Air-Sea gas fluxes at Eastern Boundary Upwelling and Oxygen Minimum Zones (OMZs) systems

8-10 November 2010
Instituto del Mar del Perú (IMARPE)
Lima, Perú
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Focus 3: Air-sea flux of CO₂ and other long-lived radiatively active gases.

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The Sonderforschungsbereich (Collaborative Research Centre) addresses "Climate-Biogeochemistry Interactions in the Tropical Ocean". It is funded by the German Research Foundation (DFG) and was proposed by scientists from the IFM-GEOMAR and the Christian-Albrechts Universität (CAU).

Dynamics of the Humboldt Current System
The main objective of the International Joint Laboratory (LMI) Dynamics of the Humboldt Current System (DISCOH) is to study the ocean-atmosphere, biogeochemical and ecological dynamics in the HCS in order to understand and anticipate the effect of intraseasonal, seasonal, inter-annual, decadal variability and climate changes on the dynamics of the coastal ecosystem. It will sustain the implementation of an ecosystem approach to fisheries.

In addition, the LMI DISCOH supports two Master programs in Marine Sciences in Peru by facilitating the involvement of IRD and other foreign scientists, and also by funding student and professor exchanges, and research thesis work related with the project. The LMI DISCOH has two formal members, the Instituto del Mar del Perú (IMARPE) and IRD and five associated members: The Instituto Geofísico del Perú (IGP), the Servicio Nacional de Meteorología e Hidrología (SENAMHI), The Universidad Nacional de San Marcos (UNMSM), The Universidad Peruana Cayetano Heredia (UPCH) and the Department of Geophysics (DCEO) of the Faculty of Physics and Mathematics Sciences of the University of Concepcion, Chile.

PALEOclimatologie tropicale: TRACEurs et variabilitéS
PALEOTRACES is a cooperative International Mixed Laboratory between IRD-France, University of Federale Fluminense-Brazil and The University of Antofagasta - Chile. The principal aim of PALEOTRACES is to reconstruct the South American climate variability, at different times scales, and their impacts on continental and marine ecosystems during the last 20 000 years. These reconstructions are based on Speleothems, Corals and marine and lacustrine sediments records.

GEOTRACES
http://www.geotraces.org/
GEOTRACES is an international programme which aims to improve the understanding of biogeochemical cycles and large-scale distribution of trace elements and their isotopes in the marine environment. Scientists from approximately 30 nations have been involved in the programme, which is designed to study all major ocean basins over the next decade.

Programme

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07:30 Bus departure from Hotel Boulevard
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Rear Admiral (r) Jorge Brousset
Introduction of SOLAS
Doug Wallace
Introduction to the workshop
Véronique Garçon
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Mike Lawler and Eric Saltzman
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16:15 Sources, sinks, and transport of carbon in Eastern Boundary Upwelling Regions: A comparative analysis
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Programme

DAY ONE

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17:30 Sensitivity of air-sea fluxes to water column remineralization Jorge Sarmiento p12
17:45 Planning for day two
18:00 Ice Breaker
20:00 Bus departure from IMARPE.

DAY TWO

07:30 Bus departure from Hotel Boulevard

FOCUS 2.2 (continued): Processes in the oceanic boundary layer Chair: Aurélien Paulmier; Rapporteurs: Elisabeth Silvestre
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10:00 Nitrogen Isotope variations in the Eastern Tropical North Pacific off Mexico: denitrification and ventilation changes at glacial-interglacial timescales Jose Caniquiry p13
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11:00 Split into working groups Chair: Michelle Graco; Rapporteurs: Véronique Garçon and Aurélien Paulmier

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WG 2: FOCUS 2
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13:00 Lunch
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Writing of future common plan along with timetable for international cruises and experiments in the OMZ of the East tropical Pacific

15:45 Coffee
17:45 Bus departure from IMARPE
20:00 Meeting dinner at La Dama Juana (Miraflores)

DAY THREE

07:30 Bus departure from Hotel Boulevard Chair: Doug Wallace; Rapporteurs: Michelle Graco and Véronique Garçon
09:15 Working group reports and future planning
10:45 Coffee
12:45 Closure of workshop
13:00 Lunch
15:00 Bus from IMARPE to Miraflores

Abstracts

FOCUS 2.1: Exchange across the air-sea interface
Brian Ward
Surface ocean and lower atmosphere turbulence: processes governing air-sea gas exchange
Air-Sea gas exchange is controlled by several processes including turbulence, which impacts gas transport by eroding the diffusive sublayer at the air-sea interface. For gas exchange parameterisations, wind speed is used as a proxy for ocean surface turbulence. Quantification of turbulence in the marine atmospheric boundary layer is necessary for the direct determination of air-sea fluxes using the eddy correlation method. This technique relies on the cross product of the small-scale vertical velocity and the concentration of the target gas species. Here we present measurements of turbulence on both sides of the air-sea interface for improved understanding of gas exchange. The Air-Sea Interaction Profiler (ASIP) can provide autonomous measurements of turbulent dissipation from below the mixed layer to the air-sea interface. A new gas detector based on photacoustic spectroscopy will provide superior quantification of gas exchange due to increased sensitivity and improved signal to noise.

Robert Upstill-Goddard
Potential effects of natural biological surfactants on air-sea gas exchange

In biologically productive waters natural seawater surfactants (i.e. biological by-products including polysaccharides, lipids, proteins etc.) have the potential to suppress air-sea gas exchange through weakening surface renewal and increasing the turbulent length scale. I present here some results of an experiment carried out during the UKSOLAS Deep Ocean Gas Exchange Experiment of 2007 (DOGEE-II) in which we examined the effect of a deliberately released quasi-biogenic surfactant on the gas transfer velocity (k_w) derived using the He/SF₆ dual gas tracer technique and measured dimethyl sulphide (DMS) fluxes. Of seven estimates of k_w made with the dual tracer technique in the wind speed range 7.2-10.7 m s⁻¹, those in the presence of applied surfactant were suppressed relative to quasi-simultaneous estimates in a control dual tracer patch nearby. Similarly, estimated transfer velocities of DMS, k_DMS, were also significantly suppressed in surfactant-applied regions; suppression ranged from 39% of k_DMS at 5.0 m s⁻¹ to 24% of k_DMS at 10.8 m s⁻¹. As well as being the first field measurements directly indicating the suppression of gas exchange by surfactants, these results suggest that in biologically productive waters sea to air gas fluxes derived using published k_w-wind speed relations will likely be overestimated.

FOCUS 3: Long-lived radioactively active gases
Carol Robinson
The impact of coastal upwelling on the air-sea flux of CO₂, N₂O and CH₄
Coastal upwelling regions significantly influence oceanic biogeochemistry and atmospheric chemistry through supply of water supersaturated with nitrous oxide, carbon dioxide and methane, and rich in inorganic nutrients and photolabile dissolved organic matter (DOM). This presentation will compare and contrast recent measurements of surface water concentrations of carbon dioxide, nitrous oxide and methane in the major Eastern Boundary Upwelling Systems, with the aim of identifying gaps in our knowledge and therefore priority research questions to be addressed in future international field campaigns.

Laura Farías
Mechanisms of N₂O consumption in the upwelling ecosystems

The presence of the hypoxia-suboxia associated with coastal upwellings off Peru and Chile drives to climatologically important processes such as nitrification, denitrification; both are responsible for N₂O cycling (i.e., production and consumption). We measure denitrification rates (dessasimilative N₂O reduction to N₂) and report for first time, the existence of biological N₂O fixation as assimilatory process. N₂O consumption by N₂O reduction to N₂ varies between 2.73 and 70.8 nmol L⁻¹ d⁻¹ with rates depended strongly on threshold O₂ levels, whereas N₂O fixation happens under variable light intensities (from photic to aphotic) and O₂ concentrations (from oxic to anoxic) at rates of 0.03-16.9 nmol N²⁻¹ d⁻¹. Both desassimilative and assimilative pathways are consuming N₂O but the latter also is transforming N₂O into bioavailable N. The biogeochemical and climatological consequences of these processes are discussed.
Coastal upwelling regions are "hot spots" for enhanced emissions of long-lived trace gases such as carbon dioxide (CO₂) and nitrous oxide (N₂O). The upwelling area off Mauretania (Northwest Africa, 16°N–21°N) is known as a very productive region since the upwelled water has high nutrient concentrations which together with rapid warming triggers intensive blooms. High supersaturation (with respect to atmospheres) of CO₂ and N₂O is observed in the fresh upwelled water masses close to the coast, while a fast decay of supersaturation of CO₂ and N₂O is observed towards the open ocean. The decay of CO₂ supersaturation is mainly driven by air-sea gas exchange and biological production which are hard to separate quantitatively. In contrast the N₂O supersaturation decreases only due to air-sea gas exchange. Using N₂O air-sea exchange rates the time elapsed since upwelling can be assigned to a water mass. Through combination of the saturation patterns of CO₂ and N₂O this information can be used to separate the air-sea exchange and biological (net community production, NCP) components of the CO₂ decay.

We present surface ocean data for CO₂ and N₂O from three cruises in the Mauritanian upwelling region that were conducted in two different seasons (spring and summer): Poseidon Cruise 320-1: March/April 2005; Meteor Cruise 68-3: July 2006; L’Atalante Cruise: February 2008. The upwelling shows strong variability but is most pronounced in early spring with highest observed values of seawater partial pressure (pCO₂) of 750 µatm. We estimated NCP values ranging from 0.4 ± 0.1 g C m⁻² d⁻¹ during times of weak upwelling to 2.2 ± 0.5 g C m⁻² d⁻¹ during a strong upwelling situation, which is comparable with other studies in this region. The estimated NCP values show a strong relationship with a wind derived upwelling index. We used this relationship to estimate annual NCP, which is characterized by high interannual variability.

FOCUS 1: BCG interactions between the ocean and the atmosphere

Bill Miller

Marine photochemistry in upwelling systems

Glyoxal is an indicator for oxidative hydrocarbon chemistry, and a building block for secondary organic aerosol (SOA). SOA modifies the hygroscopic properties of organic aerosols, and can add to the growth of small particles to sizes that can more easily activate to form cloud droplets. Iodine oxide (IO), and/or to add to the growth of pre-existing particles. Due to the very high solubility of the glyoxal molecule, concentrations in excess of 1000 ppb over the open ocean like we found over the Pacific Ocean require an airborne source mechanism (Sinreich et al., 2010). We have investigated the source mechanism further during a ship campaign in 2009, as well as a first research flight aboard the NSF/NCAr GV research aircraft (HAPER). Both campaigns give clues about the sources of both gases over the remote tropical Pacific Ocean, and reveal a surprising impact on the composition of the free troposphere.

FOCUS 2.2: Processes in the oceanic boundary layer

Oscar Pizarro

Observing the oxygen minimum zone in the Eastern South Pacific

We report on main initiatives that are currently in progress to study the OMZ off Chile, including objectives and observational strategies. Particularly, we present direct oxygen observations obtained with autonomous profiler floats equipped with Aanderaa Optode sensors in the eastern tropical South Pacific over around three years. Based on those data we find that the oxygen minimum zone in this region presents oxygen concentrations that are significantly lower than historical reports and extends over a much larger geographical area. The remarkable observed persistence of the oxygen-deficient waters over time and space is however interrupted by the transient injections of low-levels of dissolved oxygen, which near the coast appear to be related to the sinking of water previously upwelled. Results from Oxygen time series from the continental shelf off Chile near 21°S and 36.5°S are also used to analyze ventilation mechanisms in those two different regions. Preliminary results from ocean glider off Concepción (35.5°S) are also presented. Finally we discuss future plans and possible international collaborations for understand the OMZ of the eastern south Pacific and its spatial and temporal variability at different scales.

Carbon and nutrient fluxes in Eastern Boundary Upwelling Ecosystems (EBUEs) are reviewed with emphasis on the southeastern tropical Pacific. These fluxes include those driven by upwelling, air-sea exchange, denitrification and the biological pump. The emphasis is on how the special character of the EBUE (i.e. latitude, ocean basin, age of the subsurface water, etc.) determines or not the nature and strength of each of the fluxes. Finally we review the principal modes of climate variability over the last century and how these modes are affecting the southeastern tropical Pacific. We end with speculation of how these fluxes might change in the future.
Eastern Boundary systems, the OMZs are fed by organic material sedimenting from the generally productive upper layers. Understanding the processes and quantifying the rates of production and loss in these layers is thus essential to better address and constrain the elemental budget in OMZs. We have developed bio-optical profiling floats that combine classical T/S data acquisition with key biogeochemical, bio-optical and optical measurements: Chla fluorescence, backscattering coefficient, particle attenuation coefficient (proxy of POC), colored dissolved organic matter and spectral irradiances. These floats have been operated in various environments and have acquired meter-resolved vertical profiles for up to 2 years at a 5 day-temporal resolution. Each multivariable profile acquired by a float can be used to initialize a bio-optical model to quantitatively resolve primary production rates and to “predict” the profile (carbon or Chla) for the next float surfacing. The difference between the predicted and the realized profile allows assessing the net production terms (gains vs losses between two float surfacing). We are preparing a second generation of floats that will also allow, together with the presently performed measurements, NO3 and PO4, to be developed and adapt the modeling approach. We propose to apply this synergetic combination of bio-optical float and model to EBUES environments.

Hervé Claustre and Alexandre Mignot

Combining bio-optical profiling float observation and modeling for constraining carbon budgets in the upper layer of EBUES areas.

In Eastern Boundary systems, the OMZs are fed by organic material sedimenting from the generally productive upper layers. Understanding the processes and quantifying the rates of production and loss in these layers is thus essential to better address and constrain the elemental budget in OMZs. We have developed bio-optical profiling floats that combine classical T/S data acquisition with key biogeochemical, bio-optical and optical measurements: Chla fluorescence, backscattering coefficient, particle attenuation coefficient (proxy of POC), colored dissolved organic matter and spectral irradiances. These floats have been operated in various environments and have acquired meter-resolved vertical profiles for up to 2 years at a 5 day-temporal resolution. Each multivariable profile acquired by a float can be used to initialize a bio-optical model to quantitatively resolve primary production rates and to “predict” the profile (carbon or Chla) for the next float surfacing. The difference between the predicted and the realized profile allows assessing the net production terms (gains vs losses between two float surfacing). We are preparing a second generation of floats that will also allow, together with the presently performed measurements, NO3 and PO4, to be developed and adapt the modeling approach. We propose to apply this synergetic combination of bio-optical float and model to EBUES environments.

Arnaud Bertrand, Michael Ballot, Alexis Chaigneau, Michelle Graco, Véronique Garçon, Justyna Jonca and Aurelien Paulmier

Use of acoustic data to study high resolution biogeochemical processes

The oxycline, which delimits the top of the oxygen minimum zone (OMZ), forms a sharp barrier for living organisms intolerant to hypoxia. It is also the site of the most intense particulate matter remineralization, a process contributing to maintain the underlying OMZ and to induce feedbacks on the climate (e.g. greenhouse gases production). A recent study show that high-resolution observation of the spatiotemporal variability of the oxycline can be achieved using the vertical distribution of epipelagic organisms (mainly zooplankton and small pelagic fish) estimated using acoustics, Physical forcing at meso- and submeso- scales is increasingly suspected to play a fundamental role in the structuring and functioning of marine ecosystems.

The acoustic footprint of the spatiotemporal variability of the oxycline can be achieved using acoustics. The acoustic footprint of the spatiotemporal variability of the oxycline can be achieved using acoustics. The acoustic footprint of the spatiotemporal variability of the oxycline can be achieved using acoustics. The acoustic footprint of the spatiotemporal variability of the oxycline can be achieved using acoustics. The acoustic footprint of the spatiotemporal variability of the oxycline can be achieved using acoustics.

Marin Hernandez-Ayon

Studies of carbon dioxide system parameter along the Pacific Mexican Coast

The California current system (CCS) is one of the most extensively surveyed regions of the world’s oceans. Most of what is known about the dynamics and kinematics of the CCS has been built upon the CalCOFI program, which began regular sampling in 1949. However since 1997 Mexican Institutions took the responsibility for the Baja California region. In October 2007, IMECOCAL completed its tenth year of quarterly cruises dedicated to monitoring and analysis of the state of the pelagic ecosystem in the southern region of the California Current. IMECOCAL (Investigaciones Mexicanas de la Corriente de California) is an inter-institutional program administered through CICESE (Centro de Investigación Científica y de Educación Superior de Ensenada) with active participation of scientists from UABC (Universidad Autónoma de Baja California), CICIMAR (Centro Interdisciplinario de Ciencias Marinas), CIBNOR (Centro de Investigaciones Biológicas del Noroeste), UNAM (Universidad Nacional Autónoma de México). It has been supported principally through Mexican federal funds obtained through competitive grant awards from the National Council of Science and Technology (CONACYT). In the other hand, since 2006 it was include some coastal measurement of the CO2 system for this region but in the present we also started with a two Coastal Monitoring observatories (one in Ensenada and a second south of Baja California). In addition, since 2008 we are also participating in the subtropical region in cruises of opportunity in collaboration with Scripps Institution (UCSD), CICESE, University of Colima and the Oceanography Department from the Mexican Army.

Niki Gruber, Zouhair Lachkar, Giuliana Turi, and Lindsey Kropuenske-Artman

Sources, sinks, and transport of carbon in Eastern Boundary Upwelling Regions: A comparative analysis

The sub-tropical Eastern Boundary Current regions (e.g. Peru-Humboldt, California, and Benguela) are naturally eutrophic and, although, they comprise only 0.1% of the global ocean volume, 17% of the global fish catch occur here. The water underlying the EBC regions is depleted in oxygen and together with the Arabian Sea, the Peru-Humboldt, California, and Benguela regions make up the world major Oxygen Minimum Zone’s (OMZ’s). In terms of primary productivity, the most productive of these systems is the Benguela System off Namibia. Nonetheless, the Benguela System is the least productive region of the world’s oceans. Hydrogen sulfide is a toxin that is more deadly to multi-cellular life than cyanide and has been postulated to decimate whole generations of juvenile fish as well as benthic communities. Hydrogen sulfide is abundant in anoxic marine sediments and the water column of some isolated basins, where it is formed upon sulfate respiration by sulfate reducing bacteria. In open ocean waters, on the other hand, substantial concentrations of H2S are generally believed to be extremely rare and large expanses of sulfide-containing waters have been so far reported only for the Namibian and Indian shelves. Only anecdotal reports of “aquatics”, sulfide waters, by Peruvian fishermen, and “the smell of H2S” observed during scientific surveys report this from Peru-Humboldt OMZ, the World’s largest OMZ and most important in terms of fisheries.

Gautier Lavik, Julia Rulfs Ihss, Tim Kelvalge, Sergio Contreras, Aurélien Paulmier, Michelle Graco, Herbert Siegel, Martin Frank, Marcel Kuppers

Is sulfide in OMZ waters an increasing phenomenon as a result of global change?

The sub-tropical Eastern Boundary Current regions (e.g. Peru-Humboldt, California, and Benguela) are naturally eutrophic and, although, they comprise only 0.1% of the global ocean volume, 17% of the global fish catch occur here. The water underlyng the EBC regions is depleted in oxygen and together with the Arabian Sea, the Peru-Humboldt, California, and Benguela regions make up the world major Oxygen Minimum Zone’s (OMZ’s). In terms of primary productivity, the most productive of these systems is the Benguela System off Namibia. Nonetheless, the Benguela System is the least productive region of the world’s oceans. Hydrogen sulfide is a toxin that is more deadly to multi-cellular life than cyanide and has been postulated to decimate whole generations of juvenile fish as well as benthic communities. Hydrogen sulfide is abundant in anoxic marine sediments and the water column of some isolated basins, where it is formed upon sulfate respiration by sulfate reducing bacteria. In open ocean waters, on the other hand, substantial concentrations of H2S are generally believed to be extremely rare and large expanses of sulfide-containing waters have been so far reported only for the Namibian and Indian shelves. Only anecdotal reports of “aquatics”, sulfide waters, by Peruvian fishermen, and “the smell of H2S” observed during scientific surveys report this from Peru-Humboldt OMZ, the World’s largest OMZ and most important in terms of fisheries.

Current estimates postulate that the occurrence of shelf hypoxia, due to both human-induced eutrophication and global warming, will strongly increase within the coming decades. Expansion of the OMZ can increase the area affected by N-loss from the water column and deplete the oxidation capacity by nitrate. This might increase the zones affected by sulfidic waters and due to the newly described bacterial detoxification in the subsurface waters these events can be overlooked by remote sensing or monitoring of shallow coastal waters. On geological time scales mass extinctions in the ocean has been coupled to large expansions of sulfidic waters during climatic warm phases.
OMZs, known as suboxic layers mainly localized in the EBUS, are expanding since the 20th "high CO2" century, probably due to the global warming. OMZs are also known to contribute significantly to the oceanic production of N$_2$, a greenhouse gas (GHG) more efficient than CO$_2$. However, the contribution of the OMZs on the oceanic sources and sinks budget of CO$_2$, the main GHG, still remains to be established. We present here the dissolved inorganic carbon (DIC) structure, associated locally with the Chilean OMZ and globally with the main most intense OMZs (O$_2<20$ μmol/kg) in the open ocean. Simultaneous DIC and O$_2$ data collected off Chile during 4 cruises and a monthly monitoring (2000-2002) have been examined along with international DIC and O$_2$ databases for the other OMZs. High DIC concentrations (>2225 μmol/kg, up to 2350 μmol/kg) have been reported over the whole OMZ thickness, allowing to define for all studied OMZs a Carbon Maximum Zone (CMZ). The CMZ-OMZs constitute the largest carbon reserves of the ocean in subsurface waters and could induce a positive feedback for the atmosphere during upwelling activity, as potential direct local sources of CO$_2$. The CMZ paradoxically presents a slight "carbon deficit" in its core, but would be mainly compensated locally at the oxycline by a "carbon excess", induced by a specific remineralization and associated with anomalous C/O molar ratio. Further studies to confirm these results for all OMZs are required to understand the OMZ effects on climatic feedback mechanisms. In particular, cruises and experiments dedicated to specific process studies, in collaboration with Peru, Mexico and France are planned for 2012-2013, and a Gordon-like conference on the OMZs will be organized in Toulouse in October 2011.

Gernot Friederich and Francisco Chavez

Influence of the oxygen minimum zone on inorganic carbon ventilation along the Peruvian and northern Chilean coast.

During 2009 and 2010 detailed dissolved inorganic carbon (DIC and pCO$_2$) data was collected along the South American coast from the equator to 20° S. This region has previously been shown to have a net flux of CO$_2$ from the ocean to the atmosphere and this new data set indicates that a portion of this flux can be attributed to the nitrate deficit generated at depth within the oxygen minimum zone (OMZ). The nitrate deficit can be observed above the OMZ and if these waters are upwelled there will be insufficient fixed nitrogen to reduce pCO$_2$ levels to atmospheric levels. The most extreme cases were observed over the shelf off central Peru where hydrogen sulfide was detected and oxygen was exhausted at a depth as shallow as 15 m. At these stations the 30 m DIC concentrations were as high as those usually found at a depth of 600 m in offshore waters.

Ventilation of this 100 m water column could produce a local carbon flux of 20 moles of CO$_2$ per square meter from the ocean to the atmosphere. Since these conditions produce excess sea surface phosphate, nitrogen fixation should compensate for these high CO$_2$ fluxes over larger space and time scales. Numerous high resolution profiles between the sea surface and 200 m at 20° S indicate that the maximum DIC and pCO$_2$ levels occur near the top of the OMZ and there may even be a slight decline of these parameters with depth in spite of increasing AOU and nitrate deficits. The details of the profiles will be examined in relation to the results from biological rate and process studies.

Jorge Sarmiento, D Bianchi, Eric Galbraith, Iris Kriest, E Kwon, Andreas Oschlies, and Allison Smith

Sensitivity of air-sea fluxes to water column remineralization

Despite many decades of observational and modeling research, we continue to struggle with how to model water column remineralization and to be surprised by some of the results that come out of our model simulations. In this overview presentation, we summarize recent results from modeling research and observational analysis at Princeton and Kiel Universities, including new findings on the sensitivity of the atmosphere-ocean CO$_2$ balance to the depth of remineralization, and on the difficulty of models in properly simulating the geographic extent of suboxia. We conclude with a discussion of the possible implications of these findings for our understanding of water column remineralization processes.

Karen Casciotti, Robert Anderson and James Moffett

U.S. GEOTRACES Planning for the Eastern Tropical Pacific Ocean

After many years of planning and preparation, the U.S. GEOTRACES program is now in the implementation phase. The first U.S. GEOTRACES section cruise in the North Atlantic will commence in October 2010, and the Pacific section cruises are slated for operation in 2012-2015. The first of these Pacific cruises is expected to be a zonal section from Peru to Tahiti, through the oxygen deficient zone (ODZ) in the Eastern Tropical South Pacific ocean and the 3thpume from the Eastern Tropical Pacific. This section is designed to examine fluxes associated with ODZ, boundary scavenging, and hydrothermal processes. This presentation will summarize the scientific objectives, rationale, and timeline for participation in the upcoming GEOTRACES Pacific section cruises.
Abstracts

Water column oxygen concentrations time-series spanning the last 50 years have shown that tropical OMZ were expanding certainly as a consequence of global warming (Stramma et al., 2008). For paleoceanographic reconstructions, it is a necessary prerequisite to test whether and how nitrogen isotopes values, a proxy commonly used to track water column denitrification and hence OMZ expansion, can be quantitatively, or at least qualitatively, related to oxygen deficiency. By comparing surface sediment and water column nitrogen isotope values from the coastal upwelling area off Peru, we test the mechanisms behind $\delta^{15}$N gradients and absolute values.

We present new results from more than 60 surface sediments samples collected along the Peruvian and Ecuadorian margin between 2°N and 20°S during the Meteor cruise M772 in december 2008. Surface sediment nitrogen isotope gradients are compared with water column $\delta^{15}$N measured on nitrates, as well as with nitrate uptake. Productivity and nitrate uptake are maximal at the position of local and perennial upwelling cells. Due to continuous nutrient supply into the upwelling systems sedimentary $\delta^{15}$N values reveal an increase of only about 2 to 3 ‰ over the mean ocean value (~5.5‰), or even close to the mean ocean value north off 10°S, where the OMZ is still prominent but nutrient uptake is low. The sedimentary $\delta^{15}$N signal reaches very high values above 10 per mill only where extreme oxygen deficiency occurs between 10 and 20°S. These sedimentary nitrogen isotope gradients reflect water column $\delta^{15}$N of nitrates as we observe a strong relationship between sedimentary and water-column $\delta^{15}$N values. On a broader geographic scale, the highest SE Pacific $\delta^{15}$N values (12 to 15‰) are found off Chile between 20 and 30°S due to a combination of almost complete nitrate utilization with still strong oxygen minimum conditions. It means that nitrogen isotope variations in sedimentary records from OMZ areas are not only related to water column denitrification and oxygen deficiency and must be used with caution.

Local Information

Transport to/from Airport

Jorge Chavez International Airport (Lima) is located 16 km (10 miles) northwest of Lima. Hotels are located in the Miraflores district of Lima and are best reached by taxi.

Many taxis are available at the airport but it is recommended that participants use the services of one of the 3 official taxi companies which are located directly outside the arrivals hall. The journey takes about 40 minutes and should cost approximately 40-50 Soles (maximum 20 dollars), most taxis accept both Nuevos Soles and US dollars.

There are bureaux de change in the main hall of the International zone and ATMs are available throughout the airport.

Local Transport

The following taxi firms are recommended.

Taxi Green
Tel. (511) 484-4001
E-mail: taxigreen@peru.com (reservation)

Taxi Aeropuerto de Lima
Tel. (5111) 5752961 / cel. (511) 995013925 / 998268244
http://www.taxiaeropuertolima.com/

Conference Venue

Instituto del Mar del Perú (IMARPE)
http://www.imarpe.gob.pe/
Esquina Gamarra y Gral Valle s/n
P.O. Box 22 Callao
Perú
Tel: (511) 6250800

A bus to and from the conference venue will be provided on 8, 9 and 10 November. There will only be one meeting point which is outside the Hotel Boulevard. The bus departs at 7:30am each morning. Please be on time.
Local Information

Hotels

Hotels are located in the Miraflores district of Lima. Most participants from outside Perú will be staying in either of the following hotels. The approximate location of hotels can be seen on the map over the page. For more detailed information please refer to google maps or visit http://tiny.cc/LimaOMZ

**Hotel Aleman**

http://www.hotelaleman.com.pe/
Av. Arequipa 4704 - Miraflores, Lima 18 - Perú
Tel: (511)241-1500 / (511)241-2500
Email: haleman@terra.com.pe
hoalsa@hotelaleman.com

**Hotel Boulevard**

http://www.hotelboulevard.com.pe/
Av. Pardo Nº 771 Miraflores Lima 18 - Perú
Tel: (511)444-6562 / (511)444-6563
E-mail: hotelboulevard@speedy.com.pe

Lunches

Lunch will be at restaurants Club Regattas Union and Canottieri. Both are within walking distance of IMARPE. Lunches will be paid by participants and cost approximately Soles 12-15.

Meeting Dinner

La Dama Juana

http://ladamajuana.com.pe/
C.T.E. Larco Mar Local 502 - B Miraflores, Lima - Perú
Tel (511) 447 3686
informes@ladamajuana.com

A 3 course Creole Buffet dinner will be served after a “Pisco Sour” a traditional Peruvian drink made with Pisco a liquor distilled from grapes. Dinner will be followed by a Peruvian folklore show with native dances from 7 different regions of Perú. Price/person:  Soles 99.00 (including service taxes)

Dinner is at 8pm, Tuesday 9 November. The restaurant is approximately 10 blocks from hotels and can be seen on the map over the page. The restaurant is located in the Larco Mar shopping and entertainment complex in front of the Marriott Hotel.

For more detailed information visit: http://tiny.cc/LimaOMZ
Local Information

Useful Information

Currency
Perú uses Nuevos Soles (S). The exchange rate at time of printing was:
1 EUR = 3.87 S
1 USD = 2.78 S
1 GBP = 4.45 S
Cajeros automáticos (ATMs) are readily available and most accept international cards such as Plus (Visa), Cirrus (Maestro/MasterCard) and American Express using the 4 digit pin code system. Most ATM's dispense both US dollars and Nuevos Soles. US dollars are accepted by many hotels though Nuevos Soles will be needed to pay for local transportation, meals etc.

Telephone
International Call Prefix: 00
Country code: 51
Lima Area Code: 1
Local phone numbers have 6 or 7 digits
Time zone - GMT -5 hours

Emergency numbers
See http://www.limaeasy.com/what_if/emergency_numbers_lima.php for more details
- Police / Policía Nacional del Perú: Central Emergency Number: 105
- Fire Brigade / Bomberos: Emergency Number: 116
- Special tourist Police station: (0051 1) 423-3500
- For tourist information visit www.lonelyplanet.com/peru

For tourist information visit
http://en.wikipedia.org/wiki/Lima
http://www.limaeasy.com/

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