SOLAS Mid-Term Strategy Initiative "Air-sea gas fluxes at Eastern boundary upwelling and Oxygen Minimum Zone (OMZ) systems"

Workshop on "Towards an integrative regional coupling in the Eastern Boundary Upwelling Systems (EBUS)"
26-28 November 2012
Instituto Geofísico del Perú (IGP)
Lima, Perú

Contents

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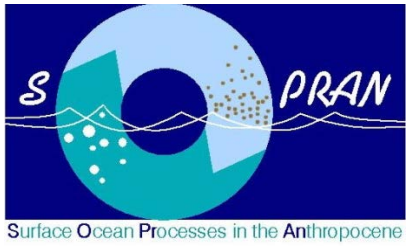

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Programme

Workshop

Monday 26 November 2012

08:30	Departure from hotel Señorial in Miraflores (José Gonzáles 567, Miraflores)	
09:45	Welcome to IGP	Ronald Woodman, Ken Takahashi, José Macharé
10:00	Introduction to SOLAS and the workshop	Véronique Garçon
SESSION: Surface (energy and water) fluxes at the air-sea interface (in situ measurements of fluxes and satellite-based flux estimates)		
10:15	Measurements of turbulence and mixing in the ocean surface layer with the Air-Sea Interaction Profiler	**Danielle J. Wain**, Brian Ward, Jonathan Lilly, Adrian H. Callaghan, Graig Sutherland
10:50	Coffee break	
11:10	Heat and freshwater closure from a model approach	**Guy Caniaux**, Sophie Belamari, Alexandre Paci, Hervé Giordani, Louis Prieur
11:45	Observed and projected changes in the surface winds off western South America	**René Garreaud**,
12:20	Challenges in modelling of regional ocean-atmosphere interaction in the Peru EBUS	**Ken Takahashi**, B. Segura, Julio Quijano, Katerina Goubanova, Boris Dewitte
12:55	Lunch	
14:25	The response of the Peruvian upwelling system to centennial-scale global change during the last ~1700 years	**Renato Salvatteci**, Abdel Sifeddine, Dimitri Gutierrez, Luc Ortlieb, David Field, Mohammed Boussafir
14:50	Benthic redox conditions and oceanographic variability in the upper Central Peruvian margin since the nineteenth century	**Dimitri Gutierrez** Jorge Cardich, C. Machado, Maria Morales, Renato Salvatteci, Abdelfettah Sifeddine
15:15	Inferring CO_2 fluxes from space: A multiscale approach	**Véronique Garçon,** Joël Sudre, Hussein Yahia, Boris Dewitte, Aurélien Paulmier, Serena Illig, Isabelle Dadou, André Butz, Christoph Garbe
15:35	Coffee break	
15:55	Assessing atmospheric gas concentrations and interfacial fluxes from remote sensing	**Christoph Garbe** André Butz, Véronique Garçon, Jevheni Vihharev, Joël Sudre, Hussein Yahia, Boris Dewitte, Aurélien Paulmier, Serena Illig, Isabelle Dadou
16:30	OMZ influence on the CO_2 system in the Midriff islands of the Gulf of California: A promising observatory for global change studies	**Martin Hernandez Ayon**
17:05	Departure to Miraflores	
19:30	Ice breaker at Restaurant “Huaringas Bar” (460/472 Ovalo Bolognesi, Miraflores)	

Tuesday 27November 2012

08:30	Departure from hotel Señorial in Miraflores (José Gonzáles 567, Miraflores)	
09:30	El Niño events in the Peru EBUS	**Ken Takahashi**, Kobi Mosquera, Aldo Montecinos, Katerina Goubanova, Boris Dewitte
10:05	Intraseasonal upwelling variability off Peru: remote and local forcings versus non-linear processes	**Boris Dewitte**, Serena Illig, Katerina Goubanova, Ken Takahashi, Kobi Mosquera, Ivonne Montes, Aurélien Paulmier, Véronique Garçon, Sara Purca
10:40	Is air-sea interaction inhibited in tropical upwelling systems?	**Tim Fischer**, Annette Kock, Tobias Steinhoff, Marcus Dengler, Hermann W. Bange, Peter Brandt
11:15	Coffee break	
11:35	Controls from a widespread surface ocean organic micro layer on atmospheric oxidative capacity	**Rainer Volkamer**
12:10	Rationale for a reference site off Peru (Hormigas Islands) as part of Ocean SITES	**Ken Takahashi**, José Macharé, Edmundo Norabuena, Aurélien Paumier, Boris Dewitte, Mohamed Chlieh
12:45	Lunch	
SESSION: Towards an integrative regional coupling in the EBUS: modelling and observations (in situ and remote sensing): atmosphere, physical and biogeochemical dynamics		
14:15	Denitrification versus Anammox in the Eastern Tropical Pacific: a numerical modeling study	**Ivonne Montes**, Andreas Oschlies, Elodie Gutknecht, Véronique Garçon
14:50	Physical influence on the biogeochemical feature and processes in the Peruvian OMZ	**Aurélien Paulmier**, Mélanie Giraud, Justyna Jonca, Violeta Leon, Jonathan Valle, Ivonne Montes, Joël Sudre, Octavio Moron, Jorge Quispe, Gaute Lavik, Patricia Grasse, Martin Frank, Lothar Stramma, Boris, Dewitte, Véronique Garçon
15:25	N_2O Cycling in Upwelling Zones and Low-Oxygen Environments	**Parv Suntharalingam** Erik Buitenhuis, Oliver Andrews, Sunke Schmidtko, Corinne Le Quere
16:00	Coffee break	
16:20	The future evolution of multiple stressors in eastern boundary upwelling systems	**Zouhair Lachkar**, Nicolas Gruber
16:55	Remote sensing assets for Ocean-Atmosphere interactions science	**Roberto Sabia**, Diego Fernández-Prieto
17:30	Closure of workshop	Ken Takahashi, Véronique Garçon
17:45	Official picture	
18:00	Departure to Miraflores	
19:30	Workshop dinner at Restaurant “El Rocoto” (Av. Federico Villareal 360 Miraflores)	

Lecture day

Wednesday 28 November 2012

08:30	Departure from hotel Señorial in Miraflores (José Gonzáles 567, Miraflores)	
09:30	Welcome and introduction to the lecture day	Véronique Garçon and Ronald Woodman
09:35	A synoptic climatology of the near-surface winds along the west coast of South America	**René D. Garreaud**, David Rahn
10:20	Recent results on air-sea interactions over the Atlantic equatorial upwelling	**Guy Caniaux**, Hervé Giordani, Jean-Luc Redelsperger, Mark Wade
11:05	Coffee break	
11:20	Oceans, atmospheric chemistry, and climate: influence of reactive halogens on the removal of greenhouse gases in the tropical free troposphere	**Rainer Volkamer**
12:05	Ocean circulation of the South Pacific gyre	**Christophe Maes**
12:50	Lunch	
14:20	Trace gases (N_2O, CH_4, DMS) in the ocean	**Hermann Bange**
15:05	Quantifying oceanic biogeochemical fluxes: M modelling applications and challenges	**Parv Suntharalingam**
15:50	Coffee break	
16:05	Modeling the OMZ of the Eastern Tropical Pacific	**Ivonne Montes**, Elodie Gutknecht, Boris Dewitte, Aurélien Paulmier, Isabelle Dadou, Andreas Oschlies, Véronique Garçon
16:50	How do ocean mesoscale eddies affect biogeochemical processes? Insights from model simulations and satellite observations	**Zouhair Lachkar**
17:35	Closure	José Macharé
17:40	Departure to Miraflores	

Abstracts

Measurements of turbulence and mixing in the ocean surface layer with the Air-Sea Interaction Profiler

Danielle J. Wain[1], Brian Ward[1], Jonathan Lilly[2], Adrian H. Callaghan[1], Graig Sutherland[1]

1. School of Physics, National University of Ireland, Galway, Ireland
2. NorthWest Research Associates, Seattle, WA, USA

Salt and freshwater fluxes in the upper ocean comprise an important element of the global hydrological cycle, an integral component of the climate system. Sea surface salinity is currently being measured on a global scale by the ESA Soil Moisture and Ocean Salinity (SMOS) and the Aquarius/SAC-D satellites. As part of an effort to ground truth satellite-based salinity measurements, the aim of this project is to study the upper ocean with the Air-Sea Interaction Profiler (ASIP), using existing data and new data to be collected during STRASSE (Subtropical Atlantic Surface Salinity Experiment). ASIP is ideally suited to measure micro-scale (sub-cm scale) temperature, salinity, and velocity shear both immediately below the ocean surface and through the mixed layer. From these measurements, the turbulent fluxes of heat and salt can be estimated and the mixing processes responsible for the fluxes can be evaluated.

In May 2010, ASIP measurements were taken during a cruise on the CCGS Hudson in the Labrador Sea to investigate observed springtime freshwater capping events. ASIP captured evidence of intense turbulence (~ $1x10^{-6}$ W/kg) at the surface and patches of turbulence (~ $1x10^{-7}$ W/kg) at the base of the seasonal mixed layer from a breaking internal wave. We investigate the impact of these mixing events on the structure of the mixed layer.

Heat and freshwater closure from a model approach

Guy Caniaux[1], Sophie Belamari[1], Alexandre Paci[1], Hervé Giordani[1], Louis Prieur[2]

1. CNRM/GAME (Météo-France/CNRS), Toulouse, France
2. (CNRS), Villefranche-sur-Mer, France

Closing heat and freshwater budgets with observation data only is a difficult task because of unknown terms in the budget equation and uncertainties affecting data. The problem is not solved when using numerical model outputs because of recurrent biases, errors, difficulty to validate the model and to calibrate paramerizations. Here we present a method that was tested with the important data set collected during the Programme Océan Multidisciplinaire à Méso- Echelle (POMME) experiment, conducted in the Northeast Atlantic in 2000-2001.

A heat and fresh water budget was computed from satellite, in-situ data, numerical weather prediction model observables and a bulk algorithm. A method using a one dimensional approach with fit to the mixed layer salt and heat content observed was then developed to adjust the precipitation and surface turbulent fluxes. The adjusted fluxes were finally used to force different 3D models. In this presentation, we discuss how these adjusted fluxes contribute to simulate realistically the region and how the heat and freshwater budgets produced by a statistical model assimilating all the data collected during the experiment is closed by applying these fluxes.

Observed and projected changes in the surface winds off western South America

René D. Garreaud

Department of Geophysics, Universidad de Chile

In the first part of this presentation we describe the changes in the surface winds and sea surface temperature (SST) along the west coast of South America during the last few decades using in-situ records, atmospheric reanalysis and satellite pictures. There is robust evidence of a coastal cooling all the way from central Perú to central Chile most likely as a result of increased equatorward, upwelling favorable low level winds. The actual mechanism of upper ocean cooling remains unclear. Just a few tens of kilometers inland the surface stations indicate a clear warming during the last decades, leading to a marked gradient in the near-surface temperature trend. Global models used in the past IPCC report fail to resolve this coastal cooling – land warming pattern. In the second part, we describe the projected changes in coastal winds and SST toward the end of the 21st century under selected IPCC scenarios. Consistent with a poleward expansion of the subtropical subsidence there is a reinforcement of the southern flank of the SE Pacific anticyclone leading to stronger winds off central Chile. Farther north along the Peruvian coast the projection is less clear and probably scale-dependent.

Challenges in modeling of regional ocean-atmosphere interaction in the Peru EBUS

Ken Takahashi[1], Berlín. Segura[1], Julio Quijano[1], Katerina Goubanova[2], Boris Dewitte[2]

1. IGP, Perú
2. LEGOS, Toulouse, France

Ocean-atmosphere interactions are two-way. Particularly, the sea surface temperature (SST) affects the atmospheric circulation, thermodynamics and clouds, which in turn control the SST and ocean circulation. This interaction takes place through the air-sea momentum and heat fluxes, which depend on the states of both media. Although modeling of the ocean or

the atmosphere by itself is useful (and necessary) to study and understand the relevant processes and mechanisms, the simulation of climate variability and change at a scale small enough to resolve coastal upwelling and other mesoscale processes relevant to climate, biogeochemistry and ecology in the Peru EBUS requires high-resolution coupled ocean-atmosphere regional modeling. Preliminary results with the IGP-LEGOS regional coupled model based on WRF and ROMS indicate that bias amplification, common in global climate models, is also present in the regional models. This is to be expected, since the regional and global models both rely on parametrization of unresolved processes such as the planetary boundary layer (PBL) turbulence. Particularly, a subestimation of low level cloudiness, which is associated with an inability of the atmospheric model to adequately represent the thermal inversion on top of the marine boundary layer, results in a strong positive SST bias in the coupled model. Sensitivity experiments with different PBL schemes in un-coupled WRF are presented, which show a) substantial differences between schemes, b) a general inability to reproduce the observed cloudiness and thermal inversion. Strategies and plans to understand and reduce these biases are presented and discussed.

The response of the Peruvian upwelling system to centennial-scale global change during the last ~1700 years

Renato Salvatteci[1,2], Abdel Sifeddine[1,3], Dimitri Gutierrez[2], Luc Ortlieb[1], David Field[4], Mohammed Boussafir[5]

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2. Instituto del Mar del Perú (IMARPE), Chucuito, Callao, Perú
3. Departamento de Geoquimica, Universidade Federal Fluminense, Niteroi-RJ, Brasil
4. Hawaii Pacific University, Kamehameha, USA
5. Institut des Sciences de la Terre (ISTO), Orléans, France

The Peruvian Upwelling System (PUS) sustains high biological productivity and one of the world's largest fisheries due to upwelling of nutrient-rich waters from the subsurface Oxygen Minimum Zone (OMZ). The PUS undergoes large temporal variability from annual to millennial timescales, and is experimenting considerable changes in response to global warming. Throughout the last 2000 years, warmer (the Roman Warm Period [RWP], the Medieval Climate Anomaly [MCA] and the Current Warm Period [CWP]), and colder (the Dark Ages Cold Period [DACP] and Little Ice Age [LIA]) intervals occurred with considerable changes around the globe. To reveal the mechanisms that controlled the PUS during these contrasting periods, we use a multi-proxy approach including, paleontological, organic and inorganic proxies in finely laminated sediments retrieved off Pisco (~14 °S), Peru and compare them with other relevant paleoclimatic reconstructions. According to our analyses and interpretations the productivity and OMZ intensity off Peru show a strong link between

the PUS and Northern Hemisphere climate. The warm periods (CWP and the MCA) are characterized by an intense OMZ, high export production and high anchovy and oceanic species biomass, while the cold periods (DACP and LIA) are characterized by a an inverse pattern. Finally, during the CWP the PUS experienced the strongest OMZ, the highest export production and the highest anchovy biomass due to an increase in upwelling since ~1900 AD.

Benthic redox conditions and oceanographic variability in the upper Central Peruvian margin since the nineteenth century

Dimitri Gutiérrez[1,2], Jorge Cardich[1,2], C. Machado[3], Maria Morales[4], Renato Salvatteci[1,6], Abdelfettah Sifeddine[3,5]

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Subsurface and benthic biogeochemical conditions over most of the upper Peruvian continental margin are characterized by oxygen deficiency in the bottom waters, strong fluxes of settling organic matter and reducing conditions in the surface sediments. These processes interact among each other and are amplified or relaxed according to the variability of climatic/oceanic conditions at different spatial and temporal scales. The present study aims to reconstruct the decadal to multidecadal variation of benthic paleo-redox conditions for the last two centuries off Central Peru, based on laminated sedimentary records of redox-sensitive metals (Mo, V, Re, etc.) and benthic foraminiferal assemblages from Callao outer shelf (12°S) and Pisco upper slope (14°S). Bio-indicators of anoxic (e.g. sulphidic) and postoxic (non sulphidic) conditions were determined based on calibration work with modern communities and previous information on the spatial distribution of key species. Three major multidecadal periods were determined for both site records: i) the mid to late nineteenth century, characterized by the occurrence of massive diatom-rich sedimentation events and development of bottom anoxia; ii) the late nineteenth century to mid-twentieth century, featuring interdecadal alternations between anoxic and postoxic conditions; and iii) the late twentieth century until the early 2000's, in which redox-sensitive metal records exhibit a trend towards less reducing conditions, accompanied by an average increase in the relative abundance of postoxia foraminiferal species, though with decadal variations. In the latest period, the decadal redox changes of both sites tend to differ, suggesting a higher influence of local processes on the benthic biogeochemistry. The results are compared with proxy and instrumental records of regional oceanographic conditions, upwelling intensity and productivity. Remarkably, the first multidecadal period is associated with a higher ENSO

activity, whereas the latest one is parallel to the period of coastal cooling and increasing fluxes of productivity proxies. Our findings suggest that local and remotely-driven processes, such as coastal stratification/mixing and subsurface ventilation, respectively, should also be considered to explain the benthic biogeochemical dynamics in the system.

Inferring CO_2 fluxes from space: A multiscale approach

Véronique Garçon[1], Joël Sudre[1], Hussein Yahia[4], Boris Dewitte[1], Aurélien Paulmier[1], Serena Illig[1], Isabelle Dadou[1], André Butz[3], Christoph Garbe[2]

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4. INRIA, Bordeaux, France

The EBUS (Eastern Boundary Upwelling Systems) and OMZs (Oxygen Minimum Zone) contribute very significantly to the gas exchange between the ocean and the atmosphere, notably with respect to the greenhouse gases (hereafter GHG). Off Peru, very few in-situ data of ocean-atmosphere CO_2 fluxes are available presently, which justifies alternative approaches for assessing these fluxes. GHG air-sea fluxes determination can be inferred from inverse modeling applied to VCDs (vertical column densities), extracted from satellite spectrometers, using state of the art modeling, at low spatial resolution. For accurately linking sources of GHGs to EBUS and OMZs, the resolution of the source regions needs to be increased. This task develops on new non-linear and multiscale processing methods for complex signals to infer a higher spatial resolution mapping of the fluxes and the associated sinks and sources between the atmosphere and the ocean. Such an inference takes into account the cascading properties of physical variables across the scales in complex signals. The use of coupled satellite data (e.g. SST and/or ocean colour) that carry turbulence information associated to ocean dynamics is taken into account at unprecedented detail level to incorporate turbulence effects in the evaluation of the air-sea fluxes. We will present a framework as described above for determining sources and sinks of GHG from satellite remote sensing. The approach includes resolution enhancements from a multiscale processing method. Preliminary results will be presented.

Assessing atmospheric gas concentrations and interfacial fluxes from remote sensing

Christoph Garbe[1], André Butz[2], Véronique Garçon[3], Jevheni Vihharev[1], Joël Sudre[1], Hussein Yahia[4], Boris Dewitte[3], Aurélien Paulmier[3], Serena Illig[3], Isabelle Dadou[3]

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The EBUS (Eastern Boundary Upwelling Systems) and OMZs (Oxygen Mini- mum Zone) contribute very significantly to the gas exchange between the ocean and the atmosphere [Waldron et al, 2009; Hales et al, 2005], notably with respect to the greenhouse gases (hereafter GHG). Invasion or outgasing fluxes of radiatively-active gases at the air-sea interface result in coupled or decoupled sink and source configurations [Paulmier et al, 2008]. From the in-situ ocean measurements, for example, the uncertainty of the net global ocean-atmosphere CO_2 fluxes is between 20 and 30%, and could be much higher in the EBUS-OMZ. Off Peru, very few in-situ data are available presently, which justifies alternative approaches for assessing the fluxes, and notably satellite, earth-observation data, and the outputs of modeling systems as well.

GHG vertical column densities (VCD) can be extracted from satellite spectrometers. The accuracy of these VCDs need to be highly accurate in order to make extraction of sources feasible. To reach this level of accuracy is extremely challenging, particularly above water bodies, as water strongly absorbs infrared (IR) radiation. To increase the amount of reflected light, specular reflections (sun glint) can be used on some instruments such as GOSAT. Also, denoising techniques from image processing may be used for improving the signal-to-noise ratio (SNR).

In this contribution, we will present the work we are conducting within the ESA Oceanflux initiative. We will demonstrate the extraction of atmospheric VCDs from spectrometers and an optimal control approach for coupling a simple model to them. We will demonstrate the applicability of our approach and discuss preliminary results.

OMZ Influence on the CO_2 System in the Midriff Islands of the Gulf of California: A promising observatory for global change studies?

Martin Heranandez-Ayon

Universidad Autónoma de Baja California (UABC), Mexico

In the Midriff Islands (RI), tidal mixing plays a very important role on the distribution of chemical properties. Although the water masses temporal variability is linked with the

dynamic oceanography, its importance had not been considered before. We estimate the water mass effect in the spatial distribution and seasonal variation of dissolved inorganic carbon (DIC) at RI with special emphasis on the Ballenas Chanel during winter 2002, spring 2003 and summer 2004. The Gulf of California water (AGC) was found throughout the area in the first 100 m. Below, Subtropical Subsurface Water (ASsSt) was filling Dolphin, Salsipuedes and Tiburon basins, while at the southeast it was found between 150 and 350 m. Pacific Intermediate Water did not cross the threshold. ASsSt enriches the RI surface water with DIC when ASsSt increases its volume and when mixed with the AGC by tidal effects. This contribution decreases towards summer, when the ASsSt is sinking and while AGC volume increases. The AGC in winter had three sub-regions associated with oceanographic mixing processes and in combination with the presence of ASsSt. There was a strong relationship Ct RI vs T, which is a good tool for future applications to analyze the carbon dynamics at RI, both on the surface using satellite imagery, and vertically to simulate physical processes.

El Nino events in the Peru EBUS

Ken Takahashi[1], Kobi Mosquera[1], Aldo Montecinos[2], Katerina Goubanova[3], Boris Dewitte[3]

1. IGP, Perú
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3. LEGOS, Toulouse, France

In the late El Niño 1800's, Peruvian scientists recognized that in some years, an unusual warming of the northern coast of Peru was responsible for strong rainfall in this otherwise arid region. They proposed that an unusual strength of "El Niño" counter-current, opposed to the cold Humboldt current, was responsible of bringing warm tropical water further south than normal. Later scientific studies showed that there is a relationship between El Niño events with large-scale ocean-atmosphere variability in the tropical Pacific, which became known as El Niño-Southern Oscillation (ENSO). Although ENSO and El Niño along the coast of South America do not necessarily coincide (e.g. Deser and Wallace, JGR 1987), the very strong events of 1982-83 and 1997-98 have led to a perception that they do. However, the recent decade has shown a disconnection between the large-scale ENSO (with center of action in the eastern-central equatorial Pacific ocean) and the coastal variability, perhaps associated with a decadal-scale variability in the Pacific and/or climate change. These considerations have led to the recent adoption in Peru of an operational practice for El Niño monitoring based on a minimum of two indices, one considering sea surface temperature off the coast of South America (Niño 1+2 region) and the other in the eastern-central equatorial Pacific (Niño 3.4). Examples will be presented of manifestations of historical El Niño and La Niña (the cold version of El Niño) events off Peru and their relation to the large-scale ENSO and decadal-scale variability.

Intraseasonal upwelling varability off Peru: remote and local forcings versus non linear processes

Boris Dewitte[1,] Serena Illig[1], Katerina Goubanova[1], Ivonne Montes[2], Ken Takahashi[3], Kobi Mosquera[3], Sara Purca[4], Aurélien Paulmier[1,4], Véronique Garçon[1]

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The Eastern Boundary Current systems experience a strong variability at intraseasonal timescales that may modulate the regional climate through air-sea interactions or the biogeochemical oceanic processes. Whereas in most of these systems, intraseasonal upwelling variability is mostly wind-driven, in the Peru upwelling system, the oceanic intraseasonal equatorial Kelvin wave is also effective in modulating the coastal upwelling, through either mean vertical advection of anomalous temperature and/or through its impact on the mesoscale activity.

Here the characteristics of the intraseasonal variability off Peru for Sea Surface Temperature, winds and oxygen are documented based on satellite observations and a diversity of high-resolution model experiments (forced ocean model, ocean-atmosphere coupled model and biogeochemical coupled model). Two regimes of variability are evidenced. A low-period regime ([10-25] days) is the signature of Ekman transport/pumping dynamics and is remotely forced by the migratory atmospheric disturbances across the South Eastern Pacific anticyclone. A high-period regime ([35-60] days band) is associated to the combined forcing of oceanic equatorial Kelvin waves and migratory atmospheric disturbances in the mid-latitudes. However the later is shown to be enhanced by the internal variability (mesoscale activity) of the oceanic circulation. Experiments with a high-resolution biogeochemical ocean model using climatological forcing as ocean boundary and lateral conditions are shown to simulate an energetic intraseasonal upwelling mode. The characteristics of this 'internal' intraseasonal mode depend on a number of parameters (model resolution, location of the boundary forcings, characteristics of the mean seasonal cycle). Implications for the understanding of the air-sea interactions and the oxygen minimum zone variability in this region are discussed.

Is air-sea interaction inhibited in tropical upwelling systems?

Tim Fischer, Annette Kock, Tobias Steinhoff, Marcus Dengler, Hermann W. Bange, Peter Brandt

GEOMAR Helmholtz-Centre for Ocean Research, Kiel, Germany

Two observations in northeastern tropical Atlantic mixed layers suggest that air-sea gas exchange in the tropical oceans might be systematically less than bulk formulae predict.

(1) For N_2O we find a substantial discrepancy between estimates of sea-to-air outgassing and the supply from below. This discrepancy can be remedied by using a bulk formula that accounts for surface clogging substances (surfactants).

(2) Many undisturbed CTD profiles in tropical waters are found to show strong stratification of the upper meters during large parts of the day; i.e. there is an extremely shallow mixed layer. One-dimensional simulation indicates that ignoring this temporary stratification may lead to overestimation of air-sea gas exchange.

Both features, surfactants and extremely shallow mixed layers, are typically found in tropical upwelling systems. But it is not settled if and to what extent they inhibit air-sea gas exchange. A measurement programme in the Peruvian upwelling system in framework of SOPRAN and SFB754 will take place in Dec.2012 to Feb.2013, which is designed to check how important each of the two hypothesized inhibition mechanisms may be.

Controls from a widespread surface ocean organic micro layer on atmospheric oxidative capacity

Rainer Volkamer

University of Colorado at Boulder, CO, USA

The Tropical Ocean tRoposphere Exchange experiment TORERO (Jan/Feb 2012) probed the influence of air-sea exchange of organic carbon species and very short lived halogen species on the tropical free troposphere over the eastern tropical Pacific ocean. Organic carbon is important in the atmosphere, because it influences the reactive chemistry and lifetime of climate active gases (e.g., methane, ozone, dimethyl sulfide), and because of its relevance for the formation, composition and climate impact of aerosols. This presentation summarizes results from the TORERO cruise (Hawaii to Costa Rica), and 17 research flights of the NSF/NCAR GV aircraft over the world's largest eastern boundary upwelling system, the tropical Eastern Pacific Ocean (-22S to 22N latitude, 70W to 158W longitude; 135 days at sea). These measurements identify the source for unexplained atmospheric glyoxal, a very short lived and water soluble oxygenated hydrocarbon (OVOC), is linked to the widespread presence of a surface organic micro layer. The source for oxygenated hydrocarbons (OVOC)

from the SML is found to be larger than that of primary organic aerosol. The relevance of this organic carbon source from the ocean to atmospheric oxidative capacity is assessed in terms of hydroxyl, bromine, chlorine and iodine radical sensitivities.

Rationales for a reference site off Peru (Hormigas Islands) as part of Ocean SITES

Ken Takahashi[1], José Macharé[1], Edmundo Norabuena[1], Aurélien Paumier[2,3], Boris Dewitte[3], Mohamed Chlieh

1. IGP, Perú
2. IMARPE, Lima, Perú
3. LEGOS, Toulouse, France

The coastal region off Peru is characterized by the occurrence of extreme geophysical phenomena that have dramatic consequences (social and economic) on society. It is indeed not only a place where large subduction earthquakes occur but it also contains arguably the most productive coastal upwelling ecosystem, which in turn experiences the dramatic impacts of the extreme El Niño events. Furthermore, this region also hosts one of the most intense oxygen minimum zones, which alters the most productive marine ecosystem of the planet and is implicated in the global cycle of greenhouse gases and gases involved in the stratospheric ozone destruction. Both the long-term observations of the regional climate and crustal deformation, as well as the real time monitoring of seismic activity and sea-level variability, are top-priority issues for decision-makers of Peru, as well as for the international scientific community, in order to reduce the risk of natural disasters, make progress in our understanding of geophysical phenomena, develop predictive capabilities and reduce the impact of climate change.

Here we present arguments and rationales for implementing a multidisciplinary observation platform off Peru on an island called *Hormigas de Afuera* (11.95786°S, 077.73287°W) located in central Peru about 80km NW of Lima city. Due its location and small size (<0.1 km^2), Hormigas island is considered an ideal site for carrying long-term observations representative of air-sea interaction near the coastal upwelling front, which would include standard meteorological (wind, shortwave radiation, relative humidity, air temperature, atmospheric pressure, rain rate), oceanographic (sea level, salinity, sea surface temperature), and chemical (carbon and oxygen concentrations) measurements. Additionally, its proximity to the Peruvian Trench, is key for GNSS measurements of crustal deformation, which can be used to improve the estimation of earthquake and tsunami potential in the region. This site could also include real-time seismic monitoring, to enhance the national network. The presentation will review the requirements for the Hormigas site (ANTSEA 1) to be proposed as an Ocean Site as part of the Global Ocean Observing System sponsored by the UN, illustrating relevant current scientific activities and others that it would attract and allow developing.

Denitrification versus Anammox in the Eastern Tropical Pacific: a numerical modeling study

Ivonne Montes[1,2], Andreas Oschlies[1], Elodie Gutknecht[2], Véronique Garçon[2]

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2. LEGOS, Toulouse, France

The Eastern Tropical Pacific (ETP) hosts one of the most productive eastern boundary upwelling systems of the world oceans, encompassing an extended Oxygen Minimum Zone (OMZ), which is maintained by sluggish oceanic circulation and high rates of organic matter decomposition consuming dissolved oxygen. This OMZ is also recognized as a major region of marine bioavailable nitrogen loss, brought about by the two processes denitrification and anammox. The relative importance of these processes has, however, been subject to some debate. Here, we use a high-resolution physical-biogeochemical model (ROMS-BioEBUS) of the Peruvian upwelling system that was calibrated to achieve good agreement with observed biogeochemical tracer distributions. By varying biogeochemical model parameters, we specifically construct different model configurations with either anammox or denitrification being the dominant nitrogen loss process. Biogeochemical and physical conditions governing the relative contributions of the two processes in our model are analyzed and, by comparison with field data, used to make inferences about the relative contributions of anammox and denitrification in the OMZ off Peru.

Physical influence on the biogeochemical features and processes in the Peruvian OMZ

Aurélien Paulmier[1,2], Melanie Giraud[1], Justyna Jonca[1], Violeta Leon[2], Jonathan Valle[1,2], Ivonne Montes[1,2,4], Joël Sudre[1], Octavio Moron[2], Jorge Quispe[2,3], Gaute Lavik[5], Patricia Grasse[4], Martin Frank[4], Lothar Stramma[4], Boris Dewitte[1], Véronique Garçon[1]

1. LEGOS, Toulouse, France
2. IMARPE, Lima, Perú
3. UNAC, Lima, Perú
4. GEOMAR Helmholtz-Centre for Ocean Research, Kiel, Germany
5. Max Planck Institute for Marine Microbiology, Bremen, Germany

The Oxygen Minimum Zones (OMZs) could induce large impacts on the climate and on the marine ecosystems, through specific biogeochemical features and anomalies, in particular in terms of oxygen and nutrients losses. Off Peru, the OMZ associated with one of the most productive upwelling systems, is known to be associated with the advection of Equatorial SubSurface Waters (ESSW), rich in nutrient and poor in oxygen, through the Peru-Chile

UnderCurrent (PCUC), but this circulation remains to be documented more precisely within the OMZ.

Here we present an illustration of the potential physical influence at local scale on biogeochemistry. Recent analyses of *in situ* observations allowed characterizing a relative phosphate minimum present in the ESSW. Our hypothesis is that this relative minimum is due to local biogeochemical processes triggered by the advection of slightly oxygenated waters. It is consistent with the results of a 1D model focused on the oxycline that simulates steady states for the oxygen and the nitrogen nutrients profiles. These mechanisms of auto-regulation involve specific coupling of biogeochemical processes which could be controlled by different physical forcing.

N_2O Cycling in Upwelling Zones and Low-Oxygen Environments

Parv Suntharalingam, Erik Buitenhuis, Oliver Andrews, Sunke Schmidtko, Corinne Le Quere

University of East Anglia, Norwich, UK

The ocean-to-atmosphere fluxes of nitrous-oxide (N_2O) from upwelling zones and low oxygen environments are believed to provide a significant component (25-50%) of the global oceanic flux. These oceanic environments are also characterised by large gradients in sub-surface N_2O, and high rates of N_2O turnover that far exceed those observed in the open ocean. N_2O production and consumption in these zones can involve complex combinations of denitrification, nitrification and enhanced nitrification pathways. The balance of these processes displays significant sensitivity to local environmental variables, such as oxygen level, suggesting that significant changes in the oceanic source from these zones may occur under specific environmental perturbations. Here we use an ocean biogeochemistry model (NEMO-PlankTOM), which includes a process-based representation of the oceanic N_2O cycle, to explore the changes in oceanic N_2O cycling and net flux from these regions in response to specific perturbations (changes in extent of oxygen minimum zones, increased nutrient supply). We discuss the major uncertainties in these model-based analyses, and assess the implications for reliable estimation of the impacts of anthropogenically-induced perturbations on the marine N_2O cycle in these zones.

The future evolution of multiple stressors in eastern boundary upwelling systems

Zouhair Lachkar, Nicolas Gruber

ETH Zurich, Zürich, Switzerland

Eastern Boundary Upwelling Systems (EBUS) such as the California Current System (California CS) and the Canary Current System (Canary CS) are highly productive marine ecosystems undergoing increasing stress levels driven by global environmental changes. EBUS naturally experience low pH and low O_2 due to upwelling of CO_2 enriched, O_2 depleted waters from depth. This makes these systems particularly vulnerable to global perturbations such as ocean acidification and ocean deoxygentation. The severity of these chemical perturbations may further be exacerbated by concurrent climate change driven perturbations such as enhanced vertical stratification and increased upwelling-favorable winds. Here we study the cumulative effects these multiple stressors may have on EBUS ecosystems and explore their combined potential impacts on the habitat size of O_2- and CO_2-sensitive species. To this end, we undertook a series of idealized perturbation studies with eddy-resolving setups of ROMS to which a nitrogen based NPDZ biogeochemical model was coupled. Our model simulations show that ocean acidification in EBUS is primarily driven by the rise of atmospheric CO_2, while warming, stratification, and local wind changes have a much smaller impact. In contrast, ocean deoxygenation is quite sensitive to physical perturbations, but with large differences between the two investigated EBUS, likely reflecting underlying differences in the processes that govern regional oxygen balance. Initial results also reveal that the upwelling intensification and surface warming drive opposing changes in coastal hypoxia and $CaCO_3$ undersaturation, potentially compensating each other when occurring concurrently.

Remote sensing assets for ocean-atmosphere interactions science

Roberto Sabia, Diego Fernández-Prieto

European Space Agency, ESA-ESRIN, Frascati, Italy

Over the last decades, remote sensing has proven to be a paramount technology to address key scientific aspects in a variety of applications, including ocean and atmosphere domains, benefiting from synoptic view and frequent temporal coverage. ESA offers an unprecedented capability to observe and monitor the Earth system and its dynamics, from local to global scales, through its multi-mission sensors suite (including ERS-1/2, Envisat, the current Earth Explorers and the upcoming GMES Sentinels series).

Within this context, the Support to Science Element (STSE) is one of the exploitation programmes of ESA, aiming at strengthening the link with the scientific community

promoting novel observations, new algorithms and products, and collaboration with major international scientific programmes, among them SOLAS.

Within this collaborative framework, ESA has undertaken consultation workshops and topical conferences to promote the use of EO data to improve the characterisation of the complex ocean-atmosphere processes and fluxes. It has also funded two projects (OceanFlux) which specifically target the greenhouse-gases exchange mechanisms, with an additional distinctive emphasis over the EBUS-OMZ systems. An overview of these projects will be provided together with envisaged potential opportunities for subsequent collaborations.

A synoptic climatology of the near-surface winds along the west coast of South America

René D. Garreaud[1], David Rahn[2]

1. Department of Geophysics, Universidad de Chile
2. Department of Meteorology, University of Kansas

The west coast of South America exhibits the archetypical structure of subtropical Eastern Boundary Upwelling Systems (EBUS). In the first part of the presentation we review the physical mechanism behind the mean climate conditions in this region, with emphasis in the interaction among atmospheric circulation over the SE Pacific, the Andes Mountains, the low-level stratus cloud deck and the South American Monsoon System.

A well known aspect of the regional climate is the prevailing equatorward low-level flow near the coast. Nevertheless, mesoscale details of the near-shore wind field are poorly known because of the lack of a dense network of local observation, the blind strip of satellite scaterometer data and the coarse resolution of atmospheric reanalysis. In the second part of this talk we take advantage of the recently released, high-resolution (0.3°) NCEP Climate Forecast System Reanalysis. The covariability between the alongshore pressure gradient and alongshore wind –previosly identified off central Chile at synoptic time scales- is generalized of the whole coast and over annual time scales. Particular attention is placed to the three prominent upwelling regions: Pisco (15°S), Punta Lengua de Vaca (30°S) and Punta Lavapie (36.4°S). Finally, the synoptic evolution that drives high wind events at each location is characterized and salient features are contrasted among the regions.

Recent results on air-sea interactions over the Atlantic equatorial upwelling

Guy Caniaux[1], Hervé Giordani[1], Jean-Luc Redelsperger[2], Mark Wade[3]

1. CNRM/GAME (Météo-France/CNRS), Toulouse, France
2. LPO (CNRS-IRD-IFREMER-UBO), Brest, France
3. LPAOSF (UCAD), Dakar, Senegal

The results gathered since the "**A**nalyse **M**ulti-disciplinaire de la **M**ousson **A**fricaine"(AMMA) and the "**E**tude de la Circulation Océanique et des Echanges Océan-Atmosphère dans le **G**olfe de Guin**EE**" (EGEE) campaigns of 2005-2007 in the field of air-sea interactions are presented. They show the key role of the equatorial upwelling in the eastern equatorial Atlantic on the West African monsoon.

The strengthening of south-easterlies, associated with the Saint Helena anticyclone, promotes the preconditioning of the thermocline along the equator and the development of the cold tongue. The equatorial front on its northern boundary, modifies the surface heat fluxes that affect the circulation in the lower atmosphere. This circulation helps to push moisture northward, toward the West African sub-continent, and impacts the monsoon jump.

Oceans, atmospheric chemistry, and climate: influence of reactive halogens on the removal of greenhouse gases in the tropical free troposphere

Rainer Volkamer

University of Colorado at Boulder, CO, USA

Tropospheric ozone is a greenhouse gas and the primary source for OH radicals in the atmosphere. OH radicals react with methane, another greenhouse gas, and are particularly important in the tropical atmosphere because most of the atmospheric methane is destroyed at tropical latitudes. The tropical ocean is a source for very short lived halogen species (containing bromine, chlorine and iodine), that are emitted into the atmosphere, where they react to destroy ozone and influence atmospheric removal pathways of methane. Such halogen-mediated ozone loss is currently poorly understood due to the lack of measurements of halogen radicals in the tropical free troposphere. This talk presents recent first measurements of bromine and iodine oxide radical abundances in the tropical free troposphere. These measurements were accomplished by means of the University of Colorado Airborne MAX-DOAS instrument during research flights aboard the NSF/NCAR GV aircraft over the central and eastern tropical Pacific Ocean. Halogen emissions from the surface ocean not only destroy ozone in the marine boundary layer, but their influence on the chemistry of the tropical free troposphere is larger than previously thought, with implications for the lifetime of climate active gases.

Ocean circulation of the South Pacific gyre

Christophe Maes

IRD/LEGOS, Toulouse

In each of the major ocean basins, surface winds drive currents that form the large anticyclonic subtropical gyres as well as the smaller, cyclonic subarctic gyres. In the southern hemisphere, the South Equatorial Current, centered around 15°S, and the Peru/Chile Current represent the major components of the southern subtropical gyre. Low-latitude boundary currents in the eastern Pacific are not nearly as strong as along the western boundary, but they play a significant role in closing the circulation of the Pacific Ocean. If the mean state is well identified, the variability of this system has been shown recently to exhibit strong spinup and spin down on decadal timescales, thanks to profiling float data from the global Argo array.

In complement to these dynamical aspects, surface waters in the warm subtropical gyres away from seasonal meridional frontal systems tend to be highly stratified, with a permanent thermocline that limits vertical enrichment of the euphotic zone throughout the year. These oligotrophic waters are characteristically recognized as some of the least productive waters in the world's oceans.

Trace gases (N_2O, CH_4, DMS) in the ocean

Hermann W. Bange

GEOMAR Helmholtz-Center for Ocean Research Kiel, Germany

Nitrous oxide (N_2O), methane (CH_4) and dimethylsulfide (DMS) are atmospheric trace gases which, directly or indirectly, influence the Earth's climate and chemistry of its atmosphere. The ocean is the dominating source for atmospheric DMS and a major source for atmospheric N_2O, whereas the oceanic emissions play only a minor role for the atmospheric budget of CH_4. The oceanic pathways (i.e. production and consumption) of N_2O and CH_4 are dominated by microbiological processes such as nitrification/denitrification and methanogenesis, respectively. The oceanic pathways of DMS are characterized by a complex interplay of microbiological processes, uptake/release by phytoplankton and photochemical processes. An overview about the distributions, pathways and potential future trends of the oceanic emissions of N_2O, CH_4 and DMS in a changing Earth environment, with focus on coastal upwelling regions, will be presented.

Quantifying oceanic biogeochemical fluxes: modelling applications and challenges

Parv Suntharalingam

University of East Anglia, Norwich, UK

Ocean model analyses are employed to address a wide range of biogeochemical questions including quantification of marine ecosystem fluxes, development of process-understanding, evaluation of environmental perturbations, and prediction of future changes. This lecture will present an overview of modelling applications in ocean biogeochemistry, ranging from simple box-models to coupled carbon-climate systems employed to evaluate earth system feedbacks. We will focus primarily on the oceanic carbon and nitrogen cycles, and discuss specific challenges faced by the current generation of ocean biogeochemistry models in addressing environmental perturbations to the present-day ocean.

Modeling the Oxygen Minimum Zone of the Eastern Tropical Pacific

Ivonne Montes[1,2], Elodie Gutknecht[1], Boris Dewitte[1], Aurélien Paulmier[1,3], Isabelle Dadou[1], Andreas Oschlies[2], Véronique Garçon[1]

1. LEGOS, Toulouse, France
2. GEOMAR Helmholtz-Centre for Ocean Research, Kiel, Germany
3. Instituto del Mar del Perú, Callao, Perú

The Eastern Tropical Pacific (ETP) hosts the Humboldt Current System, the most productive eastern boundary upwelling of the world oceans. This region encompasses an extended Oxygen Minimum Zone (OMZ), which is maintained due to the sluggish oceanic circulation and high organic matter decomposition consuming dissolved oxygen. This zone is also influenced by the remote variability exerted by the subsurface Equatorial Current System; since carrying oxygenated waters and thus contributing in the ventilation of the OMZ. By means of a coupled physical/biogeochemical model (ROMS-BioEBus) configured for the ETP under climatological conditions, we show the different mechanisms that should be considered when modeling the Eastern Tropical Pacific OMZ.

How do ocean mesoscale eddies affect biogeochemical processes? Insights from model simulations and satellite observations

Zouhair Lachkar

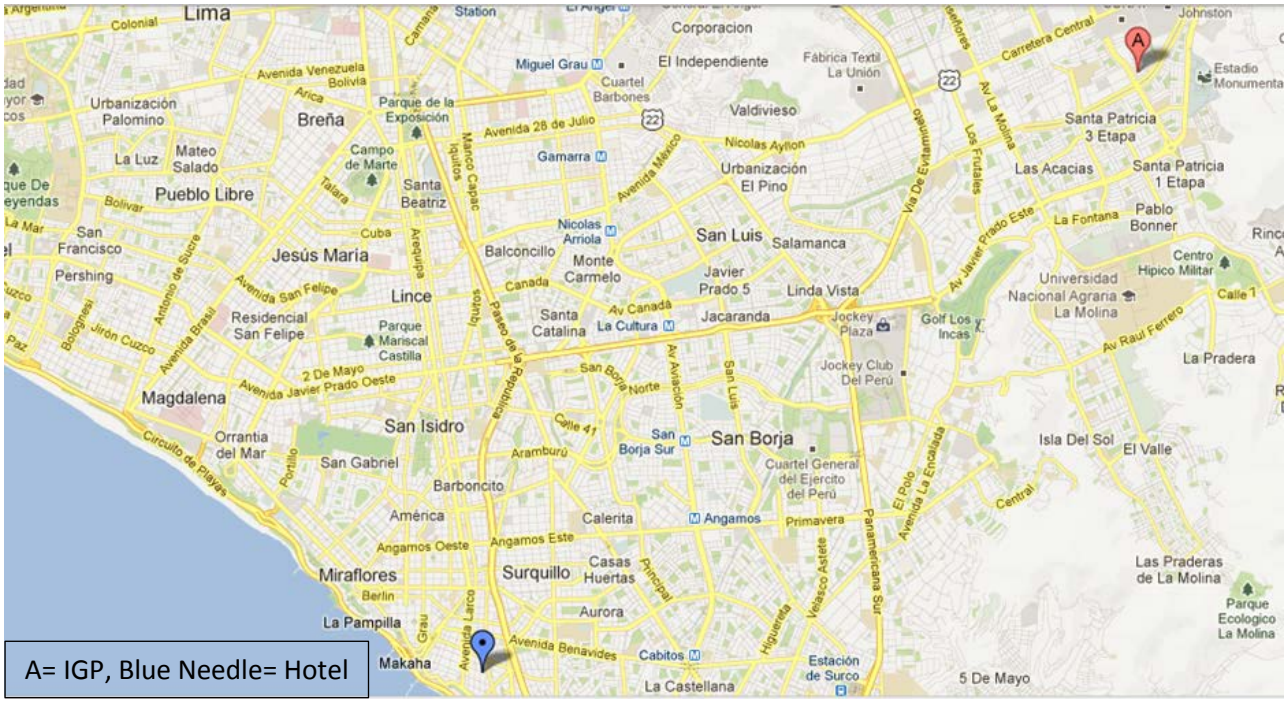
ETH Zurich, Zürich, Switzerland

Mesoscale eddies are a ubiquitous feature in the ocean. They transport and mix water masses and tracers and affect ocean ventilation and vertical stratification. Yet our understanding of their impacts on marine biology and biogeochemical cycling of carbon and nutrients remains fragmented and not well developed. Furthermore, due to the prohibitive computational cost of performing high resolution oceanic simulations, eddies are not explicitly accounted for in the current generation of climate models. In this lecture, I will review various aspects of the mesoscale ocean dynamics. In particular, I will focus on the role of eddies in controlling ocean biological productivity and air-sea CO_2 exchange. To this end, I will discuss results of recent studies based on satellite observations and eddy-resolving numerical simulations.

Local Information

Conference venue

Instituto Geofisico del Perú (IGP)
http://www.igp.gob.pe/index.html (spanish only)
Calle Badajoz # 169
Mayorazgo IV Etapa
Ate Vitarte



Hospitality

Hotel Señorial

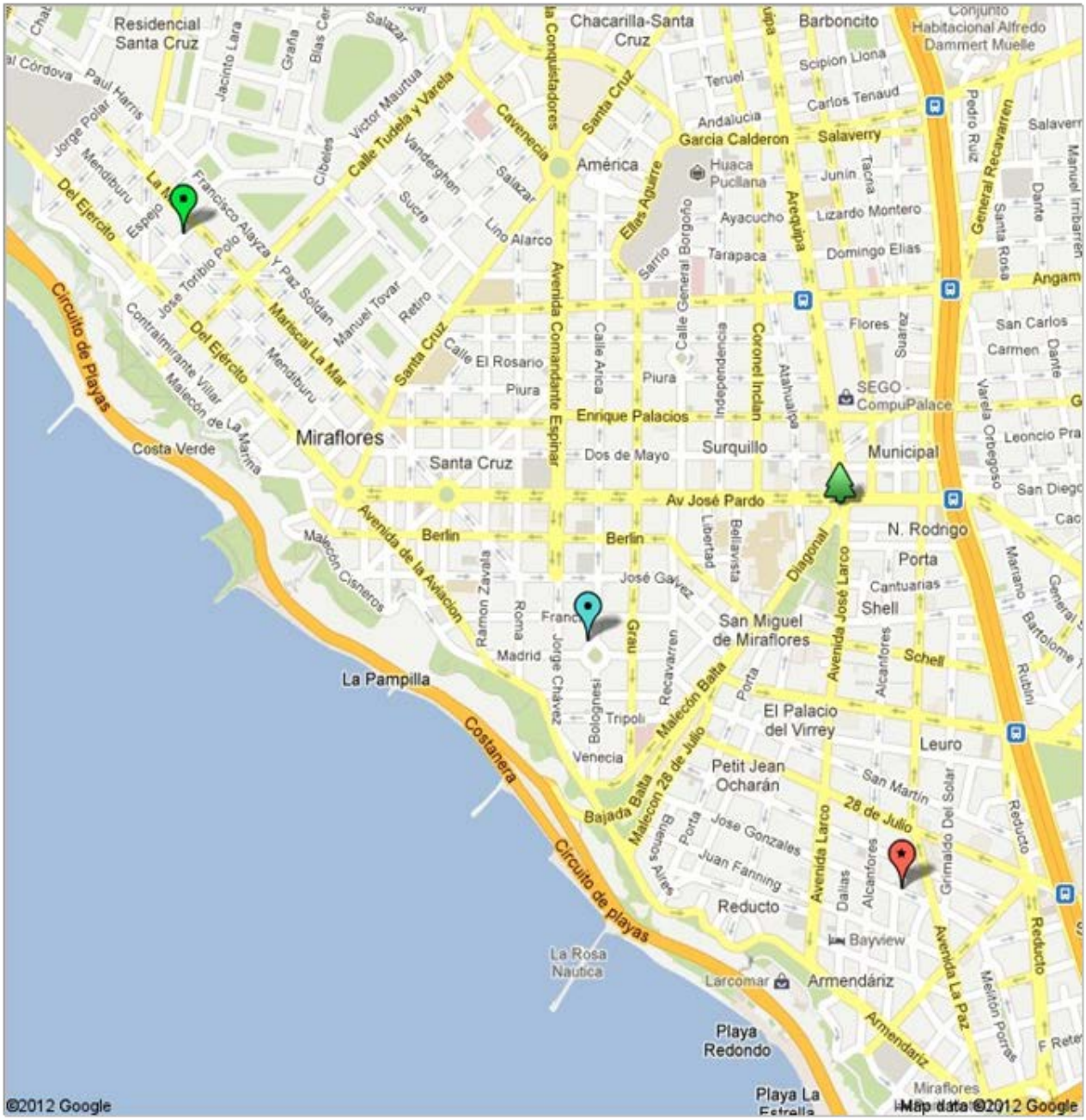
José Gonzáles 567, Miraflores Lima, Perú
Tel.+511 444-5755 445-7306 445-9724 445-2986
http://www.senorial.com/

Huaringas Bar

-Ice breaker dinner-
460/472 Ovalo Bolognesi, Miraflores
+511 4675210
Upstairs of Las Brujes de Cachiche restaurant

El Rocoto

-Workshop dinner-
Federico Villareal 360, Miraflores
Tel: + 511 448 3040
www.elrocoto.com.pe/



Hotel Señorial

Restaurant El Rocoto

Huaringas Bar

Ovalo de Miraflores

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 the three official taxi companies which are located directly outside the arrivals hall. The journey takes about 40 minutes and should cost approx. 40-50 Soles (max. 20$), most taxis accept Nuevos Soles and US dollars.

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

Local

The following taxi firms are recommended:

Taxi Green
Tel. (511)4844001
E-mail: taxigreen@peru.com
http://www.taxigreen.com.pe/main.html

Taxi Aeropuerto de Lima
Tel. (5111)572961/7916979/998268244
http://www.taxiaeropuertolima.com/

TaxiLimaPerú (english speaking)
Tel. (011-51)995185800
http://www.taxilimaperu.com/
book in advance

General information

Currency

Perú uses Nuevos Soles (S). The exchange rate at time of printing was:

1 EUR	=	3,25 S
1 USD	=	2,51 S
1 GBP	=	4,04 S

Telephone

International Call Prefix: 00
Country code -51
Local phone numbers have 6 or 7 digits
Time zone –GMT – 5 hours

Emergency numbers

Police (Policia Nacional del Perú) Central Emergency Number : **105**
Special tourist Police station: **(00511) 423-3500**
Fire Brigade (Bomberos Emergency Number): **116**

Tourist information

www.lonelyplanet.com/peru

3 days in Lima:
http://www.tripadvisor.ca/Tourism-g294316-Lima_Lima_Region-Vacations.html

http://www.limaeasy.com/

Weather and climate

Month	Nov
Record high °C (°F)	29 (84)
Average high °C (°F)	21.9 (71.4)
Daily mean °C (°F)	19.2 (66.6)
Average low °C (°F)	16.4 (61.5)
Record low °C (°F)	11 (52)
Precipitation mm (inches)	0.0 (0)
% humidity	82
Mean monthly sunshine hours	120.0

Source: http://en.wikipedia.org/wiki/Lima#Climate

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