summer stratification. We determined the horizontal phytoplankton distribution and recorded several profiles of chlorophyll, turbidity and oxygen at trace levels throughout the water column. In addition, we determined oxygenic and anoxygenic primary production via in-situ incubation experiments with 14C labeled HCO3- at various depths above and below the oxycline. We found that chlorophyll-a as well as phytoplankton was present throughout the water column highlighting the potential for oxygenic photosynthesis even in the anoxic hypolimnion. While chlorophyceae was the main class of phytoplankton in the epilimnion, hypolimnetic phytoplankton community was dominated by cyanobacteria. In situ incubations showed that carbonate assimilation by oxygenic phototrophs took place even 3 m below the oxycline. In addition, oxygen profiles recorded during day-time revealed that the position of the oxic-anoxic interface correlated with solar irradiation. Our results suggest that oxygenic primary production under changing light conditions is an important driver of the variability of the oxic-anoxic interface position. Furthermore, the occurrence of carbonate assimilation of phytoplankton in the epilimnion suggests that oxygenic primary production may be an important source of electron acceptors for biogeochemical processes in the apparently oxygen depleted zone of Lake Rot.

Breathless nights- diel cycling hypoxia and acidification effects in shallow estuarine waters

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Diel-cycling hypoxia and associated cycling pH are common worldwide in shallow waters. The relationship between dissolved oxygen and CO2 cycles is driven by diel variation in the balance between photosynthesis and respiration, and can be similar in habitats as divergent as relatively pristine ponds in the interior of tropical mangrove islands, and shallow nearshore waters of the temperate, eutrophic Chesapeake Bay. Shallow, nearshore areas of oxygen depletion and CO2 enrichment may be especially important because the conceptual model of shallow waters serving as a refuge from deep water hypoxia may not apply where entire shallow systems, or extensive areas of shallow water in systems with deep basins, are affected. The effects of diel-cycling dissolved oxygen and pH can be difficult to predict because they will depend on whether periods of stressful conditions have residual negative effects during periods of high oxygen and pH, whether acclimation occurs, and whether animals compensate for lost feeding and negative physiological effects when stressful conditions abate.

Our laboratory experiments on fish and oysters indicate negative effects of exposure, but also acclimation to cycling conditions and compensatory feeding and growth. Exposure to diel-cycling hypoxia reduced growth of juvenile fish (Fundulus heteroclitus and Paralichthys dentatus) and eastern oysters (Crassostrea virginica), and increased the acquisition and progression of Perkinsus marinus (dermo) infections in oysters. Fundulus acclimated to dissolved oxygen cycling down to 1 mg/L after 10 days of exposure. Parlichthys compensated for negative effects of exposure to cycling dissolved oxygen by growing faster than controls when returned to high, constant dissolved oxygen conditions. The effect of low oxygen on oyster feeding remained constant over a 3 month long experiment, but adult oysters partially compensated for reduced feeding during periods of low oxygen by increasing filtration rates as oxygen concentrations returned to normoxic levels. pH that cycled to 6.8 7 d/wk (fish experiments) or 7.0 4-5 d/wk (oysters) had no effect on growth or disease dynamics. Modeling is currently underway to predict effects of diel-cycling hypoxia on fish growth across a range of dissolved oxygen patterns found in the field.

Putting oxygen and temperature thresholds of marine animals in context of environmental change: a regional perspective for the Scotian Shelf and Gulf of St. Lawrence

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We surveyed the literature in order to compile reported oxygen, temperature, salinity and depth preferences and thresholds of important marine species found in the Gulf of St. Lawrence and the Scotian Shelf regions of the northwest North Atlantic. We determined species importance based on the existence of a commercial fishery, a threatened or at risk status, or by meeting the following criteria: bycatch, baitfish, invasive, vagrant, important for ecosystem energy transfer, and predators and prey of the above species. Using the dataset compiled for the 53 regional fishes and macroinvertebrates, we rank species (including for different lifestages) by their maximum thermal limit, as well as by the lowest oxygen concentration tolerated before negative impacts (e.g. physiological stress), 50% mortality or 100% mortality are experienced. Additionally, we compare these thresholds to observed marine deoxygenation trends at multiple sites, and observed surface warming trends. This results in an assessment of which regional species are most vulnerable to future warming and oxygen depletion, and a first-order estimate of the consequences of thermal and oxygen stress on a highly productive marine shelf. If regional multi-decadal oxygen and temperature trends continue through the 21st century, many species will lose favorable oxygen conditions, experience oxygen-stress, or disappear due to insufficient oxygen. Future warming can additionally displace vulnerable species, though we note that large natural variability in environmental conditions may amplify or dampen the effects of anthropogenic surface warming trends. This dataset may be combined with regional ocean model predictions to map future species distributions.

The effect of oxygen availability on microbial long-distance electron transport in hypoxic sediments

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A novel type of filamentous bacteria has recently been discovered, which can conduct electrons over centimetre distances in marine sediments (Nielsen et al, 2010). Electrons gained from sulphide oxidation in deeper sediment horizons are transported across the suboxic zone to reduce oxygen in the upper thin oxic layer of the sediment. This spatial segregation of redox half-reactions by these so-called electrofilaments imposes a typical geochemical footprint onto the sediment. Among the first *in situ* observations of these fascinating bacteria occurred in the seasonal hypoxic marine lake Grevelingen (Malkin et al, in review.) and triggered research on their role in hypoxic environments. To gain insight in the metabolism of these bacteria and their growth under various oxygen pressures, sediment cores were incubated in the laboratory under different oxygen conditions. Microsensor profiles were made in sediment cores at regular time intervals to track the development of the "electric" geochemical signature. Electrofilaments developed and persisted in sediment cores incubated with oxygen levels exceeding 20% saturation. In these cores, we always observed a sub-oxic zone devoid of free sulphide. Our results indicate that long-range microbial electron transport is not limited to fully oxic environments, but can occur under a wide range of bottom water oxygen concentrations. Secondly, we show that that sediments recovering from hypoxia are a favourable habitat for the bacteria. This finding is now supported with new observations in the hypoxic systems of the Westerschelde (Belgium), Long Island Sound (US) and the Yarra Estuary (Australia).

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Hypoxia in the Black Sea northwestern shelf : from eutrophication to climate drivers

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As other stratified continental shelves exposed to eutrophication [*Diaz and Rosenberg, 2008*] the Black Sea North-western shelf (NWS) is affected by seasonal hypoxia: summer stratification prevents ventilation to compensate for benthic and pelagic respiration triggered by large nutrients inputs. We used a 3D coupled physical biogeochemical model to investigate the dynamics of bottom hypoxia in the Black Sea NWS at seasonal and interannual scales (1981-2009). The model [*Capet et al., 2013]* integrates a dynamical representation of organic matter in the sediment layer. Specific validation procedures prove the model's ability to resolve the seasonal cycle and interannual variability of oxygen concentration as well as the spatial location of the oxygen depleted waters and the resolution of the specific threshold of hypoxia ([O2]< 62 mmolO/m3).

We quantify the annual severity of hypoxia by an index H that combines the spatial and temporal extension of the seasonal hypoxia event. A multilinear stepwise regression analysis is applied on the long time series given by the 3D model, providing specific relationships between H and key eutrophication and climate related predictors, proposed on the basis of an in-depth analysis of the seasonal mechanism of hypoxia. We show that the accumulation of organic matter in the sediments, during the years of high nutrient discharge, continues to cause an important benthic oxygen demand after the reduction of riverine discharge (in the early 1990's for the Black Sea NWS), introducing an inertial aspect in the recovery dynamics. The major climate-related driver of hypoxia are (1) the sea surface temperature (SST) in March, which fixes oxygen solubility in the last days of mixing, hence the initial pool of oxygen locked under the thermocline and the temperature of bottom waters through the summers, affecting metabolic rates and (2) late summer SST, which determines the duration of the stratification period. Delayed autumnal mixing effectively increases the damages caused by hypoxia since bottom waters then bear the lowest oxygenation levels, and eventually reach anoxic level with subsequent releases of hydrosulphide from the sediments. Higher summer temperature, observed in the Black Sea during the last decade, succeeded to eutrophication drivers of the late 80's in sustaining hypoxia. This study thus highlights an additional urge to consider foreseen global warming to derive sound GES management policies.

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Sinking Particulate Organic Carbon in the Equatorial Tropical North Pacific Oxygen Minimum Zone

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The biological transfer of organic carbon from the upper to the deep ocean ultimately influences the exchange of CO2 between the atmosphere and the ocean. However even though particulate organic carbon (POC) fluxes are frequently measured and estimated globally, the processes which control these fluxes are still not fully understood. The few publications that have looked at fluxes in oxygen minimum zones (OMZs) have found the transfer of POC to depth is more efficient than in oxic regions and this difference is often not accounted for in global algorithms and models. Potential hypotheses for the decreased attenuation in low oxygen conditions are; the increase in the use of the energetically inefficient respiration pathways, fewer zooplankton so particles are less bioavailable and lithogenic ballasting due to the proximity of OMZs to coasts. Using marine snow catchers, sinking particles were collected from the Eastern Tropical North Pacific OMZ off the coast of Guatemala. 6 stations were sampled starting on shelf at 120 m water depth and moving offshore to deeper waters of 4 km. Profiles of sinking POC were taken at noon and at night to look for the influence of zooplankton diel vertical migration on POC flux. Particle export efficiency and transfer efficiency were calculated for fast sinking POC and compared to local and global estimates. It is integral we understand the current biological carbon processes within OMZs so we may be able to predict the future outcomes of expanding OMZs on sinking organic carbon and their role in the global carbon cycle.

Seasonal and inter-annual variations of community metabolism rates of a Posidonia oceanica seagrass meadow based on continuous oxygen measurements with optodes

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We report gross primary production (GPP), community respiration (CR), and net community production (NCP) over Posidonia oceanica meadow at 10 m in Corsica (Bay of Revellata) based on the open water O2 mass balance from a data-set of hourly measurements with an array of three O2 optodes deployed from August 2006 to October 2009. The method was checked by comparison with discrete measurements of metabolic rates derived from benthic chamber incubations also based on the diel change of O2. This comparison was satisfactory and actually highlights the potential caveats of benthic incubation measurements related to O2 accumulation in small chambers leading to photorespiration, and an under-estimation of GPP. Our data confirmed previous P. oceanica meadows GPP and CR values, strong seasonal variations, and net autotrophy. High resolution data revealed strong inter-annual variability, with a decrease of GPP by 35% and NCP by 87% during 2006-2007 characterized by a mild and less stormy winter compared 2007-2008 and 2008-2009. P. oceanica meadows are then expected to decrease export of organic carbon to adjacent communities (decrease of NCP), since a decrease in frequency and intensity of marine storms is expected in future in the Mediterranean Sea, due to a northward shift of the Atlantic storm track.

The roles of physical and biological processes in determining oxygen and pH levels in the eastern Pacific Ocean

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The roles of physical and biological processes in the regulation of oxygen and pH across a wide variety of biomes is investigated from historical data and newly collected information from autonomous systems. The processes of photosynthesis and respiration of course, directly link oxygen and pH. Surprisingly we find varying and strong levels of regulation by biological processes indicating that biota can and do determine their direct environment. The data used in this presentation come from: 1) a long time series (20+ years) from Monterey Bay, CA; 2) a large and extensive coastal pCO2 data set compiled for the west coast of the Americas from Alaska to Chile; 3) repeated alongshore hydrographic sections from central California to Mexico; and 4) high frequency (10 min) observations from moorings and the intertidal from Oregon to Santa Barbara.

Concurrence of Summer Algal Bloom and Bottom Hypoxia Zone off the Changjiang Estuary

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Hypoxia zone off the Changjiang estuary is one of the largest coastal hypoxia zones in the world, but only very limited investigations have been carried out so that the understanding of the formation mechanism of this hypoxia zone is very preliminary. Since 2006, several comprehensive cruises and real time buoy and mooring monitoring have been carried out off the Changjiang Estuary. In this presentation, an overview discussion on biogeochemical causes of this hypoxia water formation was descripted and discussed based on inorganic carbon parameters (DIC, Alk, pH), nutrients, chl a, DOC/POC, opal, HPLC-pigments,PON-15N, NO3-15N as well as control experiments. The highlights of our observation and research including: (1) we found concurrence of the Changjiang diluted water, diatom bloom and bottom water hypoxia off the Changjiang Estuary; (2) we observed two different typical dissolved oxygen depletion bottom waters in autumn, one of which seemed to be the remain of the previously summer hypoxia waters, and the other was newly formed in autumn.

Drivers of deoxygenation of the Baltic Sea during the last century

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The recent expansion of dead zones in coastal ecosystems has been primarily attributed to global warming and enhanced nutrient input from land and atmosphere, although the drivers of deoxygenation (climate versus nutrient inputs) can be difficult to disintangle. The largest anthropogenically induced dead zone in the world is the Baltic Sea, where the relative importance of physical forcing versus eutrophication is still debated. We have analyzed water column oxygen and salinity profiles to reconstruct oxygen and stratification conditions over the last 115 years and compare the influence of both climate and anthropogenic forcing on hypoxia. We report a 10-fold increase of hypoxia in the Baltic Sea and show that this is primarily linked to increased inputs of nutrients from land, although increased respiration from higher temperatures during the last two decades has contributed to worsening oxygen conditions. Shifts in climate and physical circulation are important determinants of hypoxic area, however, further nutrient reductions in the Baltic Sea will be necessary to reduce the ecosystems impacts of deoxygenation.

Oceanic anaerobic zone driven by a long-lived mesoscale eddy in the South Pacific

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Eastern boundaries upwelling systems are characterized by high productivity leading to low subsurface oxygen levels. The filaments produced in the upwelling fronts generate several mesoscale eddies transporting coastal waters towards oceanic regions, resulting in an export mechanism of physical, chemical and biological properties. In the fall of 2011, during the Tara Oceans expedition, suboxic conditions (<2 µM of O_2) were observed between 200 and 400 m depth at ~ 900 km offshore (30° S/81° W). These low oxygen conditions were associated with the Equatorial Subsurface Waters (ESSW), presenting subsurface denitrifying conditions that were evidenced by high levels of N_2O undersaturation (as low as 44%) and nitrite accumulation (> 0.5 µM). The station was located in the center of an anticiclonic mesoscale eddy (~150 km) according with the sea level anomalies derived from satellite altimetry. The eddy was tracked from its origin 315 days before the sampling, on the coast of central Chile (36.1° S, 74.6° W), where begun a northwest transport at 2.1 km/day (2.4 cm/s). Additionally, oxygen concentration at the moment of eddy formation at the coast was obtained in a glidder transect showing initial hypoxic conditions, which decreased the oxygen levels during the offshore transport of the eddy at oxygen consumption rates of between 4.21×10^{-2} and 2.75×10^{-4} µmol/m^2/d. The nitrous oxide concentrations, on the other hand, were depleted during the offshore transport, from oversaturations in the coast (obtained from five cruises conducted in the coastal zone in the last decade) to subsaturations in the eddy with a N_2O consumption rate of 3.92 nmol/L/d. These results show that mesoscale eddies not only transport physical characteristics from the ESSW from the coast to the oceanic region, but also have an important role in the exportation of biogeochemical characteristics along with create suboxic environments in the oligothrophic region of the Southeast Pacific.

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EFFECTS OF HYPOXIA ON PHYSIOLOGICAL RATES OF ZOOPLANCTON IN THE OXYGEN MINIMUM ZONE OF THE EASTERN SOUTH PACIFIC.

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The decreasing oxygen concentrations and expansion of the oxygen minimum zones (OMZ) may have important ecological and biogeochemical consequences. The survival of organisms and their physiological response to oxygen changes depend on the species and their oxygen thresholds tolerance and physiological adaptations.

The aim of the present study is to understand the physiological response (survival and production of eggs and fecal pellets) of zooplankton inhabiting the OMZ of the eastern South Pacific under low oxygen concentrations. During five cruises in summer and winter 2013 and summer 2014, several species of zooplankton (*Euphausia mucronata, Acartia tonsa, Calanus chilensis, Centropages brachatus*) were collected off Mejillones (23°S) and off Concepción (36°S) and oceanographic data (physical, chemical and biological variables).

In order to determine the physiological response of zooplankton subjected to different oxygen concentrations, females of copepods and organisms of *E. mucronata* were incubated after a starvation time (~12 h) individually in 100 mL vials and fed with a monoculture of the diatom *Thalasiosira weissflogii*. Treatments with different oxygen concentrations (hypoxia: 0.3 mL/L – 1 mL/L and normoxia: 9 mL/L) were conducted in quadruplicates at 14°C, sealed and incubated by 24 h under dark. Both, eggs and fecal pellets production, and survival of organisms were checked after the incubation time. The lowest oxygen threshold (0.3 mL/L) results in no survival and no production of eggs and pellets on *A. tonsa* and *C. brachatus*, but the maxima egg and pellet productions on *C. chilensis* and maximum fecal pellet production on *E. mucronata* (which didn't produce any eggs). At higher oxygen threshold (9 mL/L) the survival was higher for all species, with, however, lowest eggs and fecal pellet production in *C. chilensis* and *E. mucronata*. Both of these species appear to have higher tolerance and physiological adaptations to decreasing oxygen concentrations. Our results show, on the other hand, that decreasing oxygen levels on the oxygen monimum zone reducing the habitat of species that are not able to adapt to lower oxygen concentrations should have important consequences over the production of the region.

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Rates of microbial sulfur oxidation in low oxygen environments

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As one of the great biogeochemical cycles, the S cycle intimately couples with the C and N cycles [Garrels and Perry, 1974]. Microbial sulfide oxidation, in particular, likely represents a globally important yet poorly constrained source of biological carbon production and fixed nitrogen loss in many low oxygen environments [Walsh et al. 2009, Lavik et al. 2009, and Canfield et al. 2010]. Rates of microbial sulfide oxidation, however, are infrequently measured, likely due to the lack of standardized methods and protocols for these measurements. Bottle experiments yield information on the sulfide oxidation activity [Zopfi et al. 2001, Canfield et al. 2010], yet their coarse temporal resolution limits the extent to which reliable kinetic data can be extracted. We present here two novel methods for the determination of microbial sulfide oxidation rates in environmental systems: 1) based on the incubation of water samples in gas-tight glass syringes with sulfide determinations by the standard spectrophotometric technique; and 2) near real time measurement of sulfide oxidation using voltammetric techniques with Au/Hg amalgam microelectrodes. We have used these techniques individually and in concert to probe sulfide oxidation rates in diverse environments ranging from stratified East African lakes to marine oxygen minimum zones to laboratory cultures. Our measurements indicate that microbial sulfide oxidation is widespread in low oxygen environments, and is characterized by sulfide uptake with high affinity kinetics.

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Namibia's "dead zone": ecosystem functioning in an extreme environment

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Earliest recorded marine investigations in the coastal waters of Namibia documented and indeed mapped the "azoic zone" off Namibia – area on the inner shelf that was discounted as devoid of life due to anoxic bottom waters, frequently smelling of hydrogen sulphide. In the last two decades many secrets of this "azoic" or "dead" zone have been revealed, where benthic-pelagic coupling plays a critical role in the ecosystem functioning of the northern Benguela upwelling system. Benthic organisms here are finely adapted and specialized to exploit an abundant organic food supply coupled with severe hypoxia, whilst often living on the edge of respiratory survival. Through remarkable combinations of physical, chemical and biological characteristics, organisms manage and even thrive in this seemingly inhospitable environment. Low oxygen and associated challenges are not new in this region, so the organisms represent an adapted biological community. However the question of resilience to forecast consequences of climate change on the ocean, as well as disruption of the seabed by threatened mineral exploitation, could change this edge habitat and disrupt the existing fine balance in the system.

Eastern Pacific oxygen time series from the Stratus mooring and from floats

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In the tropical eastern South Pacific the Stratus Ocean Reference Station (~20°S, 85°W) is located in the transition zone between the oxygen minimum zone (OMZ) and the well oxygenated subtropical gyre. This region is also known for its high eddy frequency [Chaigneau et al., 2008]. From 6 April 2011 to 29 May 2012 oxygen was measured in the mooring from 9 oxygen optodes located between 45 m and 601 m depth at the southern boundary of the oxygen minimum zone. The oxygen time series describe the passage of several eddies, including a strong anticyclonic mode water eddy in February/March 2012 with oxygen decreasing by up to 200 μmol L^{-1} and an available oxygen deficit of 10.5×10^{16} μmol in comparison to its surrounding water. The eddy observed at the mooring was formed 11 months earlier off the coast of northern Chile. During its westward propagation one float was located for 3 months in this eddy and provided hydrographic and oxygen measurements along the path of the eddy. Several other floats were placed in eddies in the region, but did not stay continuously inside these eddies. The continuous oxygen measurements in the mooring and floats indicate high oxygen variability caused by eddies with enhanced oxygen in cyclonic eddies and reduced oxygen in anticyclonic eddies. Hence, oxygen trends determined from a few measurements might be biased by eddy processes. Finally, gliders with oxygen sensors may provide better eddy surveys than floats.

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The Benguela Upwelling System within an Oxygen Minimum Zone: Potential changes over a warmer climate

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Among the different Eastern Boundary Upwelling Systems, the Benguela upwelling system (BUS) presents one of the highest primary productions of all EBUS with an Oxygen Minimum Zone (OMZ) in its northern part. We investigate the impact of different drivers on production and biomass in the BUS under future potential climate change (scenario A1B2, 2080-2100: A1B(2080-2100)) compared to present period (PD(1980-2000)).To this end, a 3-D regional high resolution coupled physical-biogeochemical model (already validated for the BUS) was forced by global climate simulations with downscaled winds from the IPSLCM4 model. The results show that in the BUS this forcing corresponds to an mean SST increase of 1.4°C over the whole domain and is associated with a decrease of alongshore winds magnitude (-10% in its northern part) and of oxygen concentrations (-20-30 mmolO2.m-3 in its northern part). These climate drivers influence the ecosystem of the BUS with a subsequent decrease of primary production (-0.12; fractional change = (A1B(2080-2100)/PD(1980-2000))-1 (-1 to 0: decrease, positive values: increase)), phytoplankton (-0.148) and zooplankton (-0.126) biomasses over the whole domain. However an unexpected ecological niche with increased production and plankton biomass could develop in the northern part of the BUS and along the coast, associated with the increase of temperature, stratification and decrease of the winds.

Evaluating the effect of tidal mixing on oxygen dynamics in an Adriatic coastal lagoon.

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The identification of key processes governing hypoxia and anoxia in transitional and coastal marine environments is essential both for improving the prediction of the short-term evolution of dissolved oxygen (DO) and for setting up sound management measures, aimed at reducing negative effects on ecosystem functioning [Vaquer-Sunyer, 2012]. This study aims at modelling the DO concentration dynamics in a shallow water area located in the lagoon of Venice, which includes a lease area where Manila clam (Ruditapes philippinarum) is farmed. Despite the high water exchange rate with the Adriatic Sea, the area was affected by an anoxic crisis during a neap tide event from the 23rd to the 28th of August 2011: as a consequence, 30% of the clam stock was lost. The event was detected by one of the ten sensors belonging to the Venice Water Authority monitoring network, which was established in 2006. The network collects DO and other water quality parameters with an hourly frequency. The evolution of DO is simulated using two deterministic DO models and a data assimilation technique, the Extended Kalman Filter (EKF). The first model includes the following processes: the primary production and respiration, the atmospheric reaeration and the global ecosystem respiration. In the second one, a further terms which takes into account the effect of the tidal mixing on DO renewal rate, is introduced. The results suggest that the inclusion of this term markedly enhances the goodness of fit and allows a more accurate prediction of the risk of hypoxia/anoxia.

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Vertical distribution of fish larvae habitats and its relationship with dissolved oxygen gradients in the Tropical-Subtropical Convergence region in the Pacific off Mexico

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The vertical distribution of fish larvae habitats are analyzed in the Tropical-Subtropical Convergence region along the Pacific Ocean from the Gulf of California entrance to the southwestern coast off Baja California during February 2010, June 2010 and May 2012. In each sampling station were obtained CTD data and zooplankton oblique hauls with a closed-open-closed net of 505 μm. The strata sampled was determined by the depth of i) mixed layer, ii) thermocline and iii) oxygen minimum zone ($<$1 mL/L) up to 220 m depth. At the entrance of the Gulf of California (February), the oxyplet of 1mL/L was observed at 100 m depth with a slightly elevation towards the southern area of the entrance (Cabo Corrientes), where it was located at 70 m depth. During this period was define one fish larvae habitat at the entrance of the Gulf which was dominated by Anchoa spp.; a second habitat defined at the Pacific waters in the mixed layer, dominated by Vinciguerria lucetia; and a third habitat between the thermocline and the hypoxic zone dominated by Bregmaceros bathymaster and Diogenichthys laternatus. This habitat was the one with highest larval abundance showing an increased from the surface to the hypoxic zone. At the southwestern coast off Baja California was located a saline front (34.4) during May and June where the oxyplet of 1mL/L was observed between 60 and 70 m at south of Cabo San Lucas, deepens to the north below the 200 m in both periods. For both periods were define two larval fish habitats at the north of the saline front with low larval abundance; one in the mixed layer dominated by Vinciguerria lucetia and the other below of it is dominated by Triphoturus mexicanus. At south of the saline front were defined other two habitats, but with higher larval abundance. One between the mixed layer and thermocline with the highest specific richness dominated by V. lucetia, and other below the thermocline where the dissolved oxygen decreased from 1 mL/L dominated by D. laternatus. The results showed that the higher specific richness is located between the mixed layer and thermocline through the entire studied region, decreasing across the hypoxic zone. Also there are two species with higher abundance in the hypoxic zone (B. bathymaster in front of Cabo Corrientes and D. laternatus in front of Cabo San Lucas), this can be showing that the oxyplet of 1mL/L does not showed a dramatic effect over the total larval abundance; while the habitat over the thermocline can be compressed increasing the competence pressure between the fish larvae that coexist within this shallow area of the water column.

Expansion of the oxygen minimum zone and the denitrification regime in the Eastern Tropical North Pacific from 1972-2012

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Expansion of marine oxygen minimum zones associated with global change (e.g., Stramma 2008) has important consequences for ecosystem health, marine life and fisheries. Additionally, if oxygen concentrations are reduced to near zero, there are important consequences for the marine combined nitrogen cycle due to combined nitrogen loss via denitrification and anammox (Deutsch et al. 2011). The Eastern Tropical North Pacific (ETNP) is one such large region of anoxic water that currently hosts widespread water column nitrogen loss through these processes and models indicate that total water column nitrogen loss may vary with changing volume of low-O2 waters, as influenced by climate variability, particularly the Pacific Decadal Oscillation. To our knowledge, shipboard studies of long-term changes in the ETNP ODZ nitrogen loss and oxygen concentrations are lacking. In this study, we compared hydrographic measurements, water column dissolved oxygen and inorganic nitrogen along a transect in the ETNP in 2012 to similar measurements taken at the same locations in 1972, 1994, and 2007. Here we show that the oxygen content has decreased and the N-deficit (the amount of combined nitrogen lost through dentirification and anammox) has increased in magnitude in the world's largest ODZ over the past 40 years, but we found no evidence that the higher N deficit results from climate oscillations. A higher N deficit indicates a stronger combined nitrogen sink, which would further imbalance the global nitrogen budget.

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Intraseasonal variability of dissolved oxygen in the upwelling regions off central Peru and Chile: a modelling study

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The sources of intraseasonal variability for the upwelling along the coast of Peru and Chile are manyfolds: First there is energetic along-shore wind stress variability off Central Peru and Chile originating from fluctuations of the South Pacific anticyclone. Second, the efficient equatorial connection provides energy through coastal trapped Kelvin waves, and third, the baroclinic instability of coastal current system is associated to strong mesoscale activity. Such a variable environment is influential on biogeochemical properties within an extended oxygen minimum zone (OMZ), potentially contributing to lower-frequency changes of dissolved oxygen (DO) through rectification processes. In this study we document the intraseasonal variability of DO off central Peru and Chile from a high-resolution (7km) biogeochemical coupled model. The focus is on the covariability between the Peru Chile Under Current (PCUC) and the DO and on its forcing mechanisms, contrasting the two regions. We show that the DO intraseasonal variability has distinct characteristics between bothregions, reflecting differences in seasonality of the environmental conditions. This implies a different balance between processes (biogeochemical versus physical) associated to the rate of DO changes in the main upwelling cells as revealed by an explicit O2 budget.

Coupled dynamics of manganese, iron and phosphorus in the water column of the Black Sea and implications for phosphorus burial.

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The only long-term removal pathway for phosphorus (P) in marine systems is burial in sediments. Recent work suggests that reduced Fe-P minerals constitute a quantitatively important P sink in euxinic (i.e. anoxic and sulfidic) basin sediments of the Baltic Sea and Black Sea. These Fe-P minerals may be formed in the water column and/or at the sediment surface, possibly through conversion from Mn-Fe-P phases formed at the redoxcline. The processes leading to formation of particulate Mn, Fe and P in the water column, and the fate of these particulates during sinking and upon reaching the sediment are still incompletely understood. Here, we study the forms of dissolved and particulate Mn, Fe and P in the water column and surface sediment along a redox transect in the north-western Black Sea. We specifically concentrate on how the cycling of Mn, Fe and P and S in the water column affects P burial in shelf and deep basin sediments of the Black Sea.

Spatial and temporal scales of oxygen variability on a stratified continental shelf using an integrated ocean observatory

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The variability and range of environmental conditions on a stratified continental shelf provides challenges for observational characterization of the parameters relevant for low oxygen formation. We provide a summary of the spatial and temporal scales of variability from 10 years of observations measured on 30 cruises and collected from a variety of instrumented ocean platforms in the hypoxic region of the northern Gulf of Mexico. Observational platforms include time series of near bottom dissolved oxygen concentration from moored instruments, traditional station casts, integrated observations from undulating towed vehicles, and shelf Slocum gliders. Spatial and temporal scales of variability are crucial metrics that drive monitoring and sampling strategies. On the Texas-Louisiana continental shelf, spatial and temporal scales vary seasonally and interannually. Scales of variability of near-bottom oxygen concentration and other biogeochemical constituents (CDOM and chlorophyll fluorescence, nutrient concentration) on the open shelf are related to water-column stratification and coastal dynamics. To reduce costs of traditional field campaigns, there is a critical need to assess the ability of autonomous systems to monitor the known environmental variability appropriately as the use of autonomous vehicles (e.g., ocean gliders, wave gliders, and floats) is increasing in world's oceans. Therefore, adaptive multi-platform observing systems with mission flexibility are recommended to efficiently capture and quantify oxygen variability on continental shelves.

Occurrence of hypoxic events in the northern Adriatic Sea

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The northernmost part of the Adriatic Sea, exposed to the influence of one of the largest Mediterranean's rivers, the Po River, is a shallow, landlocked and restricted area. Hypoxic events frequently occur in the bottom layer of the northern Adriatic Sea (NAd) from mid-summer to mid-autumn, with highly variable extensions and durations. Long-term data series in the period 1972-2012 along with freshwater influence, stratification degrees, and circulation patterns are analyzed. Seasonal hypoxic events appeared within closed, cyclonic or anticyclonic circulation cells which contain low salinity waters in the surface layer. These gyres represent isolated circulation areas in which riverine waters reside for a certain period of time. Oxygenation of bottom waters during the period August-November of the last two decades has increased, whereas a decreasing trend was observed in surface waters, due to the increase in sea surface temperature. The frequency of hypoxic events seem to have decreased more recently during the studied period, especially on the eastern part of the NAd, roughly following a decreasing trend of the Istrian Coastal Counter Current frequency, which is geostrophic current in the eastern NAd and indicates the presence of an anticyclonic gyre [*Supić et al.*, 2003]. However, the year to year fluctuations in this current and bottom oxygen concentrations do not correspond closely pointing also other factors contribute to the interannual variability of bottom oxygen content in the NAd.

The decrease of the occurrence of hypoxic events can be additionally explained due to a general decrease of riverine phosphorus loads after the ban of polyphosphates in detergents (after the mid-1980s). Oligotrophication of the region was also supported by a period of marked reduction of freshwater discharge after 2000 [*Djakovac et al.*, 2012]. Intense nutrient regenerations occur in bottom waters during hypoxic events in the NAd [*Giani et al.*, 2012]. A trend of increased N/P ratio over the investigated period was observed, which coincides with general phosphorus limitation in the NAd.

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Linking benthic biodiversity and oxygen conditions at the sea floor combining statistical and mechanistic modeling. Case study on the Black Sea's northwestern shelf affected by recurrent seasonal hypoxic events.

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Coupled biogeochemical-circulation models provide a large amount of information on physical (e.g. currents, salinity, temperature, shear stress) and biochemical conditions (e.g. oxygen, inorganic nutrients, sinking detritus) but cannot provide information on species richness. We propose to link these aspects by applying canonical ordination techniques (e.g. Redundancy Analysis, CoInertia Analysis) on a large data set of macrobenthos collected on the Black Sea's north-western shelf with in-situ sediment data (e.g. granulometry, carbon and nitrogen content, C/N ratio, CaCO3 content) and bottom conditions (e.g. shear stress, level of oxygen stress, flux of organic matter to the sediments) provided by a three dimensional model. Beyond taxonomic description, the analysis is performed on the functional composition of the macrobenthos: A trait-based approach is used to assess the functional composition of the macrobenthos by associating the considered species to a list of biological, ecological and behavioral traits. This approach allows appraising how local conditions determine the functional and taxonomical diversity and provides a mean to evaluate the impact of habitat alteration on the ecological role of benthic assemblages. A particular attention is given to the influence of seasonal hypoxia on benthic biotopes composition.

Seasonal dynamics of the oxygen budget on the Namibian shelf: a model perspective

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We derived the oxygen budget for the Namibian shelf ecosystem in the northern Benguela Upwelling System (BUS, 16-28°S), here defined as the region down to 300 m depth. Simulation results of a fully coupled hydrodynamic and biogeochemical ecosystem model were used to identify the relevant source and sink terms governing the regional oxygen budget. Seasonal cycles based on an 8 year climatology from model results (2000-2008) were employed. In order to investigate spatial heterogeneity along the Namibian shelf caused by the great variability in the bathymetry of the continental margin, it was divided into four domains of equal latitudinal dimensions. This offered the opportunity to specifically compare the dynamics of the oxygen budget of the two major upwelling cells (Cape Frio and Lüderitz) with those of the two central regions off Namibia. Coastal upwelling of nutrient rich water fuels primary production and hence oxygen evolution in the euphotic zone. The oxygen drawdown by mineralisation of sinking organic matter maintains steep oxygen gradients in the water column. The model also comprises nutrient cycling in the bottom sediment and distinguishes between thin oxic and thick anoxic sediments, the latter being covered by mats of large sulfur bacteria. This implementation turned out to be important as these benthic bacteria keep the redoxcline confined to the sediment and minimise the release of hydrogen sulfide into the water column. Furthermore, vertical migration of zooplankton in response to the oxygen concentrations in the water column may act as a positive feedback, which may even prevent a fast deoxygenation of suboxic waters. A key feature of the northern BUS is the subsurface transport of low oxygen water in the pole-ward undercurrent (PUC) along the entire coast of southern Africa. The model results show that the PUC imprints a significant seasonal signal on the local biogeochemical oxygen drawdown. In austral summer, the PUC replaces the well ventilated water at the shelf edge with oxygen poor water, but also supplies some oxygen to the otherwise anoxic bottom layer at the inner shelf.

The seasonal and spatial variations of phytoplankton community and their correlation with environmental factors in Oualidia lagoon (Moroccan Atlantic)

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Physico-chemical variables in the coastal environment are subjected to wide spatio-temporal variations. The various physico-chemical parameters viz: temperature, salinity, pH, dissolved oxygen and nutrients of the environment are the factors which mainly influence the phytoplankton in the coastal biotopes. The ranges of values of surface water temperature (°C), salinity (psu) and dissolved oxygen (mg l^{-1}) were: 15.3-24.2; 26.6-40.8; 6.1 – 11.1, respectively. The values (µmol l^{-1}) of nutrients were: nitrite 0.33-16.21, phosphate 4.37-104.37 and ammonia 5.47-3.44. A total number of 127 species of phytoplankton representing two classes viz: Bacillariophyceae (81) and Dinophyceae (46) were recorded. Bacillariophyceae appeared to be the dominant group in respect of total species and cell numbers.
Temperature, dissolved oxygen, salinity and nitrite were found to be important parameters influencing the species composition and succession of phytoplankton at this location. Whereas, the role of ammonium and orthophosphate remained insignificant in this regard.

Keywords: Physical parameters, Phytoplankton, Moroccan Atlantic, Oualidia lagoon.

LACK OF VERTICAL MIGRATION OF ZOOPLANKTON AS PROOF OF THE HABITAT COMPRESSION HYPOTHESIS IN THE, LOW-OXYGEN, EASTERN TROPICAL MEXICAN PACIFIC, DURING SPRING.

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Zooplankton samples obtained with a MOCNESS net, from 500m to surface during the PROCOMEX XI cruise to the Mexican tropical Pacific. Two east-west transects were followed. In the North, hydrographic conditions were more influenced by the California Current, with lower temperatures and a deeper oxygen minimum (OM), than the southern transect, placed over more tropical waters with more affinity with the Oxygen Minimum Zone (OMZ) and shallower OM. A drastic change was found from 100m to 500m with lower biomasses and abundances. OM (assuming OM as 45μmoles/Kg.) was deeper in the Northern transect (90-110m) and shallower in the southern transect (60-80m). The vertical distance between 45 and 4.5 μmoles/Kg of oxygen, is greater in the northern transect. During a 48 hours period of continuous sampling, the vertical distribution of zooplankton showed the same pattern, with diel zooplankton biovolumes differences only in the first 100m and with practically no change in deeper waters. Low pH in sea water, is coincident with low oxygenated waters, more evident in the southern transect, higher pH is present due to the presence of California Current waters in the western sector of the northern transect. Vertical migrators like euphausiids, were present in low oxygenated waters during the day, and confined to the first 100 m during the night. Surprisingly, copepods were equally abundant during the day than during the night, in near surface waters. It is assumed that oxygen acts as a barrier to most zooplankton species, and only highly adapted species like euphausiids, and probably certain copepods, cross this barrier. Zooplankton Carbon is 69.42 μg C per meter in the first 100m and 5.675 in the next 400 m, a difference of 1/12 of zooplankton "concentration".

Correlation between the acoustic noise field measured in a Posidonia oceanica bed and the photosynthetic activity.

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During the period of one week, from May 8 to 15, 2013, acoustic data was gathered at three locations over a *Posidonia oceanica* bed in the Bay of Revellata, Corsica. Preliminary analysis of the acoustic data shows that the environmental noise field in the band 2-7kHz was dominant during the period. The noise in this band is generally associated with wind and surface agitation. However, the noise power was not significantly correlated with wind speed. On the contrary, the diel cycle of the noise power at three locations was highly correlated with the water column concentration of O2, as measured by optodes. These measurements of environmental noise have confirmed the correlation between active acoustic signals transmitted along a seagrass meadow and the photosynthetic activity of the plants observed in a previous experiment conducted in the same area .The results suggest that acoustic noise can be used as a proxy for the photosynthetic oxygen production of a *Posidonia oceanica* meadow. Therefore, this work is a contribution for the development of a low cost passive acoustic system to assess the primary production of coastal ecosystems.

Intercomparison of Hypoxia Models for the Northern Gulf of Mexico

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Observations of coastal hypoxia have increased dramatically over the past 50 years likely due to increased anthropogenic nutrient loading. The largest of these hypoxic zones in U.S. coastal waters (15,000 $\pm$ 5,000 km2) forms every summer over the continental shelf in the northern Gulf of Mexico due to nutrient and freshwater input from the Mississippi/Atchafalaya River System. The hypoxic zone varies interannually in terms of both, extent and location due to variations in spring nutrient load, freshwater discharge, atmospheric forcing and circulation patterns. Several coupled circulation-hypoxia models are under development for this region in order to improve mechanistic understanding of the primary factors controlling hypoxia formation and to inform nutrient management decisions in the watershed. Here we report on an intercomparsion of hypoxia models for the northern Gulf of Mexico that is being undertaken within the NOAA-funded Coastal & Ocean Modeling Testbed project. The following four models are included: 1) an implementation of the Regional Ocean Modeling System (ROMS) coupled with its native hypoxia module, 2) an implementation of the Finite Volume Coastal Ocean model (FVCOM) coupled with the ROMS hypoxia module, 3) an implementation of FVCOM coupled to a modified version of the Water Analysis Simulation Program model, and 4) an implementation of the U.S. Navy's coastal ocean model coupled with the Gulf Ecosystem Model. The comparison will focus specifically on oxygen sources (determined by primary production, air-sea gas exchange and vertical stratification) and sinks (due to respiration in the water column and sediments) with the ultimate goal of improving model formulations, hindcasts, forecasts and mechanistic understanding.

The potential of Mn/Ca in benthic foraminifera as a low oxygen indicator

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Coast and shelf regions are of large importance as ecosystem service providers. They are nursery areas for many fish and shellfish species and in addition, a large proportion of the human population is living along the world's coasts. Increased environmental pressure, as a consequence of eutrophication and climate change, has resulted in spreading of so called dead zones, i.e. seasonal or permanently hypoxic/anoxic bottom areas, in many coastal locations. We choose to study the sediment environmental archive and its contents of shell bearing microorganisms, so-called foraminifera, to better understand the involved processes and the impact of the marine life. We were particularly interested in studying various trace metal/Ca in the calcitic shells of the foraminifera and how they vary with changes in dissolved oxygen concentration, carbonate chemistry and temperature (Groeneveld and Filipsson 2013). Foraminifera (low oxygen tolerant benthic species Buliminia marginata and Globobulimina turgida) were collected from the Skagerrak and Gullmar Fjord on the Swedish west coast several times during 1.5 years. We identified live specimens through Cell Tracker Green labelling and measured trace elements (Mg/Ca, Mn/Ca). As the specimens were alive when collected we assume it is unlikely that any diagenetic coatings have already significantly affected the trace metal/Ca. Our results indicate that Mn/Ca from Globobulimina turgida can potentially be related to variations in dissolved oxygen concentration in the microhabitat where the specimens calcify. Samples from the Skagerrak displayed increased Mn/Ca levels in specimens which lived deeper in the sediment than those that lived near the surface. Globobulimina turgida samples from the low oxygen Gullmar Fjord displayed significantly increased Mn/Ca, being highest when dissolved oxygen was at a minimum. Our study suggests that trace metal/Ca in benthic foraminifera from shelf regions have the potential to record past variations in bottom water temperature (Mg/Ca) and dissolved oxygen concentrations (Mn/Ca) but an additional impact of the inorganic carbonate chemistry cannot be excluded.

References: Groeneveld J & Filipsson HL. 2013. Mg/Ca and Mn/Ca ratios in benthic foraminifera: The potential to reconstruct past variations in temperature and hypoxia in shelf regions. Biogeosciences 10, 5125–5138, doi:10.5194/bg-10-5125-2013

Segregation patterns of MCG subgroups in stratified karstic lakes

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The *Miscellaneous Crenarchaeotic Group* (MCG) are dominant components of archaeal communities in subsurface marine sediments [*Kubo et al.*, 2012]. Representatives of this group have also been consistently found in deep-sea hydrothermal vents, coastal sediments, freshwater plankton and sediments, and soils. This widespread distribution agrees with the large phylogenetic diversity, consisting of 17 subgroups with an intragroup similarity ranging from 82% to 94% [*Kubo et al.*, 2012]. Since most of these 17 subgroups already include sequences from terrestrial, freshwater and marine sources, any inference of biogeographical trends among specific MCG clades is certainly risky. In this study we made use of massively parallel sequencing on DNA and cDNA samples from three stratified lakes differing on trophic status and oxygenation regimes (Basin CIII Lake Banyoles, Lake Cisó and Lake Vilar) to assess habitat segregation patterns among the identified MCG subgroups. Relative abundance of pyrotags affiliated to MCG was strongly influenced by oxygen concentration with a higher contribution of MCG sequences (from 8 to 45% of the total archaeal community) in anoxic samples when compared to fully oxic or microaerophilic samples (≤2% of total archaeal sequences). A detailed phylogenetic analysis comparing planktonic anoxic samples showed a clear prevalence of subgroups MCG-5a and MCG-5b in oligotrophic meromictic basin C-III (from 22 to 66% of total MCG community) and subgroup MCG-6 in eutrophic, holomictic lakes Cisó and Vilar (ranging from 33 to 68%). Subgroups 9, 10, 11, 13, 15 and 17 were also observed in planktonic and sedimentary compartments of the three studied lakes. Interestingly, MCG-15 showed a marked increase in its relative contribution to total archaeal community in cDNA fractions (40%) when compared to DNA samples (15%), suggesting that this subgroup may keep some activity in this habitat. Altogether, our analysis identified representatives sequences of only 9 MCG subgroups whereas any sequence affiliated to the remaining 7 MCG clades (MCG-1, -2, -3, -4, -7, -8 and -14) were recovered. Further work is needed to elucidate the environmental drivers behind this segregation.

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Assessing Mechanisms Controlling Hypoxia through Multivariate Regression

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Observations of the areal extent of seasonal hypoxia over the Texas-Louisiana continental shelf from Observations of the areal extent of seasonal hypoxia over the Texas-Louisiana continental shelf from 1985 to 2013 are correlated with a variety of physical and biogeochemical forcing mechanisms. We use the Louisiana Universities Marine Consortium (LUMCON) long term survey to examine the variability of hypoxic area. We identify discharge, nitrogen concentration, east-west winds, as important factors. We use the model parameters and unexplained variability to estimate the time to detect a shift in the system due to a policy intervention. We use the model to examine the marginal effects of unusual observations of hypoxic area. Understanding the observed variability of the hypoxic area measurements, the impact of past events and the potential impact of future intervention provides guidance for system management.

Changes in habitat availability under increased upwelling in the Humboldt Current System

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Increase in greenhouse gases and atmospheric temperature may lead to changes in the wind regime that controls upwelling in Eastern Boundary Upwelling Systems (EBUS). The Humboldt Current System (HCS) is an EBUS where naturally hypoxic conditions (<60 μmol/kg), low pH and low saturation states with regard to $CaCO_3$ occur near the surface. However, if an increase in upwelling-favorable wind is to occur as a result of climate change, these features could be either potentiated or dampened, as has been projected for other EBUS, i.e., the California Current System and the Canary Current System, respectively. Here a regional model simulation based on ROMS was used to investigate the physical and biogeochemical responses of the HCS to a doubling in wind stress. We then look at the changes in habitat availability combining critical concentrations of oxygen, pH, and $CaCO_3$ saturation values. This will shed some light about the changes in environmental variables that could stress not only the calcifying organisms but also all those whose livelihood critically depends on oxygen.

Monitoring hypoxia: approaches to addressing a complex phenomenon in the Black Sea

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In this contribution we present an overview of results and share experiences from monitoring and assessing various hypoxia phenomena in the Black Sea. The focus is on approaches and technologies for monitoring of, e.g., mesoscale seasonal patterns in water column oxygenation, multi-decadal trends in oxycline boundary shifts, fast oxygen fluctuations at the pelagic redoxcline and the sediment-water interface, and seasonal changes in bottom-water oxygen. The various temporal scales (from hours to decades) and spatial patterns (from local to basin-scale) in water column oxygenation were addressed using state-of-the-art technologies, e.g., a free-falling pump CTD, a profiling instrumentation platform, ARGO floats and static moorings equipped with oxygen optodes, and long-term monitoring programs based on standard CTD casts.

A free-falling pump-CTD provided high-resolution profiles of oxygen and reduced compounds in the Bosporus outflow to the Black Sea, and proved highly suitable to resolve oxygen intrusions into highly stratified systems and hence, to identify and localize processes in complex redoxclines. We also recommend an example of novel technology applied in the Baltic Sea, which would be highly suitable for the Black Sea. The time series recordings of the profiling instrumentation platform GODESS in the Gotland Basin allowed a thorough characterization of oscillating redoxclines as temporally dynamic, three-dimensional systems.

Oxygen sensor equipped ARGO type profiling floats are powerful tools to resolve seasonal changes in water column oxygenation and emphasize the importance of mesoscale processes for oxygen distribution in the Black Sea basin. Stand-alone static moorings equipped with optical oxygen sensors, Doppler current meters, and turbidity sensors allowed to resolve fast oxygen fluctuations at the sediment-water interface due to, e.g., internal waves and Ekman pumping on the Crimean shelf, and identified the formation of seasonal (summer) hypoxia as an highly dynamic process on the north-western Black Sea shelf.

Multi-decadal time-series monitoring data based on standard CTD measurements revealed the imprint of climate change and eutrophication on long-term oxygen distributions in the central Black Sea and hence, highlight the importance of maintaining long-term commitments to oxygen monitoring programs. Monitoring data from the last 90 years reflect the rising of the upper boundary of the suboxic zone in the 1970s and 1980s due to eutrophication, and again in the 1990s and 2000s due to NAO forcing, while eutrophication relaxed. Such long time series data allow separating out the effects that climatic forcing and eutrophication exert on oxygen depletion i.e., in the Black Sea.

These case studies were part of the EU-FP7 project HYPOX ("In situ monitoring of oxygen depletion in hypoxic ecosystems of coastal and open seas, and land-locked water bodies"). The challenge in any kind of monitoring is to choose the appropriate approach and technology that is suited to resolve the temporal and spatial scales on which the phenomenon occurs. Our results reveal the vital need for dedicated oxygen monitoring programs to adequately address the risk of hypoxia formation and ecosystem response.

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Transient and equilibrium responses of oceanic dissolved oxygen to global warming

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Transient simulations with current-generation Earth System Models, observations from the recent past, and theoretical arguments suggest a consistent trend toward lower oxygen content of the global ocean. In nearly all models, this trend is predominantly driven by changes in ocean circulation and mixing, particularly the increase in upper ocean stratification. This trend is to a substantial degree reinforced by upper ocean warming through a decrease in solubility. The contribution of changes in export of organic material to the deep ocean and thus respiratory oxygen consumption is comparatively small.

Proxy records of oxygenation covering the last glacial termination – the transition from the last ice age to the Holocene - support the modeling studies insofar as that oceanic oxygen concentrations are sensitive to climate warming. Both proxy records and models show a decrease in the upper ocean oxygen concentration and an increase in the volume of hypoxic waters as the ocean warms. In contrast, the deep ocean oxygenation during the last termination is opposite to the general expectation and to the simulated deoxygenation in Earth System Models. However, past changes were much slower than current anthropogenic changes making the comparison between proxy data and transient model projections challenging.

Here, we analyze output from a multi-millenium simulation of the comprehensive coupled carbon cycle-climate model GFDL ESM2M. For the first time, an IPCC-class Earth System Model was integrated into equilibrium under doubling of atmospheric CO_2. We show that the deep Southern Ocean shows a nadir in ocean deoxygenation about six to eight centuries after the doubling of CO_2, after which the oxygen concentration starts to rise again. This suggests that rapid transient warming may cause deep ocean oxygen to decrease, whereas at steady state, deep ocean ventilation may actually be more vigorous in a warm ocean. The exact processes that contribute to the nadir in deep ocean oxygen will be presented and the implications for past and future changes in the global carbon cycle will be considered.

Metabolic versatility of a globally distributed nitrite oxidizer, *Nitrococcus sp.*

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In the ocean, aerobic nitrite oxidation constitutes the major pathway that produces nitrate, the thermodynamically most favorable electron acceptor in the oxidation of organic matter under oxygen deficient conditions. In oxygen minimum zones (OMZs) nitrite oxidizing bacteria (NOB) have been found to recycle a substantial portion of previously reduced nitrate, thereby retaining nitrate in the system and potentially reducing N-loss. Our knowledge on the distribution and activity of NOB in OMZs and their ecological adaptation to oxygen deficient conditions is however limited. Only a few genera of NOB have been described so far, of which *Nitrospina* appears to show marine dominance, but the lesser-known *Nitrococcus* can also occur in great numbers (4.9 % DAPI) in OMZ waters.

To investigate the metabolic adaptation mechanisms of *Nitrococcus* to oxygen depleted conditions prevailing in OMZs, we combined environmental and pure culture incubation experiments, single cell analyses and genome annotation. Surprisingly, *Nitrococcus* abundance was found to correlate with rates of nitrate reduction to nitrite in the Namibian OMZ, and its nitrate-reducing capability was verified in pure culture experiments. Meanwhile, the chemolithoautotrophic bacterium *Nitrococcus mobilis* adapts an organoheterotrophic lifestyle under oxygen deficient, organic rich conditions. The genome of *Nitrococcus mobilis* encodes various sulfur metabolizing enzyme complexes, indicating the participation of *Nitrococcus* in sulfur cycling and its potential involvement in sulfide detoxification in OMZ waters. Analyses of metagenomic datasets and 16S rRNA libraries further revealed a global distribution of these NOB. Our observations suggest an important role of *Nitrococcus* in oxidative as well as reductive branches of the nitrogen cycle, and its metabolic versatility could explain its high abundance in dynamic ecosystems such as the Namibian OMZ.

Inference of super-resolution ocean pCO2 and air-sea CO2 fluxes from non-linear and multiscale processing methods

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In recent years the role of submesoscale activity is emerging as being more and more important to understand global ocean properties, for instance, for accurately estimating the sources and sinks of Greenhouse Gases (GHGs) at the air-sea interface. The scarcity of oceanographic cruises and the lack of available satellite products for GHG concentrations at high resolution prevent from obtaining a global assessment of their spatial variability at small scales. In this work we develop a novel method to reconstruct maps of CO2 fluxes at super resolution (4km) using SST and ocean colour data at this resolution, and CarbonTracker CO2 fluxes data at low resolution (110 km). The responsible process for propagating the information between scales is related to cascading properties and multiscale organization, typical of fully developed turbulence. The methodology, based on the Microcanonical Multifractal Formalism, makes use, from the knowledge of singularity exponents, of the optimal wavelet for the determination of the energy injection mechanism between scales. We perform a validation analysis of the results of our algorithm using pCO2 ocean data from in-situ measurements in the upwelling region off Namibia.

Filamentous bacteria involved in long-distance electron transport in marine sediments.

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In marine anoxic sediments, reduction of sulfate is the predominant electron-accepting process coupled to organic matter degradation, and results in the production of sulfide. Prolonged exposure of such a sediment to overlying oxic seawater has been shown to result in the separation of oxygen and sulfide. A suboxic zone developed which was devoid of free sulfide, and a pH maximum was observed just below the sediment surface [*Nielsen* et al., 2010]. Recent research showed that the presence and depth of the suboxic zone coincided with the presence of bacteria that are most closely related to the *Desulfobulbaceae*. These bacteria formed filaments spanning the distance between oxygen and sulfide, and appear to be actively involved in the coupling of electron-donating and -accepting processes over distances up to several cm. Cutting the bacterial filaments relieved the separation of oxygen and sulfide gradients, supporting the idea that electrons are transferred over long distances [*Pfeffer* et al., 2012]. Not only laboratory incubations, but also *in situ* suboxic sediments have been observed to be populated by filamentous bacteria related to *Desulfobulbaceae* [*Malkin* et al.]. The aim of the present research is to study the ecophysiology of these filamentous bacteria in more detail. Questions that we try to answer concern the metabolism and growth requirements of the filamentous bacteria and the interactions with other bacteria in the sediment, e.g. sulfate-reducing bacteria and competing aerobic microorganisms. Resolving these aspects will help to elucidate the processes that link the physiology of the filamentous bacteria to the observed geochemical gradients of sulfide, oxygen and pH in marine sediments.

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Oxygen deficiencies in the Schelde and Elbe estuary: same difficulties, different causes

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The expansion of oxygen minimum zones (OMZ's) in estuaries, sometimes also referred to as 'dead zones', is catastrophic for ecology and economy [e.g. *Diaz*, 2001; *Conley et al.*, 2009]. At low oxygen levels, benthic invertebrates and fish are physiologically stressed [e.g. *Vaquer-Sunyer & Duarte*, 2008] while estuarine biogeochemistry is drastically changed [e.g. *Middelburg & Levin*, 2009]. In the Elbe estuary a minimum oxygen zone can be found around 50 km downstream the weir at Geesthacht [*Amann et al.*, 2012], while in the Schelde two minimum oxygen zones can be found, one around 20 km downstream the sluice of Merelbeke, and another one around 70 km downstream the sluice [*Soetaert et al.*, 2006].

When studied over a time period of six years (2004 – 2009), oxygen conditions have greatly improved in the Schelde estuary, while in the Elbe estuary, the existence of this oxygen minimum zone seems to persist. This while biochemical oxygen demand measurements are about two times lower in the Elbe than in the Schelde estuary. To understand which processes are causing these different oxygen dynamics, we applied a one-dimensional reactive transport model to both estuaries. In the Schelde we found oxygen problems to be mainly related to organic matter input from the major tributaries, while in the Elbe oxygen dynamics were found to be more influenced by estuarine morphology. This implies that water quality management will be more effective to remediate hypoxia related problems in the Schelde than in the Elbe.

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Foraminiferal capacities to survive anoxia: comparison of two species developing various anaerobic strategies

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Foraminifera are marine micro-organisms protected by a shell. They can constitute an important part of the total benthic biomass, particularly in the deep marine environments. Various foaminiferal species of foraminifera have been observed in hypoxic and anoxic sediment layers. Therefore, the specific microhabitat distribution seems to be related to sediment geochemistry.

The aim of our study was to compare the capacity of two species to survive in anoxia and to understand their potentially anaerobic metabolism. We studied an intertidal species *Ammonia tepida* living preferentially at the sediment-water interface and compared its behaviour with that of the open marine species *Globobulimina turgida* living in deeper sediment layers.

Laboratory experiments showed that both spieces were able to survive prolonged anoxia, apparently with different startegies As shown in previous studies (Risgaard-Petersen et al., 2006; Piña-Ochoa, 2010) *Globobulimina turgida* was able to accumulate and respire nitrate to sustain anaerobic respiration for at least 3 month . A. tepida did not accumulate nitrate and had no capacity for nitrate respiration.

Summarising, a denitrification has been demonstrated for some species of foraminifera, while other species surviving anoxia do not show this capacity. Consequently, they must adopt other survival strategies, such as other types of anaerobic metabolism than denitrification.

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Oxygenation trends in the coastal waters of Gulf of Trieste (Northern Adriatic Sea)

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The Gulf of Trieste is a shallow basin, located at the northernmost latitude of the Mediterranean Sea and it is subject to riverine inputs, strong seasonal variations in temperature and salinity and intense wind regime. The river-borne nutrient discharges coupled to the circulation regime, which occasionally determines a closed circulation and the entrainment of waters in the northernmost part of the sub-basin, have caused episodic late summer – early autumn hypoxic and anoxic events during the 1970s, 1980s and beginning of the 1990s, causing mortality of benthic fauna [*Kollmann and Stachowitsch,* 2001]. In recent periods, however, an oligotrophication trend has been detected (*Mozetic et al.,* 2009, *Giani et al.,* 2012) which is the consequence of a marked decrease in the continental discharge of nutrients [*Cozzi et al.,* 2012]. In order to verify if this trend has induced changes in the occurrence of hypoxic events in the northernmost part of the Adriatic and if there are any signals of deoxygenation due to the warming tendency observed in the gulf of Trieste *[Malacic et al.,* 2006], we have analyzed some of the existing decadal and multidecadal time series of dissolved oxygen data, based both on polarographic sensors and on Winkler chemical analyses on discrete samples. Preliminary results of the analysis of data collected in the deeper part of the Gulf from 1986 to 2013, mostly on a regular monthly basis, and in a time-series coastal station which is part of the Long Term Ecosystem Research (LTER) network, from 1986 to 2013, show an overall tendency toward increasing oxygen concentrations in the bottom waters and no deoxygenation trend in the surface waters.

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Using fish ear bones as proxies for tracing hypoxic events.

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Environmental water allocations are used in the Murray-Darling Basin (MDB), Australia to maintain habitat and food resources, but can trigger toxic cyanobacterial blooms and hypoxic events. Fish kills due to hypoxic blackwater events have been recorded in the MDB, but some fish are thought to have adapted to low oxygen environments. Tracing the oxygen history of fish throughout their life is difficult, but the ear bones (otoliths) of fish, which grow incrementally and accrete $CaCO_3$ along with trace elements may provide a novel option. Our aim was to determine if trace elements in the otoliths of fish could be used as a natural tracer of hypoxic events in freshwater systems. We used two approaches to test this aim, a laboratory experiment and examination of field-caught fish that had either experienced or died from hypoxic events followed by investigation of historical otoliths. Our controlled laboratory experiment exposed fish to varying levels of dissolved oxygen in combination with temperature and dissolved organic carbon and measured trace elements in otoliths using laser ablation inductively coupled plasma-mass spectrometry (LA ICP-MS). Transects across field caught fish otoliths from normoxic and hypoxic conditions and historical otoliths were also investigated using LA ICP-MS. Relationships between experimental conditions and trace elements (e.g. Mn:Ca) will be presented. These experiments represent the first empirical investigation of how hypoxia affects fish otoliths in a controlled setting. This research helps to understand how hypoxia may affect fish, which is important for management of environmental water allocations.

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Ecosystem disruption in the Arabian Sea with potential links to the spread of hypoxia

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In the last decade, the northern Arabian Sea has witnessed a radical and unexpected shift in the composition of winter phytoplankton blooms which previously comprised mainly of diatoms, the unicellular, siliceous photosynthetic organisms favoured by well-mixed, nutrient-enriched waters from convective mixing. Recurrent and trophically important, winter diatom blooms were an annual feature until the late 1990's, but have since been replaced by widespread blooms of a large, green heterotrophic dinoflagellate *Noctiluca scintillans*, that combines carbon fixation from its chlorophyll containing endosymbiont with ingestion of prey. First observed in small numbers in the Gulf of Oman, *N. scintillans* now appear as thick green blooms from Jan. to Mar. across the entire northern Arabian Sea basin. Here we report that these massive outbreaks of *N. scintillans* blooms are possibly being facilitated by an unprecedented influx of oxygen deficient waters from mid-depth into the euphotic zone and that their growth to bloom proportions is being aided by the extraordinary ability of its endosymbiont *Pedinomonas noctilucae*, a Prasinophyte to fix carbon more efficiently than other phytoplankton under hypoxic conditions. We contend that *N. scintillans* blooms could disrupt the traditional diatom-sustained food chain of the Arabian Sea and cause shifts in carbon export to the detriment of regional fisheries and the long-term health of an ecosystem supporting a coastal population of nearly 120 million.

Kinetics of oxygen uptake in pure cultures of marine bacteria

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Several families of terminal oxidases have been identified in the prokaryotes, and their Km values for oxygen have been determined. Based on genomic data analysis, some bacteria hold both high and low oxygen affinity terminal oxidase genes, and the high affinity terminal oxidases may have Km values as low as 3-8 nM O2, enabling these bacteria to maintain high respiratory activity down to low nanomolar levels of O2. It has, however, been difficult to measure O2 at such low concentrations, and the few performed investigations at the nanomolar level have been done by spectroscopy of oxygenated/deoxygenated hemoglobins yielding information about O2 changes only in a very limited range of O2 concentrations. No investigations of marine bacteria have apparently been performed by these methods. The aim of our study is to examine the Km value for oxygen of different bacteria species with both high and low oxygen affinity terminal oxidase using oxygen microsensors with extreme sensitivities and short response times. We furthermore investigate how the Km values change as a function of time and changes in O2 concentration, and how these changes are reflected in gene expression. Our data shows that many marine bacteria adapted to low O2 have Km values below 0.1 μM. The respiration rates by such low-O2 adapted bacteria were constant from concentrations of several micromolar down to < 0.2 μM O2.

Looking beyond stratification: A model-based analysis of the biological drivers of oxygen depletion in the North Sea

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Dissolved oxygen is an important indicator for the ecological status of the North Sea ecosystem, especially in relation to eutrophication. Seasonal oxygen minimum zones (OMZ) in the bottom waters of the central and eastern North Sea are mainly controlled by thermal stratification. Furthermore, the sinking of organic matter and its degradation by bacteria modulate the intensity of the OMZ.

Measurements of bottom oxygen with high temporal and spatial resolution are difficult and expensive. They can be supplemented by physical-biogeochemical models by the extension of monitoring data in space and time. In addition, these models allow for the quantification of biological processes involved in the formation of OMZ like sinking of organic matter and remineralisation.

The three-dimensional physical-biogeochemical model ECOHAM is used to investigate the effect of stratification and biological processes on the inter-annual variability of the OMZ in the North Sea for the period 2000 to 2010. The model results are compared with time series of *in situ* measurements in order to validate the temporal development of temperature, phytoplankton and oxygen. Furthermore, the results are validated with regard to the horizontal oxygen gradients in the bottom water.

Applying the OSPAR threshold of 6 mg O_2 l^{-1} for oxygen depletion, the model results illustrate the inter-annual variability of the spatial and temporal extent of the OMZ. The analysis of the simulated variations of the OMZ related to stratification and vertical mixing reveals non-linear responses of the timing and spreading of the OMZ. Calculations of the apparent oxygen utilization and estimates for bacterial degradation of organic matter are complemented by detailed budgets of the related model fluxes. In addition, the analysis of these budgets displays the regional characteristics in different North Sea areas.

This process analysis related to the OMZ constitutes a key element for the assessment of the eutrophication status in the North Sea and its future development under climate change.

210Pb-derived ages for the reconstruction of terrestrial contaminant history into a coastal lagoon.

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210Pb-derived sediment ages, as well as a suite of geochemical proxies (OC, C/N, $\delta^{13}C$, $\delta^{15}N$, and Hg), were used to assess the time-dependent variations of OC, TN, and Hg recorded in sediment cores collected at Pialassa Baiona, a coastal lagoon connected with the North Adriatic Sea, Italy, during the last 100 years. Pialassa Baiona is a high-priority site for conservation efforts in Italy because it is inhabited by a wide variety of birds (EU Wild Birds Directive, EU Habitats and Species) and is a wetland of international importance (RAMSAR Convention). Previous studies have documented elevated concentrations of mercury and polycyclic aromatic hydrocarbons (PAHs) [*Fabbri* et al., 2003; *Trombini* et al., 2003], and have attributed these to anthropogenic processes. In this work, the sedimentary records were marked by abrupt changes in OC, TN and $\delta^{13}C$ in the upper portion of the cores at 10 cm depth corresponding to the 1950s and 1960s. Hg showed broadly similar trends in concentration with depth, with a slight surface maximum overlying near-constant concentrations to ca. 10 cm depth. Below 10 cm depth, Hg concentrations declined towards cores base. ^{210}Pb dating indicates that concentration maximum for Hg correlate to the 1970s through the 1990s when vinyl chloride synthesis made use of the Hg-based technology in the chemical industry. A vinyl chloride plant discharged their effluent directly into the lagoon between 1953 and 1973, after which the use of Hg catalysts in vinyl chloride production was reduced and finally discontinued after 1991. It was estimated that 100-200 tons of mercury had been dumped into the Pialassa Baiona lagoon system between 1957 and 1977 (*Miserocchi* et al., 1993).
Our data indicate that major changes in OC composition and Hg deposition in the Pialassa Baiona lagoon began rather abruptly between the 1950s and the1960s and are undoubtedly related to multiple anthropogenic stressors.

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Influence of acid-volatile sulfides on metals bioavailability in sediments of a coastal lagoon

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The acid-volatile sulfide (AVS) and associated trace metals were studied in surface sediments (0-5 cm) collected at Pialassa Baiona, an eutrophic coastal lagoon connected with the North Adriatic Sea, Italy. Nutrient loads cause phytoplankton blooms and massive growth of opportunistic seaweeds (*Ulva* sp., *Enteromorpha* sp., *Gracilaria* sp.) [*Sfriso* et al., 2012], leading to frequent hypoxic events between July and September during which the concentration of dissolved oxygen falls below 2 mg l^{-1} [*Ponti and Abbiati*, 2004].
Acid volatile sulfide (AVS) has been shown to be a major factor controlling the bioavailability and toxicity of many common trace metals, such as Cd, Cu, Ni, Pb, and Zn. When the molar concentration of AVS exceeds that of the metals (i.e., the metal/AVS ratio is less than unity), they exist predominantly as insoluble metal sulfides, which presumably are not biologically available. Thus, at metal/AVS ratios less than 1, toxicity of sediment-associated metals to benthic macroinvertebrates has not been observed [*Ankley*, 1996].

The concentrations of AVS and the sum of the simultaneously extracted metals (ΣSEM) in surface sediments of Pialassa Baiona coastal lagoon varied in the ranges of 1.4 and 9.2 and 0.4-5.2 μmol g^{-1} dry weight, respectively. AVS and ΣSEM were significantly and positively correlated with sedimentary organic matter ($r = 0.50$ and $r = 0.94$, respectively; $p < 0.05$). The molar contributions of the metals investigated to the ΣSEM were Zn > Cu > Ni > Pb > Cd, and the ratio of the ΣSEM to AVS ranged from 0.1 to 1.1.

The AVS-SEM method predicted that sediments from Pialassa Baiona lagoon would have few effects due to high AVS-forming metal sulfides complexes, thus reducing trace metal bioavailability on resident biota.

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Hypoxia and biogeochemical processes concomitantly influence acidification in the seasonally stratified coastal marine Lake Grevelingen, the Netherlands

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Coastal waters experience stronger short-term pH fluctuations than the open ocean due to higher rates of biogeochemical processes such as primary production and respiration. These processes and fluctuations therein can mask or amplify the ocean acidification signal driven by increasing atmospheric pCO_2. Acidification in coastal areas can also be enhanced as eutrophication-induced hypoxia develops, since the CO_2 produced during respiration decreases the buffering capacity of the hypoxic bottom water. Coastal Lake Grevelingen (SW Netherlands) has limited water exchange with the North Sea and experiences seasonal bottom water hypoxia. Hence this lake provides an ideal site to study how seasonal hypoxia and biogeochemistry concomitantly affect coastal acidification.

In 2012, we examined the carbonate system in the water column of Lake Grevelingen over the full annual cycle. Monthly carbonate system, chlorophyll-a, oxygen and nutrient measurements were complemented with estimates of primary production and respiration using O_2 light-dark incubations. Gross primary production (GPP) was also estimated via ^{14}C-incubations and sedimentary DIC and TA fluxes were estimated from core incubations.

During stratification and hypoxia, pH differed up to 0.75 units between the well-buffered oxic surface and less-buffered hypoxic bottom waters. Rates of GPP peak in summer and range up to 200 $mmolC\ m^{-2}\ d^{-1}$. On a yearly basis, Lake Grevelingen is a sink for atmospheric CO_2, although significant outgassing takes place in autumn after the termination of stratification, concurrently with high sedimentary DIC fluxes. A proton budget calculated from measured process rates indicates proton cycling was fastest in the hypoxic bottom water and buffering capacities were lower after the stratified period than before. This highlights the significance of buffering in controlling pH dynamics and explains the increasing vulnerability of hypoxic coastal waters to any acidifying process.

Application of FerryBox measurements to oxygen flux estimates in European Coastal waters

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The monitoring of marine environments in coastal seas is still a challenge when continuous and reliable observations are needed, especially in context of climate change and increased anthropogenic impact on coastal waters. Ships of opportunity (SoO) are a platform for marine measurements, undertaken by FerryBox measurement systems. They are cost-effective and provide dependable long-term in-situ measurements of near-surface parameters. Since many years, several FerryBox routes along European coastal waters have been established. One of these routes has been selected for biogeochemical analyses. In context of climate change, the evaluation of quantitative values regarding the cycles of oxygen in the oceans is an important task as dissolved oxygen plays a major role in net primary production and ocean acidification. The processes of gas exchange, that is a part of the carbon and oxygen cycles, are strongly influenced by water temperature, salinity and wind speed. Empirical functions are used for parameterisation of the gas transfer velocity and have been under discussion for years. Onboard the FerryBox systems, optodes provide continuous measurements of dissolved oxygen concentrations along transects and, thus, are a valuable instrument for monitoring the oxygen levels in the ocean surface layer. Together with temperature and salinity observations as well as wind field information derived from ECMW reanalyses and from DWD forecasts, the air-sea exchange of oxygen has been calculated for parts of the southern North Sea and the German Bight. Details of the analyses procedure as well as results will be presented.

Hydrogechemical and isotopic characteristics of groundwater in Ras Jbel and Guenniche aquifers (North Eastern Tunisia)

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The Ras Jbel and Guenniche aquifers are both located in North-Eastern Tunisia. Over- exploitation of their groundwater resources, due to increasing population, is the major cause of water crisis in the region with degradation of the water quality. Artificial recharge of groundwater in Ras Jbel and Guenniche watertables is achieved by putting surface water in some injection wells and water was carried by conduits. Hydrochemical and environmental isotopic (^{2}H, ^{18}O and ^{13}C) data were used to investigate the hydrogeochemical and isotopic characteristics of groundwater within Ras Jbel and Guenniche aquifers before and after artificial recharge.

Hydrogeochemically, at the conclusion of many surveys, salinity degree in water samples collected from both aquifers had decreased from a concentration of approximately 3.5 mg/l (before artificial recharge) to approximately 0.4 mg/l (after artificial recharge). A drop in piezometric level is be remedied by artificial recharge.

In the conventional δD- $\delta^{18}O$ diagram, the distribution of data points indicates that the stable isotope signature for Ras Jbel groundwater falls near the global meteoric water line (GMWL). The stable isotope signature for the groundwater of Guenniche watertable also falls near the GMWL, but is depleted in heavy isotopes relative to Ras Jbel groundwater. The oxygen isotopic distributions reveal seasonal variations. The seasonal fluctuations are most likely the results of climatic effects, i.e. rainfall, temperature and evaporation.

Physical controls of the variability and predictability of hypoxia

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Low oxygen environments are found in many coastal and estuarine regions. These regions are becoming more extreme and more common over the last few decades, in part, due to increased supply of anthropogenic nutrients. However, variability at interannual scales and shorter may be dominated by physical controls on the system that modify stratification, mixing, and ventilation of low oxygen regions. Four systems are examined in which seasonal variability in regional winds is found to alter the severity of hypoxia. The first case is the Texas-Louisiana shelf, where changes in seasonal mean wind stress are can explain about on quarter of the variance in hypoxic area over the shelf, similar to the amount of variance in hypoxic area that can be explained by changes in riverine nitrogen load. In Chesapeake Bay, wind direction and magnitude play a key role in controlling hypoxic volume at both seasonal and inter-annual time scales. In Chesapeake Bay and the northern Gulf of Mexico, consideration of both wind forcing and nutrient loading is necessary to statistically account for the majority of the variance in observed inter-annual variations in hypoxic volume in this system. Along the US west coast, strong upwelling can cause hypoxia in regions isolated from coastal anthropogenic nitrogen loading. Finally, a long-term increase in stratification in western Long Island Sound is shown to contribute to the persistence in hypoxic conditions despite recent reductions in nutrient supply. These four systems demonstrate that it is critical to understand the physical factors that modulate hypoxia. This understanding is essential in order to quantitatively evaluate the effectiveness of nutrient management programs in these and other vulnerable coastal systems.

Egg production rate and survival of dominant pelagic copepods associated with the Oxygen Minimum Zone off northern Chile in the Humboldt Current ecosystem

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Egg Production Rate (EPR) and female survival of the copepods *Acartia tonsa, Calanus chilensis* and *Centropages brachiatus* were exposed under hypoxic and oxygenated conditions to evaluate the effect of the Oxygen Minimum Zone (OMZ) over their physiological responses. The females were collected from the coastal upwelling system of northern Chile at the Bay of Mejillones (23°S; 70°W). The females were sorted and individually incubated for 24 hours, under hypoxia (~0.4 - 0.8 ml L^{-1}) and oxygenated (~4 - 5 ml L^{-1}) conditions. After the incubation period, the eggs were counted and the survival of females was evaluated. Differential responses were observed for the three species under study. The egg production of *A. tonsa* was negatively affected under low oxygen conditions in contrast with *C. chilensis* and *C. brachiatus*. The female survival was higher for *C. chilensis* than the other species. Our results suggest that variations of the physiological responses in copepods could be affected under stressful conditions due to hypoxia, determining the structure and functioning of the pelagic system. These variations could result in changes of species dominance and ecosystem productivity, influencing pelagic food web associated with the OMZs of eastern boundary upwelling systems in face of a future scenario of expansion and intensification of the OMZs.
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Past deep water oxygen reconstructions

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As a result of global warming global ocean oxygen concentrations are decreasing. This has led to an expansion of oxygen minimum zones.

For the future it is predicted that oxygen concentrations will decrease globally due to warmer surface waters, increased upper ocean stratification and reduced deep water formation. These changes will severely impact marine life and biogeochemical cycles. The extend of change is however heavily debated due to limited data availability and unknown natural variability.

We are developing and applying a novel method to reconstruct past deep water oxygen concenrations to constrain longer term natural variability, based on the the carbon isotope gradient between bottom water and pore water at the anoxic boundary.

Application of our novel method on a core from the Northeast Atlantic for the last 150,000 years shows that glacial bottom oxygen concentrations were considerably lowered (by 55 μmol/kg last glacial maximum and 75 μmol/kg penultimate glacial) compared with today. We propose that lower glacial bottom water oxygen concentrations and associated increased respired carbon concentrations are due to ocean circulation changes in combination with an increase in the biological pump.

Seasonal hypoxia off Changjiang Estuary and its relation with river plume and tidal front processes

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Based on the four seasonal multi-disciplinary surveyed data, the spatial and temporal variation of dissolved oxygen and its relation with the oceanic processes were studied, in particular with the pathways of organic matter through river plume process and cross tidal front transport. The observed results indicate that seasonal hypoxia is primarily related to the pathway of the river plume through phytoplankton dynamics and vertical sinking across pycnocline. The directly transport of riverine organic matter by the cross frontal circulation also make important contribution to the variation of dissolved oxygen.

Preservation processes of sedimentary organic matter off Central Peru (12ºS – 14ºS) inferred by molecular geochemistry

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The organic matter (OM) in the ocean, due to its sensitivity to natural and anthropogenic environmental variations, provides key information for the characterization of actual and past sedimentary environments. In coastal upwelling areas, the high production and consumption of OM cause, in combination with other factors such as topography and oceanic circulation, the depletion of dissolved oxygen. Therefore aerobic degradation processes in the water column, and bioturbation and benthic respiration in the sediment are limited, thus favoring anaerobic processes. The Humboldt upwelling system off Peru is one of the areas around the world with the highest rates of primary productivity and an intense oxygen minimum zone (OMZ), favoring in this way the accumulation and preservation of organic matter in bottom sediments. The aim of this work was to study the effect that low oxygen conditions have in the preservation processes of the OM deposited in surface sediments off Central Peru (12ºS – 14ºS). For this purpose, 12 surface sediment samples were collected from the central part of the Peruvian Continental Margin and analyzed by organic petrography (palynofacies), Rock-Eval pyrolysis, GCMS (gas chromatography - mass spectrometry) and pyrolysis GCMS. Our results putted in evidence the effect that the preservation mechanisms have in the composition of free lipids, especially of saturated alkanes and fatty acids during early diagenesis, influencing in this way the expression of the phytoplankton signal in the free lipid fraction of OM. With the results obtained, a conceptual model of OM preservation for the central part of the continental margin was developed. In the inner continental shelf, preservation by natural vulcanization predominated, while in the outer continental shelf and in the core of the OMZ, selective preservation of OM predominated; in the lower slope, different mechanisms were associated to OM accumulation, such as natural vulcanization, selective preservation and re-condensation. This study showed that minimum variations in OMZ conditions off Central Peru have an important effect in the preservation pathways, leading to the accumulation of OM with different geochemical qualities.

International Group for Marine Ecological Time-Series – IGMETS

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The biogeochemistry of the ocean varies across a range of temporal and spatial scales, with anthropogenic forcing, resulting in e.g. warming, acidification, desoxygenation. In a growing effort to distinguish between natural and human-induced earth system variability, sustained ocean time-series measurements have taken on a renewed importance. Shipboard biogeochemical time-series programmes provide the oceanographic community with the multi-year, high-quality data needed for characterizing ocean biogeochemistry and ecosystem variability.

There are an extraordinary number of unexploited data sets obtained by long-term ocean time-series. Large spatial-scale analyses using many different time-series will allow us to detect and interpret links between climate variability and ocean biogeochemistry, ultimately improving our understanding of marine ecosystem change. However, in order to bring together datasets from different time-series, it is important that the sampling and analytical protocols used at each site are homogenous, consistent, and inter-comparable. It is critical to improve positive synergies among individual sites and scientific coordinators, to facilitate research proposals utilizing the facilities, and to involve as many researchers and institutions as possible in sites where on-going ship activities are being reduced due to decreased resources. Therefore one of the IOC-UNESCO's objectives is to compile and disseminate a comprehensive, integrated interpretation of global biogeochemical ocean changes as seen through time-series.

The International Group for Marine Ecological Time Series (IGMETS) currently prepares a report, which seeks to integrate the selected variables to look at holistic changes within different ocean regions, to explore plausible reasons and connections at a global level, and to highlight any regions of especially large changes that may be at greater risk.

So far meta-data from more than 160 time series were compiled and a subset will be used to obtain new insights on how shifts in oxygen concentrations among the ocean and how they influence species distribution and domination.

The report will be featured by online based data repositories and interactive maps to enhance the outreach and broader the usability of time series data.

Ocean (de)oxygenation across the last deglaciation – Insights for the future

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Anthropogenic warming is expected to drive oxygen out of the ocean, as the water temperature rises and the rate of exchange between subsurface waters and the atmosphere slows due to enhanced density stratification of the upper ocean. Observations from recent decades are tantalizingly consistent with this prediction, though these changes remain subtle in the face of natural variability. Earth system model projections unanimously predict a long-term decrease in the global ocean oxygen inventory, but show regional discrepancies, particularly in the most oxygen-depleted waters, owing to the complex interplay between oxygen supply pathways and oxygen consumption. The geological record provides an orthogonal perspective, showing how the oceanic oxygen content varied in response to prior episodes of climate change. These past changes were much slower than the current, anthropogenic change, but can help to appraise sensitivities, and point toward potentially dominant mechanisms of change. Consistent with the model projections, marine sediments recorded an overall expansion of low-oxygen waters in the upper ocean as it warmed at the end of the last ice age. This expansion was not linearly related with temperature, though, but reached an extreme of deoxygenation midway through the warming. Meanwhile, the deep ocean became better oxygenated, opposite the general expectation. These observations require that significant changes in apparent oxygen utilization occurred, suggesting that they will also be important in the future.

Abundance distribution of Nitrogen transforming microbes along oxygen gradients in two major oxygen minimum zones

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Oxygen Minimum Zones (OMZs) exist under regions of high primary productivity, where the remineralization of organic matter consumes oxygen in excess of its limited supply through ventilation. While many coastal sites experience acute and transient anoxia, the Eastern Tropical South Pacific (ETSP) and Arabian Sea are two of the three major permanent OMZs in the world oceans. Remineralization is catalyzed by diverse groups of microbes in these ecosystems, where the community composition shifts from aerobic in the oxic upper layer to anaerobic metabolic pathways within the OMZs. Fixed nitrogen (N), a key element in primary production is lost from oceans via anaerobic pathways in low oxygen environments. We investigated the distribution of microbes involved in N cycling in the OMZs in order to link microbes to processes. Abundance and distribution of N transforming microbes were quantified by targeting key genes in these pathways: denitrifers (nirS, nirK); anammox bacteria (16S rRNA and a functional gene, hzo); ammonia oxidizing bacteria and archaea (amoA). The abundances of denitrifiers, and anammox bacteria were high within the low oxygen waters of the Arabian Sea and the ETSP, where their activity is expected to be high. Their abundance was low to insignificant in the oxygenated waters. The abundance of the denitrifers was an order of magnitude higher than that of the anammox bacteria within both OMZs. Ammonia oxidation requires oxygen, so it was surprising to find high archaeal amoA gene abundances within the OMZs. amoA gene abundance from bacterial nitrifiers was more or less evenly distributed in the oxic and anoxic water column. Thus the distributions of microbial groups involved in N loss correlate with the N deficit and nitrite concentration in both the OMZs. Nitrifier distribution appears to be uncoupled from their respective rate distribution and may reflect some alternative metabolism.

Conclusion: Abundance distribution of microbial groups involved in anaerobic N loss pathways reflect nitrogen dynamics in the ocean, where the total abundance of these groups correlate with the chemical distributions. The proportion of denitrifiers to anammox also reflect their relative contribution to nitrogen removal from the Arabian Sea OMZ whereas rates and distributions are less coupled in the ETSP.

Recent spreading of hypoxia in continental zones: a meta-analysis from lake sediment archives

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Spreading hypoxia in aquatic systems is a growing problem worldwide that urges researches to quantify its past temporal dynamic on large-scales. In marine environments, world assessment efforts from monitoring data showed the number of hypoxic coastal sites has increased with an exponential growth rate over time (e.g., Vaquer-Sunyer and Duarte, 2008). In continental zones however, world overviews of past hypoxia dynamic are still missing, mainly due to the lack of past monitoring series over long periods ($<$ 60 years). Here we relied on a paleolimnological meta-analysis of about 300 lakes over short (200 years) and long (10000 years) timescales to reconstruct the long-term trends of historical changes of hypoxia in continental environments. We used the presence of varves (or annually laminated sediments) as an indicator of severe hypoxia (Jenny et al., 2013) in order to date in each lake the historical onset of oxygen depletion over a year leading to the disappearance of most benthic macroorganisms. Preliminary results show that continental development of hypoxia seems about 40-50 years antecedent than in coastal environments. Furthermore, despite implementation of restoration programs and the related phosphorus (P) limitation since several decades, European and North American lakes still presents no sign of return to past well-oxygenated condition. It highlights how persistent is hypoxia and how it could affect future aquatic ecosystems despite nutrient reduction.

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Climate controls hypoxia dynamic in low phosphorus conditions: Paleolimnological retro-analysis from 3 large perialpine lakes

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Worldwide spreading of hypoxia threatens aquatic ecosystem function and service by the decline in biodiversity (Villnäs et al., 2012). The extension of hypoxia over the last decades is the consequence of eutrophication and climate (Posch et al., 2012; Rabalais, 2003), but the respective implication of each forcing still remains poorly documented on a long-term perspective due to the lack of past monitoring series and quantified paleoreconstructions. Innovative three dimensions paleolimnological investigations (Jenny et al., 2013) and generalized additive models were used to reconstruct yearly volume of oxygen-depleted waters and to identify forcings of hypoxia in three well documented large lakes over long (10000yrs) and shorter (130yrs) timescales. We show that after an uninterrupted well-oxygenated period spanning millennia, lake ecosystems shifted to hypoxic conditions in the 1950s, once total phosphorus concentrations exceeded 15$\pm$5 μg l-1. We show that in a new ecological equilibrium bumped by eutrophication, fluctuations of hypoxia are no longer driven by phosphorus but by global and local climatic factors: i.e., temperatures and hydrology.

Evidence for a typical microbial community signature associated with hypoxia

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Hypoxic events may be detected by different types of proxies in the sedimentary record, providing a way to track environmental change. To test the hypothesis that hypoxia selects for certain microbial communities and functions, we investigated the effects of varying oxygen conditions on organic matter reactivity and benthic microbial communities at the Crimean shelf of the Black Sea. Sediments were analyzed using ARISA (Automated Ribosomal Intergenic Spacer Analysis) and 454 massively parallel tag sequencing (MPTS). The distributions of sediment biogeochemical parameters and hydrolysable amino acids were measured to assess the lability of organic matter and to determine the connections between oxygen supply, benthic microbial community structure and organic matter reactivity. Overall, enhance preservation of organic matter was found in areas characterized by dynamic or permanent hypoxia, together with shifts in microbial community structure. Comparing oxic, hypoxic, and anoxic zones at the Crimean Shelf and their dynamic interfaces, the number of OTUs (operational taxonomic units, 97% clustering) based on 454 MPTS, showed an increase in richness with decreasing oxygen availability, and a shift in community structure. Along the oxygen gradient, the most sequence-abundant phylum was *Proteobacteria*, which was dominated by *Deltaproteobacteria*. The next most abundant phyla in surface sediments under hypoxic conditions were *Bacteroidetes* and under oxic conditions *Chloroflexi*. The differences in relative abundances in oxic vs. hypoxic surface sediments were preserved within the anoxic subsurface sediments. Hence, the oxygenation state of surface sediments apparently produced a typical signature which was preserved in the sedimentary record over ca. 100 years according to the accumulation rate. This study was supported by the EU 7th FP project HYPOX number EC grant 226213, with additional funding from the PFB31 Program COPAS Sur-Austral, Chile. GLJ is granted a student scholarship from CONICYT, Chile.

The Effects of Nutrient Ratios on Phytoplankton in the East China Sea: Based on Field Observation and Sediment Record

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Nutrient ratios related phytoplankton community play a very important role in hypoxia developing. Changjiang, the largest river in China discharges 9×10^{11} m^3 water and 4.86×10^{8} t suspended particles per year into the East China Sea, the second largest shelf marginal seas in the world. Since the 1980s, higher and higher nutrient loadings to the East China Sea, lead to more and more serious eutrophication, red tide events and concurrence of hypoxia in bottom water. During several comprehensive cruises in summer since 2006, nutrients and HPLC-derived pigments were analyzed in a section from the Changjiang Estuary across the continental shelf along the latitude of 31°N, in order to study how nutrients concentrations and ratios affect on the structure of phytoplankton community. "Chemtax" software was used to obtain the community structure of phytoplankton at class level based on pigments data. The community structure of phytoplankton was different between the west and East of 123.5°E. In the Estuary water dominated west part where silicate and nitrate were very abundant and N/P ratio was higher than 16, phytoplankton biomass was high and the communities were dominated by diatoms through the whole water column. In contrast, in the shelf water dominated east part, the nutrient concentrations were very low, and N/P ratio was lower than the Redfield ratio 16, the phytoplankton biomass was low and the community was mainly composed of cyanobacteria. Analysis of organic carbon $\delta^{13}C$ ($\delta^{13}C_{org}$), opal, sediment pigments from a sediment core revealed that $\delta^{13}C_{org}$ values ranged from -26.15‰ to -19.5‰, suggesting the mixing organic carbon sources of riverine and marine organisms. Opal and diatom microscope identifying data suggested that the biogenic silica and diatom production was low before 1950s and increased from 1950s to 1980s. After 1980s the diatom production decreased while the production of other phytoplankton community such as dinoflagellate increased. These sediment records correspond to the facts that nutrient input from the Changjiang has been dramatically increasing about three to five fold since the 1960s and N/P, N/Si ratio were increased at the Changjiang River Estuary since the last 40 years.

Responses of coastal hypoxia to nutrient loading and Phytoplankton blooms off Changjiang Estuary

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Nutrient ratios related phytoplankton community play a very important role in hypoxia developing. Phytoplankton pigments were investigated off the Changjiang Estuary in summer, 2011 "Chemtax" software (Mackery et al., 1996) was used to obtain the community structure of phytoplankton at class level with HPLC pigments data. Phytoplankton biomass and community composition were strongly affected by the characterization of different water mass with the concentration of suspended particles and nutrient status (concentrations and N/P, N /Si ratios). High concentrations of Fucoxanthin and Peridinin were found in the surface water near shore which influenced by ChangJiang Diluted Water(CDW), with strong stratification, highest chl a concentrations and bottom hyboxia. Indicating that phytoplankton bloom in surface layer co-coupled with bottom hypoxia. In contrast, in the offshore water the phytoplankton biomass was low and the community was mainly composed of cyanobacteria and prymnesiophytes under low nutrient status. Organic carbon $\delta^{13}C$ ($\delta^{13}Corg$), opal, sedimentary pigments from a sediment core were investigated. $\delta^{13}Corg$ values ranged from -26.15‰ to -19.5‰, suggesting the mixing organic carbon source of riverine and marine organisms. Opal and diatom microscope identifying data suggested that the biogenic silica and diatom production was low before industrialization and then increased to 1980s. After 1980s the proportion of diatom production to total chl a decreased while the production of other phytoplankton community such as dinoflagellate increased. These sediment records correspond to the facts that nutrient input from the Changjiang has been dramatically increased about three to five folds since the 1960s and lead to increasing N/P, N/Si ratio off Changjiang Estuary since the last 40 years.

Low Oxygen Environments - a Challenge for New Instruments Ensuring Unbiased Downstream Analysis

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Microorganisms are the driving catalysts of virtually all relevant biogeochemical cycles sustaining life in the ocean. Moreover, they respond rapidly to environmental changes and the presence of accordant key indicator organisms, genes and transcripts mirror contemporary environmental conditions, biogeochemical processes, and the occurrence of certain stress conditions (like low oxygen environments). In consequence, the determination of microbial metabolic processes is fundamental for the understanding and monitoring of marine ecosystems. Modern molecular techniques now allow monitoring of microbial activities and functions in the environment through the analysis of genes and expressed genes (transcripts, represented by messenger RNA [mRNA] and proteins) contained in natural microbial assemblages (metagenomes, metatranscriptomes, and metaproteomes, respectively). Unfortunately, transcripts can degrade in less than 30 seconds. It is known that their abundance patterns detected in nature, especially from hypoxic water habitats containing low or even no oxygen, are a challenge to conserve because they are subject to considerable modification simply due to sampling procedures.

Here we present data of several metatranscriptomes from a low oxygen environment of the Baltic Sea, generated from samples taken by different procedures (conventional water bottles [Free-Flow bottles], water bottle with in situ fixation equipment, and pump CTD). Expression profiles differed up to 30fold between conventionally taken and in situ fixed samples, demonstrating the need of new in situ instruments. These differences within the metatranscriptomic data indicate that also new instruments could be essential for proper rate measurements of at least for critical habitats.

Differential denitrification in the oxygen minimum zone in Eastern Tropical North Pacific: Medieval Warming and Little Ice Age.

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Eastern Tropical North Pacific have showed evidence of millennial-scale variability of the oxygen minimum zone in relation to abrupt climate variability as observed in the North Atlantic Ocean with oxygen depletion occurring during interstadial events, and interglacial rather than stadials, Heinrich events, and last glacial. Changes in marine productivity, induced by wind-driven upwelling variations, and ventilation of the water column (dissolved oxygen transport by oceanic advection via North Pacific Intermediate Water or Southern Ocean) have been proposed to modulate past oxygen minimum zone variability through oxygen consumption and inputs. In this study, we present new stable isotope records for two sites spanning the 550-700 m depth range along the southwestern margin of Baja California. Hence, the multicores collected were present allow us to constrain the denitrification of the last 1400 years (Medieval Climate Anomaly, Little Ice Age and Present) from Soledad Basin and Magdalena margin. The results indicate that both areas the denitrification was similar during the Medieval Warming. In the Little Ice Age, Magdalena margin showed a decrease in denitrification with respect to Soledad basin. The variability in the sedimentary d15N was a product of denitrification in the water column and not by early diagenesis. The biogenic silica content in both sites was very similar during the Little Ice Age, so that primary productivity was not the causative mechanism of denitrification. This suggests that denitrification differential between the two sites was due to the ventilation of the water column in the range of 550 to 700 m depth. Thus both export production and intermediate water ventilation play a role in oxygen minimum zone processes on the Eastern Tropical North Pacific.

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Globally distributed microorganisms as biogeochemical key players in marine oxygen-deficient systems

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Marine oxygen-deficient water columns occur near coastal upwelling areas, in enclosed basins, marginal seas and fjords with restricted water circulation. Oxygen-deficient waters are currently expanding on a global scale due to climate change and eutrophication. Microbial community metabolism in oxygen deficient systems impacts marine nutrient and energy flow patterns, resulting in biological nitrogen loss, climate active trace gas production, H_2S detoxification and significant chemoautotrophic production. Recent research combining "metaomics" data with process rate measurements and physiological and genomic studies on representative isolates has provided new insights into coupled biogeochemical cycling in different types of oxygen-deficient marine waters and revealed general patterns in global distributions of microbial biodiversity. Our studies on the anoxic basins of the central Baltic Sea showed that the microbial community of the pelagic oxic-anoxic interface is dominated by chemolithoautotrophic prokaryotes. Several groups can be considered as key players for distinct biogeochemical processes. These include ammonia-oxidizing Thaumarchaeota, chemoautotrophic denitrifying Epsilonproteobacteria (*Sulfurimonas* sp.) and potentially sulfur-oxidizing Gammaproteobacteria (SUP05 cluster). Accounting for up to one fourth of total cell counts in their respective redox zones, these organisms link the carbon, nitrogen and sulfur cycles, and their chemoautotrophic production is the basis of a microbial food web. Close relatives of these groups have been found in marine oxygen minimum zones worldwide. As such, the Baltic Sea represents an ideal model system for an in-depth understanding of the structure and regulating mechanisms of the biogeochemistry and microbiology of marine pelagic anoxia. Having a comprehensive picture on the abundance, distribution and functional genomics of prokaryotic key groups will allow a better integration of those key players into biogeochemical models of marine oxygen minimum zones.

Aerobic Microbial Respiration in Oceanic Oxygen Minimum Zones

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In the oxygen minimum zones (OMZs) of the tropical oceans, sluggish ventilation combined with strong microbial respiration of sinking organic matter results in the depletion of oxygen. When oxygen concentrations drop below 5 μmol/L, organic matter is generally assumed to be respired with nitrate, ultimately leading to the loss of fixed inorganic nitrogen via anammox and denitrification. However, direct measurements of microbial oxygen consumption at low oxygen levels are - apart from a single experiment conducted in the OMZ off Peru – so far lacking. At the same time, consistently observed active aerobic ammonium and nitrite oxidation at non-detectable oxygen concentrations ($<$1 μmol/L) in all major OMZs, suggests aerobic microorganisms, likely including heterotrophs, to be well adapted to near-anoxic conditions. Consequently, microaerobic ($\leq$5 μmol/L) remineralization of organic matter, and thus release of ammonium, in low-oxygen environments might be significantly underestimated at present. Here we present extensive measurements of microbial oxygen consumption in OMZ waters, combined with highly sensitive oxygen (STOX) measurements and meta-omic functional gene analyses. Short-term incubation experiments with labelled oxygen (18-18O2) carried out in the Namibian and Peruvian OMZ, revealed persistent aerobic microbial activity at depths with non-detectable concentrations of oxygen ($\leq$50 nmol/L). In accordance, examination of metagenomes and metatranscriptomes from Chilean and Peruvian OMZ waters identified genes encoding for terminal respiratory oxidases with high oxygen affinities as well as their expression by diverse microbial communities. Oxygen consumption was particularly enhanced near the upper OMZ boundaries and could mostly (ca. 80%) be assigned to heterotrophic microbial activity. Compared to previously identified anaerobic microbial processes, microaerobic organic matter respiration was the dominant remineralization pathways and source of ammonium (ca. 90%) in the upper Namibian and Peruvian OMZ. Our results reconcile so-far existing mismatches between ammonium sources and sinks in OMZs, and may help to improve biogeochemical modelling of the effects of future ocean de-oxygenation on aerobic and anaerobic organic matter remineralization in these zones.

In Situ Incubations and Targeted Proteomics as tools to evaluate carbon cycling in low oxygen marine waters

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Low oxygen waters typically have proportionally higher fluxes of organic matter than corresponding oxygenated waters, but why this occurs is not well understood. The particle flux within oxygen minimum zones is also thought to be an important driver of nitrogen loss in these systems. Understanding organic matter fluxes and associated redox cycling in low oxygen environments could provide information useful not only for understanding the present ocean, but also for predicting changes in carbon and nitrogen cycling as a function of climate-change induced variations in the oxygen content of the oceans.

To better evaluate carbon fluxes in low oxygen waters, we applied two new approaches; in situ incubation systems and targeted proteomics. In situ incubation chambers were developed in response to the common difficulties of conducting on-deck incubation experiments (imprecise control of oxygen concentrations, changes in pressure and temperature, etc). Our systems consist of sediment traps with one liter chambers that can be deployed open, closed by timed release, and used to evaluate sinking particle remineralization rates in situ. Chambers have multiple sensors including pH probes and oxygen optodes, and syringe-based injection/subsampling capabilities. Deployments in the ETNP (2012) and ETSP (2013) agree with what is suspected from the flux data – remineralization in anoxic waters is slower than in oxic counterparts. We will present recent data from the ETSP where incubation chambers were placed within 15 meters of each other, on each side of a very strong oxygen gradient.

We also utilized a targeted proteomics approach to seek evidence of chemoautotrophic carbon in the sinking material. Suspended (McLane pump samples) and sinking (net trap samples) particles were evaluated for concentrations of proteins that are specific to the processes of aerobic respiration (heterotrophy) denitrification (heterotrophy) and anammox (chemoautotrophy). The proteins targeted are ubiquinol oxidase (prokaryotic aerobic respiration), N2O reductase (denitrification), hydrazine hydrolase and hydroxylamine oxidoreductase (anammox), and cytochrome c nitrite reductase (nrfA) (DNRA). In the spring of 2012 in the ETNP we see some evidence of denitrifying bacteria in the sinking particles, but there is virtually no signal from annamox bacteria. This suggests that chemoautotrophic biomass is not contributing substantially to the flux at this location and at this time.

Organic matter oxidation in temperate estuarine sediments: experiments and modelling

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The spatial and temporal variation of biogeochemical processes at the sediment-water interface was studied in two small temperate estuaries Elorn and Aulne (Brittanie, France). Experimental data and steady-state simulations were used to investigate the coupling between carbon, oxygen and nitrogen cycles in the estuarine sediments. A numerical model of early diagenetic processes (FEMME-OMEXDIA) was used in this study which includes oxic and anoxic mineralization. It was developed to reproduce the sediment-depth profiles of carbon, oxygen, nitrogen and other chemical species. Organic carbon was modelled as two degradable fractions with different first-order degradation rates and nitrogen:carbon ratios. The values of several parameters (bioturbation coefficients, porosities, sedimentation rate, temperature, the bottom water concentrations of O_2, NO_3, NH_3, ...) were constrained using field measurements and literature values. The distributions of different chemical species predicted by steady-state calculations were compared to observed data sets from the two estuaries, at different seasons February, May, July and October 2009. After adjustment of the critical parameters, the degradability rate constants for two fractions of carbon, the organic matter flux and the fraction of fast-decaying organic carbon deposited at the sediment–water interface, the model showed a good agreement between predicted and measured profiles for each data set at different seasons and localisations. The estimated parameters indicate that the degradation rates of labile material are more important in Elorn than Aulne estuary. For both Elorn and Aulne estuaries, the degradation rates of labile material are larger in winter than in spring.

Poster

The Oxygen Supply Tracer Release Experiment in the tropical North East Atlantic Oxygen Minimum Zone

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Models are generally incapable of correctly reproducing the Oxygen Minimum Zones (OMZ) because oxygen consumption, as well as the oxygen supply pathways into the OMZs, are only insufficiently known (Duteil and Oschlies, 2011). One important process for the oxygen supply is the diapycnal and isopycnal diffusion. Fischer et al. (2013) estimated the oxygen supply via diapycnal mixing to be about one-third of the total oxygen demand within the OMZ core. An improved knowledge of these diffusivity coefficients could improve the model results and thus enable the prediction of future oxygen concentrations in the OMZ. We report on two Tracer Release Experiments (TREs) in the OMZ of the tropical North East Atlantic Ocean (TNEA) which were conducted to assess diapycnal and lateral diffusivity from the spreading of the tracer within this region.

The Guinea Upwelling Tracer Release Experiment (GUTRE) was set up to investigate the diapycnal mixing within the OMZ of the TNEA. The injection of the tracer CF_3SF_5 took place in 2008 in the oxycline above the OMZ core, at 350 m depth, where the oxygen gradient was steepest (Banyte et al., 2013). The tracer was sampled after 7, 20 and 30 month. The diapycnal diffusivity coefficient of $K_z = (1.19 \pm 0.18) \times 10^{-5}\, m^2/s$ (Banyte et al., 2012) was well constrained within small error bars but large uncertainties remained for the lateral diffusivity coefficients of $K_x = 1200 \pm 600\, m^2/s$ and $K_y = 500 \pm 200\, m^2/s$ (Banyte et al., 2013), respectively. To estimate the uncertainties due to the sampling strategy, the observational data were compared with the data from modelled tracer releases. The tracer spreading was attributed to eddies and zonal jets. Banyte et al. (2013) expected a slight overestimation in the GUTRE eddy diffusivity coefficient because of the interpolation needed due to the sparse sampling.

Thus, a new sampling strategy was devised to obtain more accurate results for the lateral diffusivity coefficients and their role in the lateral supply pathway for oxygen into the OMZ from the new Oxygen Supply Tracer Release Experiment (OSTRE). In December 2012, the tracer CF_3SF_5 was injected at the 27.03 kg/m^3 density level in approximately 400 m depth into the core of the OMZ. The oxygen concentrations found at this density level during the injection were below 40 μmol/kg. The first tracer mapping cruise took place in 2013 (6 months after injection), and further ones are planned for March/April 2014 and early 2015 (15 and >25 months after injection). Early results from the mapping cruises will be discussed.

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The puzzle of oceanic oxygen utilization

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The biological carbon pump is an important component of the oceanic carbon cycle and expected to respond to the anthropogenic perturbation of climate and ocean chemistry. Yet, large uncertainties exist in the quantification of the strength of the biological carbon pump of today's ocean. The export of organic matter from the ocean's euphotic zone is a critical benchmark number of this strength. Local measurements of the export flux are highly uncertain, due f.e. to severe methodological issues and undersampling of the ocean. Uncertainties in the contribution of dissolved organic matter to export further add for the global assessment. The vertical integral of oxygen utilization in the interior of the ocean is considered an independent and save estimate of export production, which accounts for particles as well as dissolved export pathways. For that purpose regional oxygen utilization rates (OUR) have been computed from apparent oxygen utilization (AOU) and an estimate of the time elapsed since the last contact with the atmosphere. Surprisingly the assumptions underlying this concept have not been tested rigorously. Using global ocean biogeochemical models we compare OUR computed from AOU and an ideal age tracer with an independent and perfect estimate of ocean respiration available in the model. Consistently in three different global models, we find that OUR underestimates true respiration by a factor of about three. Most of the differences between respiration and OUR are observed in the upper 1000m of the ocean. In addition to this underestimate in bulk global numbers, we find also important qualitative differences between the two independent approaches. For example, the contribution of dissolved organic matter driving oxygen utilization is largely underestimated when based on bulk tracer concentrations (AOU, DOC), which is the usual approach applied to observations. Also, diagnosing the global importance of denitrification relative to oxic metabolism is found to be uncertain by a factor of three when based on analysis of bulk tracers.

Typical features of dissolved organic carbon distribution in redox zone of the north-eastern Black Sea

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This work is based on studies carried out in 2 July 2010, 9 June 2011 and 26 June 2012 at the same station in the north-eastern part of the Black Sea. Our goal was to study the hydrochemical structure of the redox layer and obtain a detailed vertical profile of dissolved organic carbon (DOC), from the sea surface down to the layer where hydrogen sulphide appears. A particular attention was focused on the suboxic zone, where both oxygen and hydrogen sulfide are in concentrations below the detection limit. Concentrations of DOC were measured with a high-temperature catalytic oxidation method using an Elementar analyzer model Vario TOC Cube.

It was shown that the DOC distribution in the density field is characterized by a gradual decrease of concentration from the surface maximum (227.58 μM, 282.65 μM, 356.65 μM in 2010, 2011 and 2012 years respectively) to the middle of suboxidized zone (an upper part of the suboxic zone, where trace amounts of oxygen are present), where local increase of DOC concentrations starts. At the boundary between the suboxidized and subreduced zones (where oxygen is absent) the second maximum of DOC concentrations appears (189.00 μM, 274.21 μM, 297.29 μM in 2010, 2011 and 2012 years respectively), then concentrations of DOC begin decreasing again down to the level of hydrogen sulphide appearance. Photosynthetic activity forms the concentration maximum of DOC at the surface. In the suboxidized zone the responsible processes are chemosynthesis and destruction of suspended organic matter accumulated in the turbidity layer, a distinctive feature of that zone during late-spring and summer seasons. The minimum concentrations of DOC (160.72 μM, 214.38 μM, 174.23 μM in 2010, 2011 and 2012 years respectively) were observed at the bottom boundary of subreduced zone about 5 meters above the appearance of hydrogen sulphide, caused by redox processes dominating in this water layer where dissolved organic matter serves as an electron donor.

The DOC corresponds about 6% of total dissolved carbon, with maximum of ~8.8% situated on the surface, and minimum of ~5% at the bottom boundary of the subreduced zone. At the boundary between the suboxidized and subreduced zones DOC corresponds about 7.1% of total dissolved carbon, displaying a high DOC production in this layer.

Anoxic processes start due to the presence of a large excess of organic matter in comparison with the limited supply of dissolved oxygen. There is also usually a density stratification preventing normal ventilation of the deeper layers. Our results show that the DOC distribution in the north-eastern Black Sea is clearly connected with the redox zonation of the water column, thus being a direct indicator of biogeochemical processes taking place in the sea water as it changes from oxic to anoxic.

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Anoxic conditions in fast ice and ice cover of lakes in Antarctica: concentration of particulate matter and composition features of organic compounds

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The study of coastal areas of East Antarctica was carried out during 6 expeditions to Antarctica (cruises of R/V *Academician Fedorov* of Russian Antarctic Expedition in 2001–2012) [Nemirovskaya et al., 2013]. Geochemical researches were performed in order to determine features in the distribution and composition of organic compounds, such as chlorophyll "a", pheophytin "a", lipids, aliphatic hydrocarbons and organic carbon as well as in particulate matter in snow-ice cover on fast ice and lakes. Biogeochemical processes in Antarctic ice are still poorly studied. The phenomena of hypoxia were observed in Antarctic ice during the study of fast and lakes ice cover in some cases. Our data and data of literature are shown that autochthonous organic compounds mostly synthesized by phytoplankton are formed in a one-year growing ice (especially on the ice – water boundary) in the marine environment even at low temperatures. Therefore the highest concentration of chlorophyll "a" was revealed in the lower layer of the ice core and vice versa it low concentrations were observed in upper layer of ice and in water under the ice. Anoxic conditions were observed in the fast ice of the Haakon VII Sea (adjacent research station Novolazarevskaya) in spring 2012. This result from the high thickness of neve (~50 cm) and ice (330 cm), as well as the amount of diatomic algae (producing of large amounts of organic compounds) accumulated in the lower part (180–330 cm) of long-term ice. Decomposition of autochthonous organic compounds accompanied by intense oxygen consumption results in the formation of hydrogen sulfide. In this case the content of all studied organic compounds were decreased on the boundary ice – water. Anoxic conditions may also be a critical factor affecting chloropigment preservation [Sun et al. 1993; Reuss et al., 2005]. Concentration of chlorophyll "a" varied from 0.19 $\mu g \cdot l^{-1}$ in the upper ice core layer 0–30 cm till 112 $\mu g \cdot l^{-1}$ in lower layer 230–280 cm.

The presence and quantity of hydrogen sulfide in Stepped Lake (near research station Progress) depend on intensity of interaction between the lake and the Prydz Bay. During a low water level in the lake it becomes fresh water with traces of salinity. Anoxic conditions forms in the depressions of the lake bottom.

Contrary to popular opinion on the attenuation of oxidation processes at low temperatures, ice may have a catalytic function due to increase in the microheterotrophy content. Fast transformation of organic compounds takes place even in low temperature environment. Herewith intense oxygen consumption results in the formation of anoxic conditions. The conditions of the formation of snow–ice cover significantly control the distribution of the not only physical but cryobiological and geochemical parameters.

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Simulating remineralization processes in oxygen minimum zones: uncertainties and consequences for global biogeochemical cycles

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Despite being of importance for the simulation of OMZ and associated biogeochemical tracer distributions, the representation of oxygen sensitive processes in global ocean models is not well constrained and suffers from a lack of direct observations that could help to parameterize the relevant processes. We here examine a suite of potential parameterizations of aerobic and anaerobic processes within the framework of a global biogeochemical model for their effect on global tracer distributions and fluxes. We compare their impact to that of different particle flux profiles. Simulations over several millennia indicate that nitrate and oxygen concentrations in the Eastern Equatorial Pacific are particulary sensitive to changes in the rates and oxygen-thresholds of denitrification and aerobic remineralization. In our model, the simulated redox sensitivity of aerobic and anaerobic remineralization, in conjunction with remineralization length scale, determines the extent and stability of the OMZs, simulated global rates of pelagic denitrification and ultimately the size of the global oceanic nitrogen inventory.