

An holistic approach of international collaborations in marine sciences.

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An holistic approach of international collaborations in marine sciences

From Buzios 2013 to Brest 2014



Over the last decade of the 20th century, marine research institutes and postgraduate training organisations in Brittany have joined together in a "Blue Network" (20 members), an informal coordination structure. This network has played a key role within the region to purchase specific equipment (for instance a coastal oceanographic vessel from INSU-CNRS to work along the Channel coastline, co-funded by the Brittany Regional Council) or shared equipment (for instance the La Pérouse Library, joint between Ifremer, IUEM-UBO and IRD).

The aim of Europole Mer is to become a research center of excellence, highly visible and very attractive on the international stage. Its central activity is to support research projects around 5 research areas, whilst fostering interactions and collaborations between the Europole Mer members.

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What was the Buzios Workshop?

From the beginning, the Buzios workshop was conceived and built to be an exceptional workshop or meeting, based firmly on a common desire to determine new shared perspectives on the marine sciences. Six months later, we can look back and say that it was a highly original and ambitious venture.

The first pillar of the project was the strong desire of the Brazilian and French scientists to strongly collaborate in a truly bilateral and equitable manner. Almost a year later, with a second session to be held in Brest, in October 2014, the project has evolved and now exists within the framework of a French-European-Brazilian collaboration.

The second pillar was the resolve to find a different way of thinking about Marine Science, by building a complete holistic approach that could be fundamentally multi- and inter-disciplinary. This approach would bring combine work on different geographical areas and thematic fields to form a new large open French-European-Brazilian network, including science, technology and training, with a 10-15 year strategic project conducted in close collaboration. In short, we needed to share our different points of view from within our different disciplines. This was the ambitious venture: finding a common language to build truly interdisciplinary and holistic projects. This long-term approach intrinsically includes human exchanges and a strong commitment to the training of the future generation of scientists, engineers and technologists who will build the next European-Brazilian partnership and the future of Marine Sciences.

The third pillar concerns Brazil itself. Brazil has 8000 km of coastline, one of the most important river and forest areas of the world and a vast diversity of geographical and ecological landscapes. The impacts of natural and human-altered processes in this country extend worldwide. In scale with the emergence of modern sciences and technology, the marine scientific community is rather young and therefore very open-minded. We are all convinced that Brazil is the very place to build a new way to think Marine Science.

More than 200 scientific actors met in the workshop's holistic brainstorming session and shared their enthusiasm over the five intense days at Buzios. Many Brazilian and French Universities, scientific organizations and institutions participated in and supported the event. The purpose was to share new ideas, new results, and new projects through short presentations and leave a huge space for interdisciplinary discussion in thematic and general sessions. The discussions were always conducted within a rigorous philosophical framework (cf. schema p.53).

Each block of this diagram was taken into consideration as far as possible in each discussion. Transversal issues, such as Human Sciences, the Law of the Sea and Technology, were actively present and addressed in the different discussions and when building the different approaches.

The presentations given during these five intense days in Buzios were compiled into a document. At the workshop, these presentations provided fertile ground for high quality discussions in the plenary sessions. The synthesis of this "melting pot" of ideas is summarized in the "Letter of Buzios".

Work completed after Buzios, through a collaborative website and more conventional bilateral and multilateral exchanges was used to produce a series of documents on the five main projects that arose from this first workshop. Each of these documents needs to be considered as part of a jigsaw of several pieces: each piece is conducted on its own but must be connected to the rest of the jigsaw. The objective, as we move forward, will be to deepen and develop a programmatic implementation of our project where possible, so as to bring together the jigsaw pieces. Such will be the challenges of the "Building Marine Sciences Meeting", which will be held in Brest, 14th-16th October, within the Sea Tech Week event.

We must be ambitious, and think to the future.

Qu'est-ce que l'Atelier de Buzios ?

Dès ses origines, l'Atelier de Buzios a été pensé et conçu comme un atelier ou un symposium d'excellence, fondé sur une volonté commune de définir de nouvelles perspectives partagées dans le domaine des sciences de la mer. Six mois ont passé. Avec le recul nous pouvons maintenant affirmer que cette entreprise était à la fois très originale et très ambitieuse.

La détermination des scientifiques brésiliens et français de collaborer étroitement de manière réellement bilatérale et équitable a constitué le premier pilier de ce projet. A peine un an après sa naissance, il a évolué et s'inscrit maintenant le cadre d'une collaboration franco-européo-brésilienne, avec une deuxième session qui se tiendra à Brest en octobre 2014.

Le deuxième pilier était la volonté de trouver une manière alternative de penser les sciences marines à travers l'édification d'une approche holistique exhaustive, qui pourrait être essentiellement multidisciplinaire et interdisciplinaire. Cette approche devait permettre un travail conjoint sur différentes zones géographiques et thématiques afin de constituer un nouveau grand réseau franco-européo-brésilien ouvert, comprenant la science, la technologie et la formation, dans le cadre d'un projet stratégique d'une durée de 10 à 15 ans, mené en étroite collaboration. En bref, nous éprouvions le besoin de confronter nos différents points de vue au sein de nos différentes disciplines. L'entreprise était ambitieuse. Elle a consisté à trouver un langage commun pour concevoir des projets véritablement interdisciplinaires et holistiques. Cette approche sur le long terme intègre de manière intrinsèque les échanges humains et un engagement fort pour la formation de la future génération de scientifiques, d'ingénieurs et de techniciens appelés à construire le prochain partenariat européo-brésilien et les sciences marines du futur.

Le troisième pilier concerne le Brésil en tant que pays. Le Brésil possède 8000 km de littoral, l'une des zones de forêts et de rivières les plus importantes du monde et une grande diversité de paysages géographiques et écologiques. C'est un pays où les impacts des processus naturels et des processus modifiés par l'homme peuvent s'étendre à la planète entière. A l'image de l'émergence des sciences et des technologies modernes, sa communauté scientifique marine est plutôt jeune et donc très ouverte d'esprit. Nous sommes tous convaincus que le Brésil est l'endroit idéal pour élaborer une nouvelle façon de penser les sciences marines.

Plus de 200 acteurs scientifiques se sont retrouvés à Buzios pour la session de remue-méninges holistique [holistic brainstorming] de l'atelier et ont échangé leur enthousiasme durant cinq jours d'une rare intensité. Bon nombre d'universités, d'organisations et d'institutions scientifiques brésiliennes et françaises ont participé à l'événement et lui ont apporté leur soutien. Le but était le partage d'idées, de résultats et de projets novateurs par le biais de courtes présentations, tout en laissant une place prépondérante aux discussions interdisciplinaires en sessions thématiques et générales. Les discussions ont toujours eu lieu dans un cadre philosophique rigoureux, (cf. schema p.53).

Lors de chaque discussion, il a été tenu compte le plus possible de chaque partie de ce schéma. Les questions transversales comme les sciences humaines, le droit de la mer et la technologie ont occupé une place de choix dans les discussions et lors de la construction des différentes approches.

Les exposés présentés à Buzios au cours de ces cinq journées exceptionnelles ont été regroupés dans un document. Les présentations délivrées au cours de cet atelier ont constitué un terrain propice à des discussions de grande qualité lors des séances plénières. La « Lettre de Buzios » est une synthèse de ce brassage d'idées.

Les travaux réalisés après Buzios, à travers un site collaboratif et des échanges bilatéraux et multilatéraux plus classiques ont servi à produire une série de documents sur les cinq projets principaux issus de ce premier atelier. Chacun de ces documents doit être considéré comme les pièces d'un puzzle : chaque pièce est autonome mais fait également partie d'un ensemble. A mesure que nous progressons, notre objectif est de développer et d'approfondir la mise en œuvre programmatique de notre projet lorsque cela est possible, de manière à assembler les pièces du puzzle. Tel sera le défi du Building Marine Sciences Meeting [Symposium « Construire les Sciences Marines »], qui se tiendra à Brest du 14 au 16 octobre 2014, dans le cadre de la Sea Tech Week.

Soyons ambitieux, pensons l'avenir.

O que foi o Encontro de Búzios?

No início, o Encontro de Búzios foi concebido e organizado para ser um encontro excecional, fortemente centrado no desejo comum de determinar novas perspectivas compartilhadas sobre as Ciências do Mar. Seis meses depois, podemos olhar para trás e afirmar que foi um desafio que fez prova de originalidade e ambição.

O primeiro pilar do projeto foi a forte necessidade que cientistas brasileiros e franceses sentiram em estreitar sua colaboração de modo bilateral e equitativo. Quase um ano depois, com uma segunda sessão prevista em Brest, em outubro de 2014, o projeto se desenvolveu e existe agora sob a forma de uma colaboração entre a França, a Europa e o Brasil.

O segundo pilar foi o propósito de encontrar uma forma diferente de pensar as Ciências do Mar, construindo uma abordagem holística completa que pudesse ser essencialmente multi e interdisciplinar. Essa abordagem permitiria um trabalho conjunto em áreas geográficas e campos temáticos diferentes, com o intuito de formar uma nova rede alargada entre a França, a Europa e o Brasil, incluindo as ciências, a tecnologia e a formação, com um projeto estratégico de 10-15 anos dirigido em estreita colaboração. Em outras palavras, precisávamos compartilhar nossos pontos de vista diferentes partindo do centro de nossas diversas disciplinas. O maior desafio foi o de encontrar uma linguagem comum para constituir projetos que fossem verdadeiramente interdisciplinares e holísticos. Esta visão de longo prazo inclui de forma intrínseca um intercâmbio entre pessoas e um forte compromisso de formar a futura geração de cientistas, engenheiros e tecnólogos que serão responsáveis pela construção da parceria europeia-brasileira e pelo futuro das Ciências do Mar.

O terceiro pilar diz respeito ao Brasil em si mesmo. O Brasil possui um litoral de 8000 km, áreas florestais e um dos rios mais importantes do mundo e uma grande diversidade de paisagens geográficas e ecológicas. Os impactos de processos naturais e de ações causadas pelo Homem neste país têm repercussões mundiais. À escala do desenvolvimento das ciências modernas e da tecnologia, a comunidade científica que trabalha com questões marinhas é bastante jovem e tem, por conseguinte, uma mente aberta. Estamos todos convencidos de que o Brasil é o território onde poderemos construir uma nova forma de pensar as Ciências do Mar.

Mais de 200 cientistas se reuniram por ocasião da sessão de holistic brainstorming que ocorreu no encontro em Búzios, manifestando o seu entusiasmo durante esses cinco dias intensivos. Muitas universidades brasileiras e francesas, organizações e instituições científicas participaram e apoiaram o evento. O objetivo foi o de compartilhar novas ideias, novos resultados e novos projetos através de pequenas apresentações, consagrando um vasto espaço à discussão interdisciplinar em sessões temáticas e gerais. As discussões foram sempre conduzidas com uma perspectiva rigorosa e filosófica (veja diagrama p53).

Cada bloco deste diagrama foi tomado em consideração da melhor maneira possível em cada discussão. Algumas temáticas transversais, tais como as Ciências Humanas, o Direito do Mar e a Tecnologia, estiveram ativamente presentes e foram debatidas nas diversas discussões e no momento de estruturar as diferentes abordagens.

As apresentações realizadas em Búzios durante esses cinco dias intensivos resultaram num documento. No encontro, essas apresentações constituíram terreno fértil para debates de alta qualidade realizados nas sessões plenárias. A síntese dessa amálgama de ideias surge resumida na "Letter of Buzios" (Carta de Búzios).

O trabalho concluído depois do encontro, através de um site colaborativo e de intercâmbios bilaterais e multilaterais mais convencionais, foi usado para produzir uma série de documentos relativos aos cinco principais projetos que nasceram desse primeiro encontro. Cada um desses documentos necessita ser considerado como parte de um todo constituído por várias peças: cada peça se orienta à sua maneira, mas precisa ser integrada às outras peças. O objetivo, à medida que formos avançando, será de aprofundar e desenvolver a aplicação programática do nosso projeto para juntar, o melhor possível, as peças desse todo. Tais serão os desafios do "Building Marine Sciences Meeting" (Encontro para a construção das Ciências do Mar), que vai ocorrer em Brest, de 14 a 16 de outubro, integrado no evento Sea Tech Week (Semana das Tecnologias do Mar).

Temos que ser ambiciosos, pensemos no futuro!

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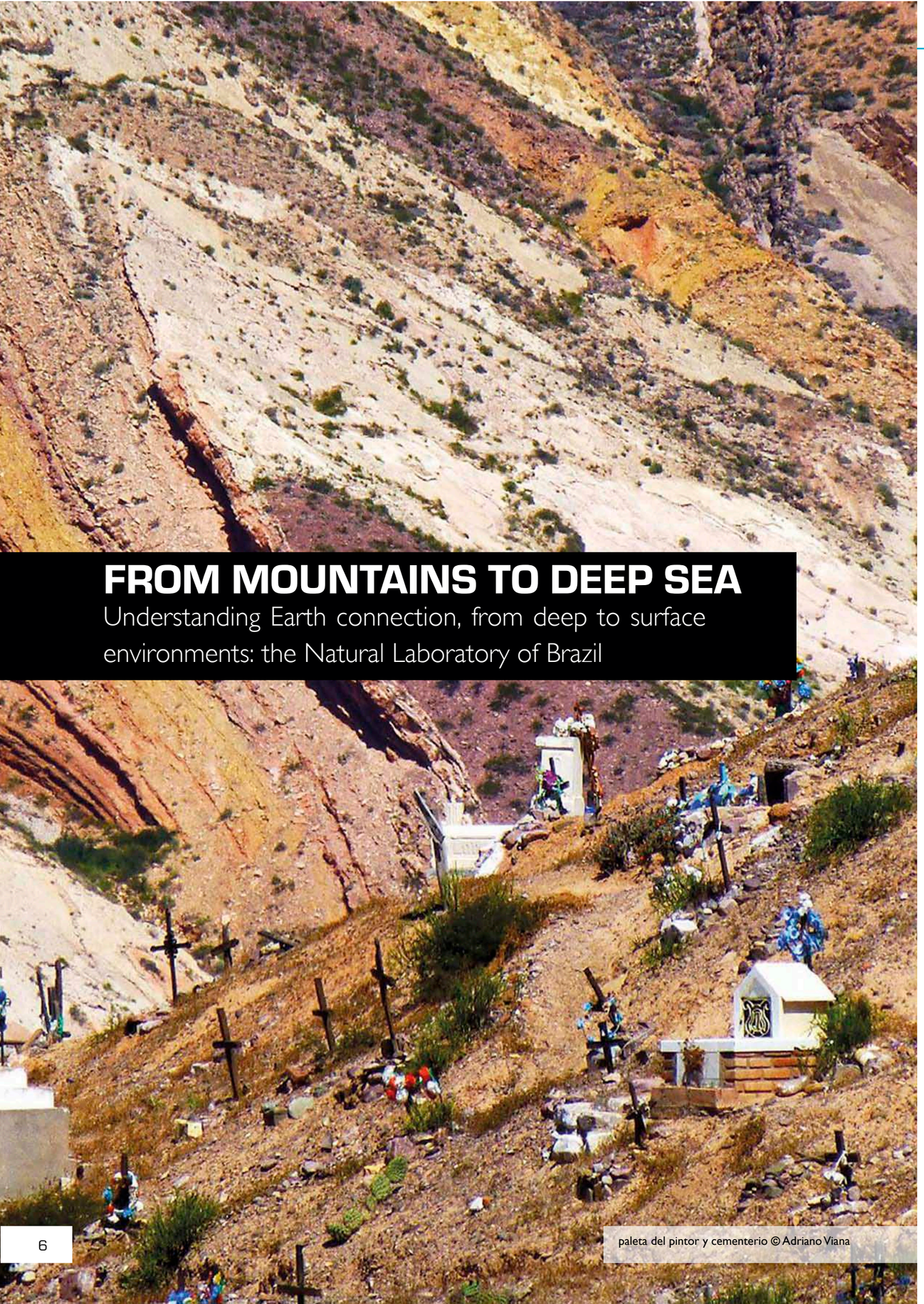
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FROM MOUNTAINS TO DEEP SEA

Understanding Earth connection, from deep to surface environments: the Natural Laboratory of Brazil

paleta del pintor y cementerio © Adriano Viana

Mountains building and their erosion and peneplenation, sediment and nutriment transfers through river into continental plate-form and deep ocean, are deeply connected with the growth cycle of the earth, the birth and the evolution of the ocean, the palaeo-climate and the palaoe-oceanography variations, which are all linked with deep earth processes. Probing the strong correlation between deep and surface processes in order to understand the Earth's growing and to model forecasts, needs the miltidsciplinary approach proposed in the following project, which still remains, as a holistic project, an « open-source» project.

Le cycle d'évolution et la morphologie changeante de notre planète Terre, la naissance des espaces océaniques, les variations paléo-océaniques et paléo-climatiques, sont intimement liés aux processus profonds, *via* la genèse des montagnes, leur érosion jusqu'à leur pénéplanation, le transport des sédiments et de la matière organique via les rivières jusqu'à la plateforme continentale et les bassins profonds, l'eustatisme. Comprendre l'évolution de notre planète Terre et modéliser des prévisions passe par la compréhension de ce lien entre Profond et Surface et nécessite l'approche multi- et transdisciplinaire proposé dans ce projet holistique qui demeure intrinsèquement un projet en « open source », collaboratif, évolutif et vivant.

O ciclo de evolução e de alteração da morfologia do nosso planeta Terra, o nascimento dos espaços oceânicos, as variações paleo-oceânicas e paleoclimáticas, estão intimamente relacionados aos processos profundos através da gênese das montanhas, da erosão até a peneplanação, o transporte de matéria orgânica e de sedimentos através dos rios até à plataforma continental e às bacias profundas, e o eustatismo. Compreender a evolução da nossa terra e criar modelos de previsões para o planeta requer uma compreensão das relações entre profundidade e superfície e exige abordagens multi- e transdisciplinares tal como proposto neste projeto holístico que inerentemente continua a ser um trabalho em «open source», colaborativo, em evolução e vivo.

Introduction

The cycle of growth of the continents on Earth implies mountains building, erosion and peneplenation, sediment and nutriment transfers trough river into continental plate-form and deep ocean through canyons and turbidite currents. The erosion of the reliefs, which produces the sedimentary supply, can be the result of the variations of the climate and/or the effect of vertical tectonic motion of the earth; deciphering the role of these two parameters allows restoring the paleo-topography and the evolution of the climate for much older times (from Jurassic to present time). Combined with the palinspatic reconstructions of the oceans, which give their size and the position of the past straits that have constrained the oceanic water circulation, this approach will allow decoding the environmental significance of Antarctica and North Atlantic water masses along the South Western Atlantic. On another hand, from the top of the mountain to the deep sea, the sediment is the storyteller of the geodynamics, and even its absence is rich in information. Deposited, they keep traces of chemical and organic exchanges with past or current lives. Integrated analysis of deep structure, tectonic movements, sedimentary transport and recording in the deep basin, at different time-scales, applying direct and indirect methods (geophysic, chemistry…) in different disciplines (oceanography, biology, geology) allow to restore the overall evolution of the margin, the continental geomorphology and tectonic history, the birth and evolution of the Atlantic Ocean and the connexion with the biosphere.

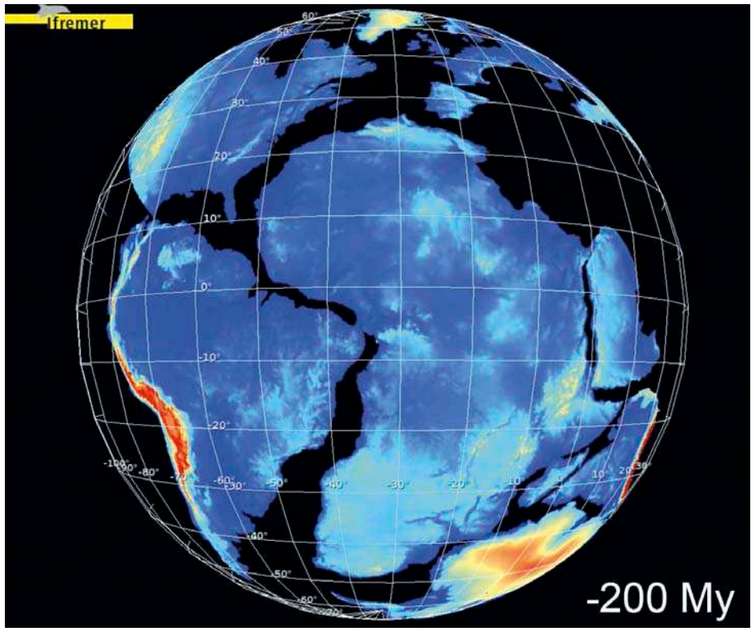
During the last decade, the interaction of deep processes (lithosphere, mantle) with surface processes (erosion, climate, sea level, subsidence, glacio-isostatic readjustment) has been intensely highlighted and explored within the International Lithosphere Program (ILP) Topo-Europe, TopoIberia, TopoAfrica projects, Earthscope/USArray initiative (www.earthscope.org/; www.usarray.org)… The use of a multidisciplinary approach linking geology, geophysics, geodesy, modelling and geotechnology, has lead to the relevance of the concept of coupled deep and surface processes (Cloetingh *et al.*, 2007 - See www.topo-europe.eu/ - or see the DREAM-GOLD IODP Project pre-proposal: Rabineau *et al.*, 2014; Aslanian *et al.*, 2012).



Present day
- Deep continental structures
- Margins morphology
- Bathymetry
- Temperature
- Salinity
- Geochemistry markers
- Currents
- Seabed habitat map
- Biology (corals...)

Quaternary (short term - high resolution)
- palaeotemperature
- palaeosalinity
- Geochemistry markers
- Palaeooceanography
- Palaeoenvironments
- Sedimentary flux and rates
- Subsidence / vertical movements
- Eustasy
- Palaeobiodiversity

Meso-cenozoic (long term - low resolution)
- Palaeoenvironments / geography
- palaeotemperature
- palaeosalinity
- Geochemistry markers
- Palaeocurrents
- Sedimentary flux and rates
- Subsidence / vertical movements
- Cinematic reconstructions
- Eustasy
- Palaeobiodiversity



Pangea visualisation, approx -200My © Ifremer

The first goal of this project is connected with the over-challenging question: **Understanding of connections between the dynamic processes that govern the great movements of the Earth, built the continent and form ocean basins and surface processes that shape it**.

This includes the study of the dynamic of Earth's upper mantle and its connexions with topography building and erosion, its response to the consecutive erosion to the Paleoclimate variations, processes of margin formation, lower continental crust behaviour, subsidence and isostatic rebound connected to sedimentary mass transfers (Source to Sink), nature and behaviour of the first oceanic crust, the birth of ocean, fluids and subseafloor tectonic, thermal and biogeochemical processes, resiliency of the ocean to chemical perturbations but also, for biological aspect: origin, composition, and global significance of subseafloor communities, limits of life in the subseafloor, and sensitivity of ecosystem to the significant chemical Aptian perturbation and link between the thickly piled salt layers and the deep biosphere, and the processes control of biogeochemical cycles.

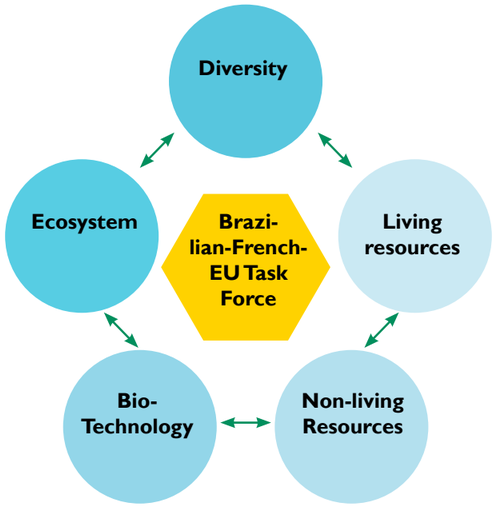
In addition to these targets, the proposed project could also shed light on the sedimentation and accumulation processes of hydrocarbon resources under the thick evaporites, and the thermal evolution of the margins, strongly connected to the « oil window »; it could also be a modern analogue to sediment-hosted base-metal deposits nowadays located on land. Furthermore, Deep Earth dynamic (topography, erosion, tectonics) is strongly connected to naturals hazards, such as earthquakes, slides, tsunamis. On another hand, mass transfers have important consequences on geo-resources and geothermal energy repartitions. The ability to read and understand the link between deep Earth dynamic and surface processes has therefore important social impacts. On the other hand, anthropogenic activities have a strong impact on coast management and environmental aspect, developed in the *Coastal Management* and in the *Amazon Blue and Green* projects, and connected with our project.

Complete analysis of present land geomorphology in association with tectonic history of uplift and subsidence, and climate changes, must be integrated with studies of the basins history of sedimentation and erosion, defining the main episodes of changes in sedimentation rates and establishing stratigraphic and subsidence models for different sectors of the Brazilian continental margins, which present a complete set of the different morphologies. This is the classic investigation approach from the source to the sink, which has never been done at the size of a continent. Beautiful and detailed works already exist in each discipline, at different scales, on the Brazilian Continent and in the South and Equatorial Atlantic oceans: Brazil is the very best and maybe the only country where such impressive holistic study can be realized.

From Moutain to Deep Sea project also integrates a part of the *From Ocean to Human* approach. Several regions can be identified in this "*Biology, Ecosystem, Fisheries and Health*" approach, Coastal areas, the Amazon, Antarctica and the Deep Sea. Therefore this approach is a trans-projects topic and will be find on *Coastal Management* and in the *Amazon Blue and Green* projects. Four main topics will be developed, depending on the concerned areas and projects

- Biodiversity, chemical diversity: Conservation, Genomic approach for connectivity
- Ecosystem functioning: biogeography, biogeochemistry, monitoring, population, community & landscape ecology, past and present approach
- Living resources: Conservation, Fisheries, aquaculture, microorganisms, threats (bio-invasions, HAB, pollutants, pathogens, acidification, impact on human health…)
- Biotechnology: bioprocessing and bio-refinery, antifouling, etc.

Acquisition of new Biological, ecological, geological and geophysical data, using high-resolution geophysical techniques, are of utmost importance, since there is a general lack of information on the near shore area as well as in the deep margins. The *Floating Universities* can be a unique opportunity to implement a systematic program to acquire good quality data, involving as well opportunities for young students from Brazil, France and Europa.



TopoMohoBRAZIL

Tomography and imaging on land and along the coast and the margins

The more robust way to infer the structure of the Lithosphere relies on seismic methods. Considering that the spatial resolution depends on the type of method and data to be used, to obtain a 3D image of the Lithosphere at several scales with good precision; it is necessary to rely on multiple adaptive seismic networks covering a broad scope of the seismic spectrum.

We propose five concomitant geophysical tasks, which cover onshore and offshore area.

Task 1: Broad band on-land seismometers network (circles on figure 1)

Over the last decade, an increasing effort has been performed to increase the knowledge of the Earth's deep interior, namely on the structure of the lithosphere following the Earthscope/USArray initiative (www.earthscope.org/; www.usarray.org) carried in the U.S.A.. Such initiative, involved a massive deployment of broadband seismic stations in a dense network of 60 km x 60 km covering the entire country, allowing to obtain a detail seismic image of the Crust and Mantle. Such huge effort required the involvement of all academic entities within the Earth Sciences, and is coordinated in the field by the US Geological Survey during the over-a-decade experiment which started in 2002 and is currently being extended into Alaska. While the BB seismic experiment (2004-2015) is the more visible component, the Earthscope initiative is actually a focusing program to cover the Earth Sciences, since it encompasses also other broad networks (magnetoteluric, geodetic) or more localized and detailed seismic experiments. The amount of data generated and connections established in the program allowed the build-up of a Science Program which is currently extending until 2020.

This inspired other programs around the world, namely the TOPOEUROPE program (www.topo-europe.eu/), aimed mainly in correlating the deep structure with surface processes. In Europe the seismic BB instrument coverage has been attained by national/regional projects, in close collaboration with the TOPOEUROPE initiative, such as: TOPOIBERIA in Spain (www.ija.csic.es/gt/rc/LSD/PRJ/indexTOPOIBERIA.html), WILAS in Portugal (http://idl.ul.pt/wilas?destination=node/389), RESIF in France (http://www.resif.fr/), ALPArray involving all countries of the Alpine Mountain Range in

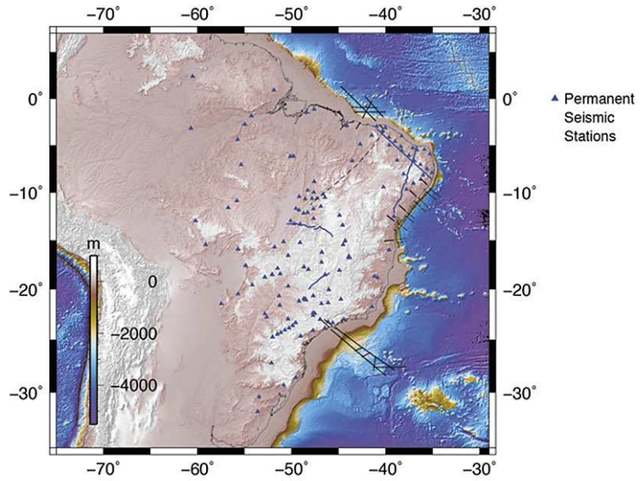
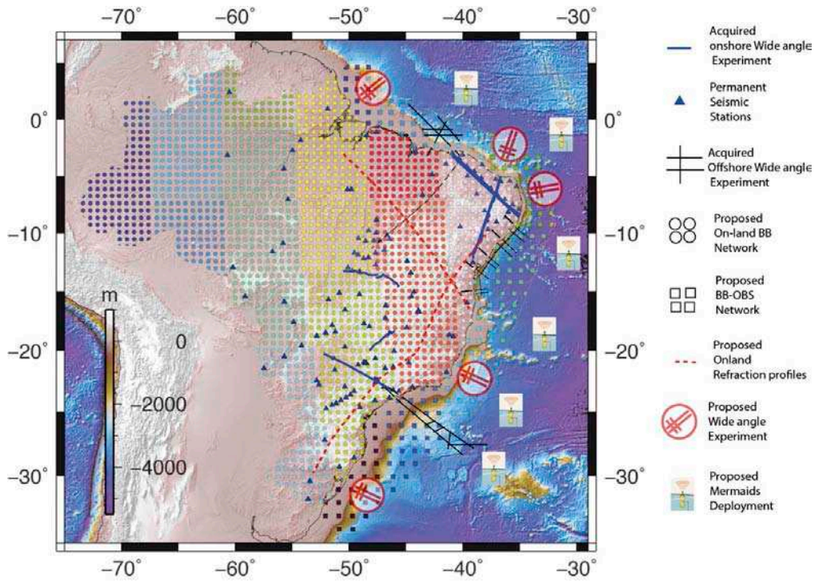


Fig 1:
On the right: Present day seismic network
Below: Proposed seismic acquisitions



Europe (www.seismo.ethz.ch/research/groups/alrt/projects/alparray/index) or the Ireland Array (www.dias.ie/ireland_array/). Another continental scale program is currently under way in Africa (TOPOAFRICA), with a structure similar to the TOPOEUROPE initiative, that is, more focused on topography evolution.

Considering the complex history of the assemblage of the Brazilian Lithosphere, to understand the present crustal composition, the evolution of the topography and the role of inherited structures from past orogenic episodes, it is necessary to build a dense broadband seismic network to cover the entire country. To image the lithosphere and astenosphere beneath Brazil, it is necessary to rely on broadband seismic data >30s, since some of the methods rely on low frequency surface waves, while for for the crustal structure, some of the methods require the usage of high-frequency body-waves; therefore, only broadband seismic networks can accommodate both demands. The continental scale dimensions of Brazil recommend an approach of successive steps, starting with areas of specific interest and where usually there is already some work performed or on-going. Depending on the instruments availability the initial deployments should start on the areas with permanent networks operating and/or near the coast,

to couple with OBS deployment (Task 2). Our proposal is the complete coverage of Brazil by a broadband seismic network with an interstation separation of 70 km x 70 km in about 15 Zones (represented by different colours).

Task 2: Broad band OBS network (squares on figure)

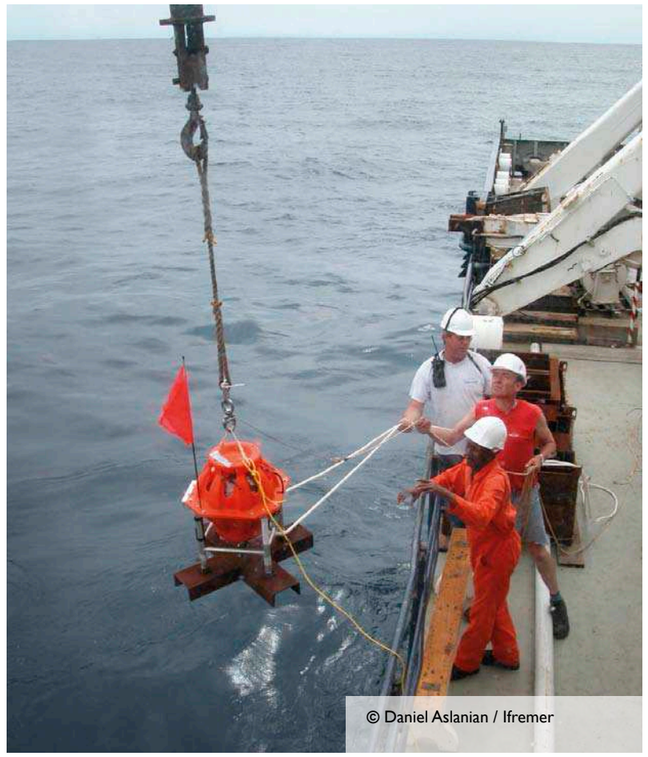
Unlike previous projects, which were confined to continental areas, thus unable the imaging of the structure beneath the margins, we propose to extend the coverage offshore with a complementary network of passive broadband OBS (Figure 1). Due to the dimensions involved it is not reasonable to consider a simultaneous operation of the entire BB network, and the deployment should be programmed by a sequential move-out: an initial deployment covering a certain area, that will be shifted periodically to an adjacent area until the entire country is covered. At sea the BB-OBS network should follow the same approach, if possible encompassing the land BB stations move-out. The inland array should take advantage, when possible, of the existing permanent operating BB stations.

Some of the initial target areas could be:

- Coastal region of the Espírito Santo Basin (in combination with the Royal Holloway (London) experiment on-land proposed to NERC founding)
- Pantanal-Chaco-Paraná area (in combination with the Univ. do São Paulo, experiment on-land proposed to FAPESP)
- The Rio Grande shield and associated coastal areas.

Task 3: On-land Wide-angle Seismic profiles

Several wide-angle seismic experiments have been conducted by our Brazilian colleagues during the last decade (thick blue lines), but a large part of the continent remain unknown. The main goal of this task is to give high resolution 2D image which will be combine with the less focused 3D tomography BB image, in order to characterize continental basins, intra-plate boundaries and to compare continental segmentation to the Margin segmentation. The exact number of transects is to be discussed but at least 2 should be considered: a North-South profile and a NW-SE profile (doted red lines on figure 1).



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Task 4: Off-shore Wide-angle Seismic profiles

Ifremer has conducted with its Brazilian partners (Univ do Brazilia, Petrobras) three wide-angle experiment at Sea (SANBA, MAGIC & SALSA) which give high resolution 2D images of the crustal morphology of the margins and a starting image of the segmentation. Five segments are missing (Figure 1) to have a complete high resolution 2D-view of the margins which will be injected into the 3D tomography BB image.

Task 5: MERMAIDS deployment

Low-magnitude earthquakes or seaslides (underwater avalanches) in oceanic areas are generally not detected, or at best poorly located, by land-based seismological networks. This is due to the rapid attenuation of seismic waves in the Earth interior, which, for low magnitude events, either do not reach any station, or do not reach enough stations for a proper localization. Given that about 70% of the plate boundaries are located in the oceans (e.g. 60000 km of seafloor spreading ridges, all the subduction zones) and that low-level earthquakes

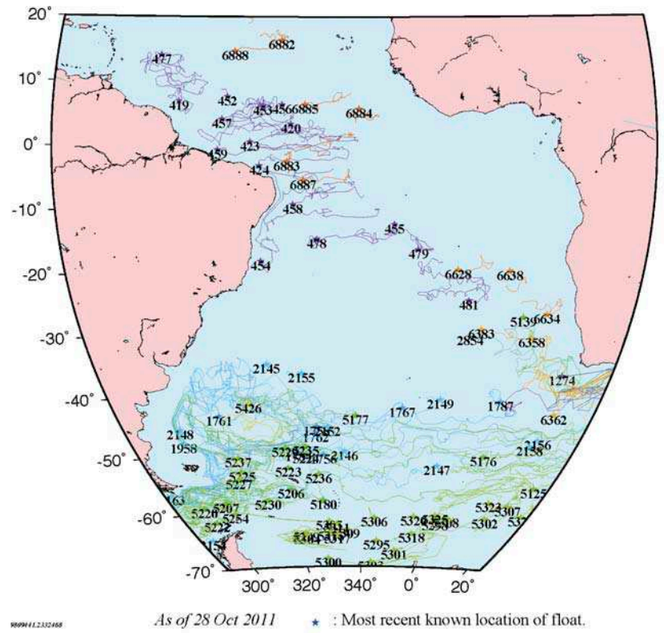


Figure 2: Examples of Argo float trajectories in the South Atlantic. The duration of each trajectory is different (up to about 5 years).
source: http://flux.ocean.washington.edu/

constitute 70% of the global seismicity, this lack of information in the oceans is a major limitation for understanding the dynamics of seafloor spreading processes, of active submarine faults or deformation zones. Deploying acoustic sensors in the ocean water column provides a powerful tool to overcome this difficulty. This is due to the exceptional acoustic properties of the ocean and to the fact that seismic waves convert into hydroacoustic waves at the sea bottom. The sound channel (low sound-velocity layer) behaves as a wave guide where so-called 'T-waves' can propagate over distances of several thousand km, with little attenuation.

Dedicated floats named 'Mermaids' (short for Mobile Earthquake Recording in Marine Areas by Independent Divers, see Figure) have already been developed as part of an ERC-funded project in global seismic tomography, to fill the gap in seismological data coverage in oceanic regions, where seismic stations are largely absent. Note that the MultiMermaids also measure temperature and ocean current at depth (up to 3000m), acoustical noises, which will involve the oceanographer and biological communities.

We propose to deploy 30 MultiMermaids (the new version of the Mermaid, available end 2015) in the Western part of the South Atlantic, enough to cover an area of 6000 km^2 for deep seismic tomography Figure 2). These multidisciplinary floats will at the same time form part of MariScope, a new, international program for monitoring the ocean environment currently subject of a FET-Open proposal to the EU, and provide high-frequency acoustic signals that allow biologists to monitor cetaceans and noise, meteorologists to estimate rainfall, and that adds temperature and ocean current information to the oceanographic Argo project. They will be able to "land" on the seafloor in the shallow continental shelf (drifting only when coming to the surface for transmission en GPS localisation). The expected lifetime exceeds five years.

TopoBRAZIL

Vertical motion, erosion, paleoclimatology and margin formation through Geology-Geomorphology-Sédimentology approach on land and along the coast and the margins

Task 6 : continental studies

The erosion of the reliefs, which produces the sedimentary supply, can be the result of the variations of the climate and/or the effect of vertical tectonic motion of the earth; deciphering the role of these two parameters allows restoring the paleo-topography and the evolution of the climate for much older times (from Jurassic to present time). Integrated analysis of deep structure, tectonic movements, sedimentary transport and recording in the deep basin, at different time-scales, applying direct and indirect methods (geophysic, chemistry…) in different disciplines (oceanography, biology, geology), together with complete analysis of present land geomorphology in association with tectonic history of uplift and subsidence, and climate changes, allow to restore the continental geomorphology and tectonic history, the overall evolution of the margin, the birth and evolution of the Atlantic Ocean. Combined with the Palinspatic reconstructions of the oceans, which give their size and the position of the past straits that have constrained the oceanic water circulation, this approach will allow decoding the environmental significance of Antarctica and North Atlantic water masses along the South Western Atlantic. On another hand, deep earth dynamics (topography, erosion, tectonics) are strongly connected to naturals hazards such as earthquakes, slope instabilities, and tsunamis and mass transfers have important consequences on georesources and geothermal energy. The ability to read and understand the link between deep Earth dynamics and surface processes has therefore important societal impacts.

This classic investigation approach from the source to the sink has never been done at the size of a continent. Beautiful and detailed works already exist in each discipline, at different scales, on the Brazilian Continent and in the South and Equatorial Atlantic oceans: Brazil is the very best and maybe the only country where such impressive holistic study can be realized; Brazil is a unique natural laboratory for addressing key questions on Paleoclimat, dynamic topography, passive margin genesis, the first atypical oceanic crust, the timing of subsidence, and the impact of the mass transport.

Passive margins represent excellent archives that record evolution of sedimentary processes, paleoclimate and environmental changes at different scales and resolution. These archives also include a record of changes taking place in major drainage basins feeding sediments to the margin. Studies with such a focus are still very incipient in the Brazilian passive margin for several reasons, but mostly resulting for a lack of technical means to conduct research in deeper areas (outer shelf, slope). Most of the recent effort has been concentrated in the acquisition of both seismic and shallow cores in the coastal and inner shelf areas around Brazil (*e.g. Rio Grande do Sul, São Paulo, Rio de Janeiro, Espirito Santo, Bahia, Pernambuco, Rio Grande do Norte and Ceará, among others*). Therefore there is a lack of a much broader perspective linking these more coastal settings to the passive margin evolution and the environmental changes that affected both the margin and its feeding systems. Present needs to tackle this and other questions includes the acquisition of high and very high resolution regional seismic profiles from the coast to the deepest part of the ocean in combination with long cores (tens of meters or even longer such as those available thorough IODP).

The purpose is to divide the entire area in four parts (Equatorial, North-East Brazil, Central Brazil and South Brazil) and to develop the following series of items in each part.

Characterization of vertical motions
- Synthesis and new acquisition of Fission Track data (on-land sampling and analalysis)
- Subsidence : Stratigraphy - Modelling

« Source to sink »
- Paleo-drainage – Continent/ocean sediment yield balance - Source to Sink budget
- Calculation of the sediment flux budget
- Estimation of dissolved phases (with a link with Amazon blue-green)
- Tracing the geochemical sources

Palinpastic Reconstitution
- Sédimentology + stratigraphy
- Biostratigraphic synthesis
- Geomorphological studying term of climatic signatures

Paleoclimatical reconstitutions
- Clay Mineralogy
- Paleobotanic
- Geochemical markers (ʒ018)
- paleotemperature / paleo-precipitation maps
- Numerical modeling

Paleoceanographic reconstitutions
- Paleocurrents: geochemical tracing
- Evolution of the paleobiodiversity
- Surface and deep paleotemperature
- Paleosalinity

Task 7: Sedimentary processes and recording on Passive Margins

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Given the large areas represented by the Brazilian Margins, these investigations would need a strategic implementation and/or be coupled with proposals submitted to other thematic areas.

We suggest projects with a minimum of 5 year duration including key seismic and long-core acquisition on land-to-sea transects. Study areas should be carefully selected to address points above.

This task has strong connexion with *Coastal Management*, *Amazon Blue-Green* and *(palaeo)oceanography—(palaeo)climatology projects*.



AMAZON BLUE-GREEN PROJECT

Looking Amazon is looking at global scale

Amazon mouth © Image courtesy NASA/GSFC/JPL; MISR Team

The meetings that took place in Buzios revealed the existence of a large array of questions and scientific approaches centered around the Amazonian system, from the river's watersheds to its zone of influence in the Atlantic ocean. It appeared that the development of an integrative, holistic approach of the entire Amazon system is the most promising strategy to address these scientific issues at the crossroads of different disciplines. The following text, the result of a collaborative effort from the Buzios group, establishes a prospective vision of the main axes of the program.

Les rencontres de Buzios ont mis en évidence la multiplicité des questions et des approches scientifiques centrées sur le système Amazone, depuis ses bassins versants jusqu'à sa zone d'influence Atlantique. Il est apparu que le développement d'une approche intégrative, holistique, de l'ensemble du système Amazone était la plus fertile façon d'adresser des questions scientifiques à la croisée des différents champs de spécialité. Le texte qui suit, élaboration partagée de la communauté issue de Buzios, trace de manière prospective les grandes lignes de ce programme.

O encontro de Búzios destacou a multiplicidade de temas e de abordagens científicas voltadas para o sistema amazônico, desde de sua área de abrangência até a sua zona de influência atlântica. Dali depreende-se que o desenvolvimento de uma abordagem integradora, holística, de todo o sistema do Amazonas seria a maneira mais fértil para tratar de questões científicas que estão na intersecção de diferentes áreas de especialidades. O texto a seguir, fruto do desenvolvimento da comunidade criada desde Búzios, apresenta prospectivamente o contorno de tal programa.

Introduction

The Amazon River delivers 20% of the freshwater discharge to the oceans (Fig.1) and represents 6% of the global riverine sediment discharge. At the Atlantic scale, the Amazon River delivers 37%, 32% and 24 % of the freshwater, particulate sediment and dissolved sediment discharges respectively (Milliman and Farnworth, 2011 for a synthesis). Any study on water, sediment, chemical and organic discharges on the Amazon, helps to strengthen the knowledge and the modelling of processes at global scale.

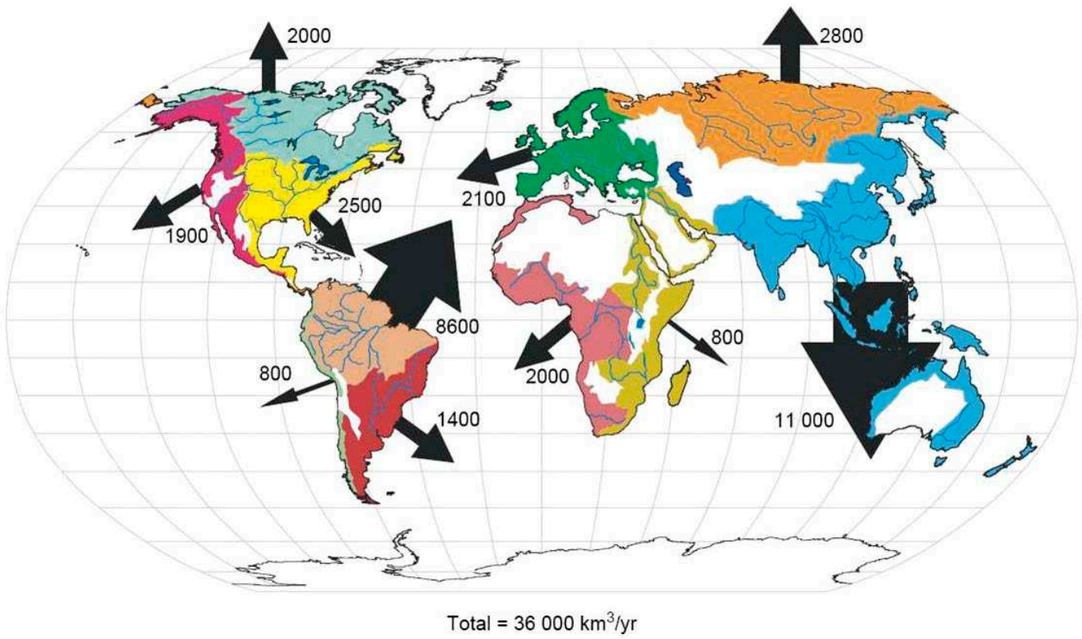


Fig. 1: River Freshwater Discharge to Coastal Ocean, from Milliman & Farnsworth, 2011

Amazon continental fluxes reach the ocean passing through an extensive area where any modification of physical and chemical conditions impact the land to sea continuum. Different physical and chemical contexts induce modifications of the particulate and dissolved matter characteristics transported by the flow in terms of sizes, compositions and spatial distribution with strong impacts on ecosystem functioning. The extremely high discharges of river water with relatively low pH (pH around 6.8-6.9), high particulate load, high nutrient contents, and high microbial concentration have shaped the benthic systems of the outer continental shelf and slope of the equatorial margin. The occurrence and characteristics of benthic communities in this area will be intimately connected to the functioning of the Amazon river. The geographical limit of this critical land-sea area is not easily defined because it dependson the flux of a specific type of matter which does not always correspond to sharp gradients. For example coarse, fine sediments and dissolved matter show different spatial gradients at the Amazon estuary and along the coast andshelf of Brazil, Guyana and further north. At least the area of study proposed in the *Amazon Blue-Green* project could be relative to high concentration limits of Amazon fine sediments meaning from Obidos (continental limit with significant tide influence on the water discharge) to the Guyana coast at the Orinoco estuary but also including the shelf and the deep-sea fan delta zone.

Such an area can be interpreted

- as a sink for coarse and most of fine sediments,
- as a biogeochemical reactor, where physical and chemical characteristics of both organic and inorganic matter could change significantly in space and time,
- as a source of a new foodweb allowing suitable conditions for specific species some of them constituting important halieutic resources.

If the Amazon delta area is certainly a significant sink of sediment at a global scale, it is also a huge reactor where continental matter follows physical and chemical processes before reaching a fully oceanic environment. This justifies any action of research that helps to deepen our understanding of such system.

A number of Brazilian and international research projects on the Amazon delta have been or are under way (see § "*Building research network*" below). But, due to the size of the Amazon delta and logistic difficulties, knowledge on this system remain incomplete whatever the thematic, and basic data are still poorly documented or completely missing. For instance, the annual sediment load of the Amazon River is estimated from monitoring at Obidos city which is 800 km upstream from the estuary (Martinez *et al.,* 2009, Callède *et al.,* 2010, Wittman *et al.,* 2011). There is no good quantification of the sediment discharge at the Amazon estuary and therefore no real estimation of the sink effect for the sediment in the delta zone. Similarly on a larger time-scale, there is no 3D quantification of the evolution of sediment fluxes during the last 11 Ma since the arrival of the Amazon River in South Atlantic (Figueiredo *et al.*, 2009). The lacks of knowledge concerning the most recent periods and on the temporal variability of the processes are also immense. Many other questions remain open because of the long-term research efforts needed on such a huge system, but also because of the lack of data and logistic sharing. To overstep these difficulties, methodologic cross disciplinary efforts between projects and countries should be planned and coordinated.

The *Amazon Blue-Green* project is a proposal designed to build an integrated research network from the upper part of the estuary of the Amazon River to the deep-sea fan, which will connect: Hydrology (river water and sediment discharge variability), Geophysics and Sedimentology (morphology, sedimentary facies distributions, facies variations in time, hard substrate for settlement), Physics of sediment transport (suspended matters, bed-load transport), Biogeochemistry (chemical diversity, fate of key biogeochemical descriptors: nutrients, organic carbon, flux quantifications), Ecology and Biology (biodiversity: micro- meso- and macro- fauna, foodwebs, ecosystem functioning including recent variations reconstruction), environmental conditions and their variability (T, salinity, nutrients, pH, turbidity, light

Fig 2: Area of Amazon delta defined in the text

environment), human activities and their impacts (fisheries, aquaculture, pollution), human Sciences (passed and recent human-environment interactions, as the tuna fishery reports linked to decadal-scale climate variations). It will also imply to look at the evolution of these natural and anthropic processes through time, involving also palaeoceanographic and palaeoclimatic integrated studies at a larger scale. The *Amazon Blue-Green* project has therefore strong connexions with *From Moutain to Deep Sea, (Palaeo)oceanography-(Palaeo) climat* and *Coastal Management* projects of the overall *Building Marine Science* workshop. This network would integrate both current and new research projects between Brazilian-French and international communities working on the Amazon delta (see below a non exhaustive list of current research projects on this area with collaborators interested to participate to *Amazon Blue-green* project).

Note that *Amazon Blue-Green* is fully consistent with other international research networks like *HybAm*, *Clim-Amazon*, *Geotraces* and *IODP* focused on the continental part of the Amazon basin or Atlantic Oceanic domain. Note taht *IODP* proposals under consideration (Baker *et al.,* and Jovane *et al.* propositions) recently strengthen by the fact that Brazil joined the IODP international network.

Monitoring, modelling and estimating fluxes along Amazon River Land-Sea continuum

Short time scale (annual, decanal cycles)

One important question is to understand the mass transfer and transformation processes that drive the coastal evolution from the Amazon River mouth to the northern South America. Several research groups try to monitor, with a multidisciplinary approach and new technologies, the suspended sediment discharge from the Amazon River in the internal and external estuary as well as the fluid mud dynamic. Different techniques are used such as remote sensing, geochemistry, field acoustic, seismic and radiometric measurements to determine the sediment characteristics and fate. *Amazon Blue-Green* promotes the collaboration between these teams giving opportunities to share logistic, technologies, data and modeling tools.

Monitoring fluxes requests data acquisition at pertinent time scales relative to the driving processes. Because complex tide effect on water discharge is significant in the estuary, flux monitoring should be at hourly scale on a wide area. This is a real challenge that has never been performed by any work. Currently no technology alone can give such time resolution on the delta. Only spatial punctual measure can be managed at hourly scale. However, combining optics and acoustic technologies, satellite images and field campaigns, databases and modelling should help greatly the access to data with a proper time and spatial resolution on water, sediment and different kinds of suspended matter fluxes in the estuary. This challenge requests development of new monitoring protocols and metrology that can be organized and financed by an ambitious *Amazon Blue-Green* project.

Proper database on dynamics of spatial variability of concentrations and discharges give relevant information to balance fluxes of different kinds of matter exported from the Amazon delta and to model current physical process of transfer. These data are fundamental to help modelling on palaeo- or future fluxes with various climatic, geological or anthropogenic contexts.

Marine calcareous species, as molluscs or rhodoliths or other skeleton builders present in the fan, are also helpful witnesses of the inter-annual or higher frequency variations of the system. Internal structures, the trace elements contents and the calcite/aragonite isotopic ratios of their skeleton, analysed jointly with growth rhythmic structures, can offer priceless tools to define the variability of different processes linked to the Amazon regime at high time resolution.

Mass transfer in the Amazon fan

A coupled mechanism of gravity tectonics and mass-transport processes have been recurrently operating in the Amazon Fan (Reis *et al.,* 2010; Silva *et al.,* 2009, 2010; Araújo *et al.,* 2012). Occurrence of two regional submarine mass-transport complexes was revealed, up to 300–600 m thick and 8,000–10,000 km² (mapped area limited by data coverage) that were triggered by gravitational compression of gravity-tectonicfold-and-thrust belts. These significant volumes of structurally-induced mass-transport deposits, geographically coincident with some of the MTDs that had been previously mapped in the upper 200 m section of the Amazon Fan, document a clear link between two scale modes of gravitational processes in the Foz do Amazonas Basin – gravity tectonics and mass wasting. The occurrences of megaslides, involving thicker and older sedimentary sections of the Foz do Amazonas Basin (between 4.5 and 8.0 s), were also recently reported by Silva *et al.* (2010). On the south-eastern flank of the Amazon fan, the Pará-Maranhão Megaslide was mapped as a unique allochthonous mass of up to 1,000 m thick and as large as 90,000 km², composed of a combination of debris flows, slide blocks and compressively-deformed sedimentary units. On the north-western flank of the fan, the Amapá Megaslide Complex was recognized as a succession of superimposed slope allochthonous masses, recurrent through the entire sedimentary section and covering a total estimated area of about 80,000 km².

However, although the entire marine sequence of the Foz do Amazonas basin is deformed by gravity tectonics (an upslope set of extensional faults and huge downslope fold-and-thrust belts considered to root into basal weak levels) these megastructures are not sufficiently discussed in the scientific literature, and many questions related to the origin and nature of related decollement levels remain opened, not to mention the role of fluid migration. As a consequence, and probably for strategic and commercial reasons related to oil exploitation, very little information has reached the public domain and important aspects concerning gravity tectonics remain open in the area. Besides that, although the gigantic megaslides, impressive by their dimensions, affect large areas of the Foz do Amazonas basin, they were neither stratigraphically constrained nor were their internal structures and features analysed in detail until now. As a consequence, little is known about their emplacement and associated triggering mechanisms, neitherhow about they are spatially and chrono-stratigraphically correlated to the Amazon fan – the basin main sedimentary built-up, or their tsunamogenic potential. In this context, further details about how these mega mass-transport deposits occur and how they are stratigraphically organised is fundamental for exploration purposes in the Foz do Amazonas basin, as well as



Amazonian mangroves in Guyana © Christophe Proisy / IRD

for the assessment of their potential risks for geotechnical hazard for offshore structures.

Long time scale (geological time scale)

The Amazon submarine delta and the Amazon Deep-Sea Fan hold continuous records of terrestrial material transported by the river over time and deposited in the oceanic domain. These records provide unique insight not only into the evolution of continental climate and landscapes, but also into the formation and evolution of the major oceanic features in the equatorial Atlantic and beyond. Understand quantitatively the role of sea level, tectonics and sedimentary processes controlling sequence formation and influencing sequence architecture is one of the most important challenges in modern stratigraphy. The Amazon margin, with its giant delta, has been a particularly well-suited area to study how gravity driven instabilities affect the sedimentary architecture (including the Amazon Fan, Reis *et al.,* 2010; Silva *et al.,*2009, 2010. Araújo *et al.*, 2012).

A french research group (PICS and PHD involving UERJ, UFF, University of Brest, IFPen and UPMC) is studying the Cenozoic evolution of the offshore Amazon Mouth basin (Foz do Amazonas basin). The project involves two main research axes:

- (1) depositional cyclicity and dynamics of the continental shelf and slope environments of through an interdisciplinary and approach integrating seismic analysis and digital stratigraphic modelling, with a zoom on the last 900 kyr (Reis *et al.*, 2010; Cruz *et al.*, 2011; Cruz, 2013; Cruz *et al.*, 2013);
- (2) slopes gravitational processes (gravity tectonics and mass-transport).

This multi-scale and source to sink approach will allow us to understand:

- (1) the main processes involved in the sedimentary architecture evolution of the Amazon Mouth basin;
- (2) the evolution of sedimentary environments in mixed systems (carbonate, mixed carbonate-siliciclastic and siliciclastic environments).

The main purpose is to reconstruct the geological history since the post continental break-up by determining the relative importance of the different parameters/processes (tectonics, climate, eustasy and hydrodynamics) controlling sediment deposition and preservation.

A delta with a specific biology

In particular, the unknown reef systems in the outer shelf of the French Guiana and the Amazonian margins need an integrated holistic approach. Reef systems, widespread through different environments and through geological times, are formed by calcified organisms, such as corals, rhodoliths, sponges, and molluscs and are highly sensitive to ocean warming, acidification, overfishing and pollution. Moreover, biogenic carbonates are excellent proxies of major environmental changes through structural variations, isotopic and trace-elements records they contain. Our aim is to characterize this new reefs systems with geophysical, remote sensing, biological (gene to whole holobionts) sclerochronologicaland biogeochemical (e.g. isotopes, organic and inorganic nutrients, particulate and dissolved organic carbon) methods.

One goal is to characterize the fate of the Amazon River discharge and its impact on the biogeochemical characteristics of adjacent marine waters by developing the monitoring of key biogeochemical descriptors (e.g. phytoplankton, nutrients, dissolved and particulate organic carbon...). This will be performed through the development of cross border observation activities that will benefit from franco-european-brazilian partnership as well as through the use of innovative observation means (e.g. autonomous platforms, satellite remote sensing techniques...) needed to capture the very strong spatio-temporal dynamics of these marine ecosystems. Moreover we will share the most innovative methods to elucidate the temporal messages held by the biogenic carbonates (shells and rhodoliths mostly) as it has been done with great efficiency in other world ecosystems.

Building research network

Several projects of collaboration between Brazilian and European researchers have been and are ongoing to quantify and to model modern and passed fluxes along the Amazon stream, along the coast and the Amazon fan. The non-exhaustive following list of projects marks the current direction of research about this topic:

AMANDES

Impact of the Amazon River Atlantic Ocean

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www.obs-vlfr.fr/cyber/amandes/

The main objective of the Amandes project (2006-2010, although we are still working on the data) was to better understand the physical and chemical fluxes, including geochemical tracers, from continents to the oceans. Amandes S focuses in particular on the physicochemical exchange at the passive margin of the Amazon River estuary, characterized by an important continental influx, and a significant impact on Atlantic Ocean water masses.

Three approaches were followed to achieve the main objective:

- Method development (ex. characterizing the Amazon River suspended matter composition for river discharge evaluation, and trace element and isotope analysis as tracers for solid-solute exchange (REE, Nd, Ra, Pb, Be, Hg)
- Four Oceanographic expeditions (15 days each) on the Amazon shelf to deploy buoys for current measurements, and water column sampling during different seasons (ANTEA,/IRD, Nov. 2007, jan ., Apr and July 2008)
- Development of a hydrodynamical model of the tidal dominated Amazon estuary, consistent with local forcing (river influx, Eastern currents) and validated by field (tides, currents) and remote sensing observations.

New developments on chemical and isotopic analysis of collected water samples were successful for Hg as well as for Rare Earth Element (REE) concentrations. More specifically, Rousseau *et al.* (2013) developed a very powerful and precise method for the REE analysis, using 10 spikes. He successfully applied this method in the salinity gradient and along the Brazilian margin (T. Rousseau PhD thesis defended in 2013, CNPq/CNRS; 2 other papers submitted). In addition, Ra isotope results (van Beek*et al.*, in prep.) allow estimation of the « age of water » following the river exit and/or its last contact with margin sediments: such information coupled to the concomitant Nd parameter evolution allows –for the first time- establishing kinetics of dissolved/particle exchange within the estuary. Results are consistent with in vitro batch experiments under controlled conditions (Jones *et al.,* 2012; Oelkers*et al.,* 2012).

Important progress was made on the ocean circulation model for the Amazon plateau by the PhD work of Y. Le Bars (financed by ANR). Model-observation correlation standard deviation for the M2 wavelength was improved by a factor 2 (le Bars *et al.,* 2009) and a tidal atlas is currently under construction. The final phase of this work will include an improved simulation of wave impact on sediment resuspension in order to properly account for sediment transport.

The *Amandes* project has brought together numerous researchers at LEGOS-GET-CEREGE and helped shape the "Coastal Oceanography Pole" at OMP, which before only consisted of coastal dynamics research: because of AMANDES, this pole now includes a geochemistry theme (tracers and particle transport). 26 publications in peer-reviewed journal have been published based on *Amandes* so far. Finally, numerous international collaborations have started with Brazil (Brasilia, Recife, Rio) and the UK (Univ. Bristol, Derek Vance, U isotopes). Expedition reports, hydrological, bathymetry and current data as well as meta-data can be found at SISMER, and are currently sent to the *Geotraces* data Center. *Amandes* is a *Geotraces* network process study (www.geotraces.org).

Foundings of Amandes project are coming from ANR, INSU/LEFE, IRD, CNPq, Universitad Federal Pernambuco;

CLIM-AMAZON

PI leaders : Franck Poitrasson (CNRS), and Elton Dantas (Universidade de Brasilia)
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elton@unb.br
www.clim-amazon.eu

The Clim-Amazon project is a joint Brazilian-European scientific initiative supported by the EU (European Union) through the FP7 (Seventh Framework Programme for Research and Technological Development). The project started the first December 2011 and has duration of 4 years.

The overall objective of this proposal is to extend the research capacities in geological and environmental sciences in Brazil and to maximize scientific partnerships through exchange visits of students and scientists from the European Union. This will be made possible by building on the existing capacities of the Brazilian-French joint laboratory "Observatoire des Changements Environnementaux" (OCE) based on field work and analytical facilities at the University of Brasilia laboratories. Four specific objectives have been defined in order to meet the scientific and political stakes:

- Open the activities of joint laboratory OCE to researchers from different EU Member States and Associated Countries (MS/AC) research institutions with physical participation of researchers in Brazil;
- Enhance the research capacity of the joint institute with a view of further opening it to new participating researchers (through equipment resources, consumables and support staff);
- Increase the scientific cooperation between researchers from EU MS/AC and Brazil through the preparation and implementation of new joint projects via the organisation of joint workshops, training seminars, and an international conference;
- Explore the possibilities for opening the institutional arrangement of the Brazilian-French laboratory OCE to additional EU MS/AC research organisations, using a specific feasibility study.

The overall strategy of CLIM-AMAZON is built on 5 interconnected work packages:

• **WP1** comprises the coordination of project activities and meetings and handling of the financial and administrative issues. The Management team in Brazil will deal with management and organisational issues.

• **WP2** includes 3 tasks and is the main nodal point for interactions between the joint lab and EU scientific institutions through workshops,involving EU funded PhDs , Post-Docs, Brazilian and EU scientists.

• **WP3** refers to the human and material needs of Clim-Amazon. This WP encloses 3 tasks that include complementary laboratory and field equipment, support to hire personnel to work in the laboratory, consumables and maintenance services.

• **WP4** includes promotion, workshops and training seminars to be held in Brasília. The promotion refers to presentation and discussion with authorities and community from the five main cities of the Amazon region (Manaus, Porto Velho, Macapa, Boa Vista and Belém). Workshops and training seminars will allow the opening of the project to a wider international community. The Clim-Amazon project will close with a large international symposium in Manaus.

• **WP5** aims to integrate Clim-Amazon with other research institutions by identifying potential partners. This integration and search for potential partners will be provided by the workshops of WP4, which will include both project members as well as invited people from the scientific community. Because of its infrastructure, Clim-Amazon will provide a scientific environment that will allow strong interactions with other research institutions, thus requiring a center focused on Climate, Hydrology, Erosion and SEDimentary transport and deposition in tropical regions - CHEESED.

The research work developed within Clim-Amazon will thus address the following research topics:

• Determine Amazon basin sediment sources based on the geology database.

• Study the water and suspended load of the Amazon River and tributaries.

• Study the drillings of the Amazon delta and fan within a chronological framework.

• Remote sensing studies to assess the present temporal dynamic of sediment discharge within the basin.

• Predictive modelling for high fan rate sedimentation.

• Upper Miocene to Holocene climatic and geodynamic evolution of the Amazon basin based on the sedimentary record

The approved research proposals are:

• "**Assessing Amazon paleohydrological and paleotemperature changes using lipid biomarkers (HYDRAULIK)**", Stichting Koninklijk Nederlands Instituut Voor Zeeonderzoek (NIOZ), The Netherlands

• "**Geochemistry of Particle-Reactive Elements in River Waters of the Amazon River Basin**", Jacobs University Bremen, Germany

• "**Testing present and past atmospheric transport and deposition of mineral dust, particulate matter and trace element to the Amazon basin and its implication for climate change and anthropogenic forcing**" Imperial College London United Kingdom

• "**Sedimentary load estimates for the past 5 Myr based on cosmogenic 10Be and 26Al in the lower Amazon Basin**" Helmholtz-Zentrum Potsdam DeutschesGeoForschungsZentrum (GFZ)Germany

• "**New insights on the evolution of the Amazon drainage basin and its effects on algal blooming at the Brazilian Atlantic coast: an integrated palynological study**" Universiteit van Amsterdam, The Netherlands

• "**Fluid dynamics, sediment transport and turbulent mixing at large confluences of the Amazon River**" Università degli Studi di Napoli Federico Italy

This project could be strongly connected to the *From Mountain to Deep Sea* project

ORE HYBAM

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http://www.ore-hybam.org

This project is focused on geodynamical, hydrological and biogeochemical control of erosion/alteration and material transport in the Amazon basin. It operates since 2003, answering an invitation to bid from the French Ministry of Higher education and Research. The aim of the OREs is to provide the research community with the high quality scientific data needed to understand and model the Amazon system behaviour and their long-term dynamics. Hybam shares logistic and national institutions competencies from Ecuador, Peru, Bolivia, Colombia, Brazil and France to produce a free up-to-date database on hydrology, sediment and geochemical fluxes on the continental Amazonian rivers network. This project promotes also research programs where masters and PhD are involved.

GEOMARGEM Research Group

Geology and Oceanography of Passive continental Margins

PI leaders: Antonio Tadeu dos Reis (UERJ) and Cleverson Guizan Silva (UFF)
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www.geormargem.org

GEOMARGEM has been conducting submarine multidisciplinary studies in the Amazon margin. A CAPES-COFECUB (2007-2011) programme has first focused on the interplay of gravity-driven instabilities, gravity tectonics, sediment architecture and sediment processes along the Amazon Fan based on seismic analysis and physical experimental models, including many PhD and master students. Different approaches have been subsequently applied in the area, including stratigraphic forward modelling to better constrain sediment fluxes and subsidence rates.

In this context, GEMARGEM group has been gathering efforts to integrate seismic, sedimentological, geochemical and numerical models to evaluate the relation of the Amazon Fan age, related sediment fluxes origin and volume to better constrain and understand relationship between tectonics, sedimentation and gravitational processes.

PIC

International CNRS/INSU collaboration program

PI leaders: Christian Gorini (UMPC) and A. Tadeu dos Reis (UERJ)
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Tutoring of the French Brazilian PICS between the UERJ (Rio de Janeiro), UMPC (Paris) and UBO Brest (Marina Rabineau) since 2012, for 4 years.

The aim of this project is to construct quantitative records of past climate and climate variability, global change and sea level fluctuations. Part of this project is concerning the tectonic-stratigraphic evolution of the Santos platform-basin area (PHD thesis Renata Maia, 2012-2014). The second part of this project concern the Amazon Mouth basin passive margin, with very high sediment fluxes and relatively high sedimentation rates, allowing the preservation of geometries and configurations of main sedimentary bodies. We have recently modelled a dip-section of the Amazon Basin using the Dionisos© software. This 2D simulation was based on the preliminary results of our sequence stratigraphic analysis, and brought forward a new age constrain for the top of the carbonate platform. However, many post-rift stratigraphic and structural aspects of the basin remain unconstrained. The main goal of this PhD project is thus to focus on the evolution of the post-rift sedimentary environments of the Brazilian Amapa Platform, the Amazon Deep-sea fan, the continental shelf and slope depositional systems that took place in alternating carbonate-siliciclastic environments and under the effect of gravity tectonics. One of the major difficulties associated with is the understanding whether the gravitational deformation is continuous through time, or if it only occurs as a result of the rising siliciclastic sedimentary fluxes (Reis *et al.,* 2010), or carbonate production, linked with major tectono-eustatic cycles. Besides that, many aspects concerning regional tectonics are still poorly constrained (e.g., individualization of watersheds of the Amazon, Orinoco and Magdalena, Guyana plateau) as well as how the basin responded to climate variations and eustasy. Seismic and well analyses and 3D stratigraphic modeling of the Amazon Platform will allow us better understanding the main reasons and mechanisms behind the shift from a carbonate-rich platform into a siliciclastic domain, and possibly the identification of the key processes at the origin of gravity-driven deposition at the slope-platform transition.

Science Sans Frontières

(2014-2016)

PI leaders: Gorini & Dos Reis)
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Integrated geological, geophysical and numerical modeling approaches/studies applied to the evolution of Brazilian continental shelves. The project is focused on two very contrasted geodynamic domains: the Amazon Basin on the tropical margin (transform margin), and the Santos and Campos continental margins in the south-eastern Brazilian continental margin (hyper-extended margin). (See also the « Mountain-to-deep-sea » theme).

IODP

Deep Drilling of the Amazon Continental Margin

Cenozoic Climate and Biodiversity; Gravity Tectonics; Microbes, Diagenesis, Gas Hydrates and Fluid Flow. Apart of IODP session in the Buzios workshop (conv. Silva, Do Reis, Jovane & Manatschal), a recent IODP workshop devoted to Amazon area was held 24th-26th March (conv. Rigsby, Silva & Baker), in Buzios to discuss and prepare an IODP drilling Proposal

MICROBIV

CAPES-COFECUB 2014-2017

PI leaders: Fabiano Thompson (UFRJ) and Christine Paillard (UBO)
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Host microbe interactions are critically important for the functioning of all life forms. We will perform research in three complementary lines, defining the genetic features of the marine invertebrate hosts, host responses to infection and environmental parameters, characterization of microbiomes and their response to the hosts. Microflora of molluscs is poorly known, although it could play a major role in protecting against disease, as it is the case in infections coral or algae. The objective of this project will be to study host- microbiota interactions in an environmental context with four main components:

- genetic of clams, with possible determination of genetic variants with increased resistance to infectious diseases.
- immune response following infection clams by transcriptomic approaches,
- the characterization and the response of the microflora associated with the infection of clam by metagenomics and metatranscriptomics.
- an integrative approach will be to model the interactions between microbes and the host in an ecological context, and various environmental change (global warming and acidification).

Sciences sans frontieres

PVE-Pesquisador Visitante Especial Fellowship. PEPS "Reef Discovery"

PI leaders: Fabiano Thompson (UFRJ) and Christine Paillard (UBO), involving researchers from UFRJ, CNRS, UBO, Ifremer, UENF, USP, UFF

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The first step of the research will be developed in the French Guyana in order to discover new reef structures in the continental shelf. Research will be carried out comprising geophysics, ecologic, biodiversity, and physical chemical oceanography surveys.

Reef systems, present both in shallow tropical waters and deep-sea environments, are highly sensitive to ocean warming, acidification, overfishing and pollution (e.g. Pandolfi *et al.,* 2011; Pandolfi *et al.,* 2005; Roberts *et al.,* 2006). The recent discovery of unknown reef systems thriving off the Amazonia mouth, in shallow but turbid waters, could shed a new light on reefs research as they occur in a rather unexpected environment. From a geologist point of view, reefs are widespread over geological time and changed substantially in abundance, composition, paleogeographic distribution and geometric attributes (e.g. Copper 1994; Stanley 2001). The current project will be developed in, the Amazonia mouth and the French Guyana coasts, which represent a unique natural environment to conduct interdisciplinary studies of the impact of complex coastal dynamics on local biodiversity, that include the newly discovered reef ecosystem. It also provides a very unique, and so far unreported, modern analog as a key to understand the Past and the evolution of reefs systems.

The objectives here will be to provide a detailed mapping and thorough characterization of previously unreported biogenic structures off the Amazonia mouth and the French Guyana coasts. To achieve this goal, multidisciplinary methods will be deployed that encompass geophysics, remote sensing, biodiversity assessments (gene to whole holobionts) and biogeochemical analyses (organic and inorganic nutrients). This research project is therefore fully integrated and will have three main research axis: 'Biology/Biogeochemistry', 'Geology/Sedimentology' and finally 'Physical oceanography'. An integrated and holistic approach will be promoted using cutting-edge technology, and implying an inter-disciplinary and close collaboration between French and Brazilian research teams. The international team will focused on some specifics aspects of benthic ecology, fluxes and bentho-pelagic coupling and functioning variability of these reef systems. An accent will be made on the use of calacareous skeletons (Mollusks, rhodholiths, sponges,...) which constitute the major part of the reefs in the aim to understand temporal dynamic of these biomes.

This project is entering a first phase of development and will be extent through new applications in the framework of Sciences Without Border.

MAGIC

Margins of brAzil, Ghana and Ivory Coast

The aim of the MAGIC project is to study and understand the kinematic, tectonic, stratigraphic, palaeogeographic and palaeoclimatic evolution of the entire Equatorial Atlantic Ocean. The purpose is to produce structural and palaeogeographic maps at different time slices, in order to characterize each system of homologous margins, within each segment, by its deformation including kinematic reconstructions, their upstream catchments and associated downstream deposits, with respect to its palaeoclimatic setting. The last step will be to model in 2D and 3D the deformation and thermal evolution of the basins (Temis), and the stratigraphic infilling of the associated sedimentary basins (Dionisos) for testing key points that would have been highlighted during the first phases of the project.

The MAGIC project will finally result in a plate to basin scale characterization of the Equatorial Atlantic Ocean, providing insights into majors concepts such as lithosphere dynamics in an oblique extension setting or geodynamic evolution of oblique extended margin and its influence onto associated petroleum systems. The deliverables of the project will thus be, for example, a chronostratigraphic update and synthesis, stratigraphic and tectonic architecture (outcrop to seismic) of the basins, margin segmentation and characterization, palaeogeographic maps, tests of scenario and hypothesis of the basin dynamics (Dionisos/Temis modelling), and then a tectono-stratigraphic conceptual model for Equatorial Atlantic Ocean, base of a better understanding of the petroleum systems.

This project is subdivided into 5 tasks with clear objectives and deliverables, organized in a four years long project:

- Existing knowledge review: bibliography, websites,
- Basin infilling and catchments geomorphology studies: 2D section, charts,
- Deep structures of the margin: Data acquisition - Seismic refraction
- Thematic maps: structure, palaeogeography, palaeoclimate,
- Basin modelling.

The objective of the MAGIC project is to answer the following questions:

Pre-rift

- What is the role of the tectonic heritage on the segmentation and the morphology of the passive margins of the Equatorial Atlantic Ocean?
- What is the pre-rift history of these margins? Is it synchronous along the whole Equatorial Atlantic Ocean? What were their initial topographies? Does the rift phase start with an uplift of the margins?

Rift

- What is the rift phase on these margins? What is the global geometry of a syn-rift basin in that context (asymmetry, importance of the brittle deformation…)? What is the relationship between the transform area and the divergent area? Do the transform borders play as free limits? What are the subsidence rates?
- What are the nature and the geometry of the syn-rift sediments (deep lakes with turbidites, shallow lakes with fluviolacustrine deposits, alluvial fans)? What are the factors of control of the baselevel variations (hydrological budget of the lake in relationships with the tectonic and climatic evolution of the surrounding watersheds)?

Structure of the margin

- What is the exact location of the first typical oceanic crust? What is its age? In which phase did it appear? What are the consequences of its formation? How does it take place in the transform boundary?
- What is the nature of the intermediate domain? Is there an exhumed phase, as it is proposed in the central Segment of the South Atlantic? What is the nature of the exhumed material (lower continental crust vs upper mantle)?
- What is the evolution of the lithosphere from the rift phase to the passive margin phase s.s. ?
- What are the lateral structural variations within a sub-segment? Within a segment? Within the entire equatorial Atlantic Ocean? Which implications in terms of thermal segmentation and subsidence?

Post-rift

- What is the post-rift evolution on these margins? What does it happen along the transform limit during the rift phase? Does the intracontinental transform phase exist (what is the nature of the involved crusts on both sides)? Does the passive margin really behave differently in the intracontinental and intraoceanic transform phases? What are the differences in the nature and the geometry of the associated sedimentary systems?
- What is the effect of the post-rift uplifts on the geometry of the margins and their thermal history?

Sediment fluxes

- Where did the sediment come from during each phase? What are the siliciclastic fluxes? Is it possible to discriminate between the lateral fluxes (from the transform borders) and the longitudinal fluxes (from the continent) and what are, for each of them, the nature and the involved volume?

The marine part of the MAGIC (Task 3) was operated in 2012 through a joint project of the Department of Marine Geosciences (IFREMER: Institut Français de Recherche pour l'Exploitation de la MER, France), the Laboratory of «Oceanic Domain» (IUEM: InstitutUniversitaire et Européen de la Mer, France), the Faculdade de Ciências da Universidade de Lisboa (Lattex and CGUL, Portugal), the Universidade de Brasilia (Brazil) and PETROBRAS. It is a part of the wide-angle and reflection seismic exploration that the Laboratory of Geophysics and Geodynamic of IFREMER and its collaborators are developing since 1994 on the Passive Margins over the world.

This project is strongly connected to the *From Mountain to Deep Sea* project

Remark on current research networks

Note that only few part of these projects concern the internal delta. Most of the research effort is focused either on the continental part (upstream of Obidos) or either on the coast and shore area (downstream of Belem). The area between the two former domains is still poorly described in many topics and should be one of the major field sites of the *Amazon Blue-Green* as the shore and coast domains. *Amazon Blue-Green* is the



The setting sun glints off the Amazon River and numerous lakes. Astronaut photograph on board the ISS; 2008 © NASA

place to fill the gap of knowledge about fluxes between continental and oceanic domains and to build an interface between "continental" and "marine" research communities. It can definitely benefit from the current projects (listed above) of franco-brazilian and international collaborations with the implication of research teams already involved in those projects.

Promote support and logistics

Annual studies must be scheduled for studying the evolution of the system and the anthropogenic impacts, but also specific one-shot cruises on the French, European or Brazilian fleets (geophysical, geo-biological, paleoceanography and so on), with both students of the North Brazilian, French and European Universities, with researchers of both parts. **Deployment of consequent means of instrumentation and shipping facilities is definitely a crucial point for the success of any long time monitoring**. Several examples of cancelled expensive cruises, because of administrative problems, show that there is a strong need to simplify and secure the authorization procedures to facilitate field campaigns. Avoiding, or at least limiting, administrative procedures should be one of the main objective of Building Marine Sciences to facilitate exploration with cruise deployment and to keep motivation to promote collaborations between Brazilian, French and Europeanresearch teams. Developing the bilateral formation and exchanges between E.U. and Brazil through the Floating University Project, which is deeply connected to the four main projects, is one of the maintask of the Building Marine Sciences.

Bibliography

Araújo, E.; Silva, C. G.; Reis, A.T. ; Gorini, C.; Droz, L. ; Perovano, R. ; Vendevile, B. C. M (in preparation). Mass-transport complexes in the Foz do Amazonas Basin – Brazilian Equatorial Margin. Submitted to Marine Geology

Araújo (2012). Evolution stratigraphique du Cône de l'Amazone depuis sa mise en place pendant le Miocène Supérieur. Doctorat en co-tutelle entre l'Universidade Federal Fluminense-UFF et l'Université Pierre et Marie Curie (Paris 6), en collaboration avec l'Université de Bretagne Occidentale-UBO

Dubinsky, Z.V.Y., and Stambler, N., (1996), Marine pollution and coral reefs: Global Change Biology, v. 2, p. 511-526.

Callède, J.; Cochonneau, G.; Ronchail, J.; Alves, F.; Guyot, J.; Guimarães, V. and De Oliveira, E. (2010). Les apports en eau de l'Amazone à l'Océan Atlantique. *Revue des Sciences de l'Eau*. 23(3): p. 247-273.

Copper, P., (1994), Ancient reef ecosystem expansion and collapse: Coral Reefs, v. 13, p. 3-11.

Figueiredo, J., Hoorn, C., van der Ven, P. and Soares, E., (2009). Late Miocene onset of the Amazon River and the Amazon deep-sea fan: Evidence from the Fozdo Amazonas Basin. *Geology, July 2009, v. 37, p. 619-622, doi:10.1130/G25567A.1*

Martinez, J.; Guyot, J.; Filizola, N. and Sondag, F.. (2009). Increase in suspended sediment yield of the Amazon River assessed by monitoring network and satellite data. *Catena*. 79:p. 257-264.
http://dx.doi.org/10.1016/j.catena.2009.05.011

Milliman, J.. Farnsworth, (2011). River Discharge to the Coastal Ocean: A global synthesis. Cambridge: Cambridge University Press.

Pandolfi, J.M., Jackson, J.B., Baron, N., Bradbury, R.H., Guzman, H.M., Hughes, T.P., Kappel, C., Micheli, F., Ogden, J.C., and Possingham, H., (2005), Are U. S. Coral Reefs on the Slippery Slope to Slime?: Science(Washington), v. 307, p. 1725-1726.

Pandolfi, J.M., Connolly, S.R., Marshall, D.J., and Cohen, A.L., (2011), Projecting Coral Reef Futures Under Global Warming and Ocean Acidification: Science, v. 333, p. 418-422.

Reis, A. T.; Perovano, R.; Silva, C. G.; Vendeville, B.; Araújo, E. F. S.; Gorini, C.; Oliveira, V. (2010). Two-scale gravitational collapse in the Amazon Fan: a coupled system of gravity tectonics and mass wasting processes Journal of the Geological Society, 167 (3): 593-604.

Roberts, J.M., Wheeler, A.J., and Freiwald, A., (2006), Reefs of the deep: The biology and geology of cold-water coral ecosystems: Science, v. 312, p. 543-547.

Silva, R.P. (2008). Colapsogravitacional e estruturação da seçãomarinha da bacia da Fozdo Amazonas no contexto de múltiplosníveis de destacamento. Master Dissertation. Lagemar – Universidade Federal Fluminense – UFF, 99 pages.

Silva, R.P.; Reis, A.T.; Silva, C.G.; Vendeville, B.; Gorini, C.; Araújo, E.F S. (2009). O processo de colapsogravitacional e aestruturação da seçãomarinha da bacia da Foz do Amazonas- Margem equatorial brasileira. RevistaBrasileira de Geofísica, 27(3): 459 - 484.

Silva C.G.; Ferreira E.; Reis A.T.; Perovano R.; Gorini C.; Vendeville, B.C.; Albuquerque N. (2010). Megaslides in the Foz do Amazonas Basin-Brazilian equatorial margin. In: Mosher, D.C.; Shipp, C.; Moscardelli , L.; Chaytor, J.; Baxter. C.; Lee H.; Urgeles, R. (eds.). Submarine Mass Movements and Their Consequences, Series Advances in Natural and Technological Research, Amsterdam. Springer Verlag,

Stanley, G.D.J.e., (2001), The history and sedimentology of ancient reef systems: New York, Kluwer Academic/Plenum Publishers, 458 pp. p.

Wittmann, H.; Von Blanckenburg, F.; Maurice, L.; Guyot, J.; Filizola, N. and Kubik, P. (2011). Sediment production and delivery in the Amazon River basin quantified by produced cosmogenic nuclides and recent river loads. *Geological Society of America Bulletin*. 123(5-6):p. 934-950.
http://dx.doi.org/10.1130/B30317.1



PALAEOCLIMATE - PALAEOCEANOGRAPHY

Understanding the impact of South Atlantic on worldwide Climate

Storm clouds over the Atlantic Ocean near Brazil © NASA

Global and regional climate variations (past and future) are linked with ocean-atmosphere regional processes and are frequently associated with ecosystems modifications and biotic alterations. In particular, the importance of South and Equatorial Atlantic Oceans is crucial for the inter-oceanic heat transfer from the Southern to the North Hemisphere, which maintains the planetary thermodynamic equilibrium. This project presents a multi-proxies study in order to better understand the worldwide Climate Machine and help in climatic modeling to predict future trends.

Les variations climatiques régionales et globales (passées ou à venir) sont liées à des processus régionaux d'interactions océan-atmosphère et sont fréquemment associées à des modifications des écosystèmes et des changements biotiques. En particulier, le transfert thermique inter-océanique de l'hémisphère sud vers l'hémisphère nord, qui maintient l'équilibre thermodynamique au niveau planétaire, est intimement lié à l'évolution des océans Atlantiques Sud et Equatorial. Ce projet repose sur une étude multi-proxy afin de mieux comprendre la machine climatique mondiale, passée et actuelle, et de participer à l'amélioration des modèles climatiques permettant de mieux prédire les tendances futures.

As variações climáticas globais e regionais (passadas e futuras) estão relacionadas com processos regionais oceano-atmosfera e estão frequentemente associadas com modificações nos ecossistemas e demais alterações bióticas. Em particular, a importância do oceano Equatorial e do Sul Atlântico é crucial na transferência do calor inter-oceânico do Sul para o Hemisfério Norte, que sustenta o equilíbrio termodinâmico planetário. Este projeto apresenta um estudo multi-proxies, a fim de aumentar a compreensão da máquina climática mundial e ajudar na elaboração de modelos climáticos em vista da previsão das tendências futuras.

Introduction

The South and Equatorial Atlantic Ocean have great importance in inter-oceanic heat transfer from the Southern to the North Hemisphere to maintain the planetary thermodynamic equilibrium (Fig. 1), and therefore, should be investigated in paleoclimate studies, in order to better understand the worldwide Climate Machine with important application to climatic modeling to predict future trends. Western Boundary Currents are important carriers of heat to higher latitudes, which influences the atmosphere circulation and consequently the climate of those regions. The Brazil Current (BC) and its northern branch, the North Brazil Current (NBC) is the western boundary current representatives of the Western South Atlantic, flowing south- and northward respectively. The BC flows along the Brazilian Southeastern Continental margin until it reaches the Malvinas Current at the Subtropical Convergence Zone in the area of South Atlantic Central Water (SACW) formation. On the other hand, the North Brazil Current flows along the Northeastern Coast of Brazil, on the border of a narrow continental shelf (Peterson and Stramma, 1991). The oceanic heat transport from the Southern to the Northern hemisphere is highly influenced by the North Brazil Current (NBC), which is a fast western boundary current formed by the South Equatorial Surface ocean circulation when it meets the Brazilian north-eastern coastline. This oceanic circulation has a strong effect on climate variability, as the NBC transport is correlated with north-south migration of the Intertropical Convergence Zone (ITCZ), resulting in associated changes in precipitation on land, especially in the north-eastern and northern Brazilian territory. It has also been shown that these precipitation changes can generate wet to dry anomalous conditions registered on a variety of time scales (intra-annual, decadal, centennial/millennial).

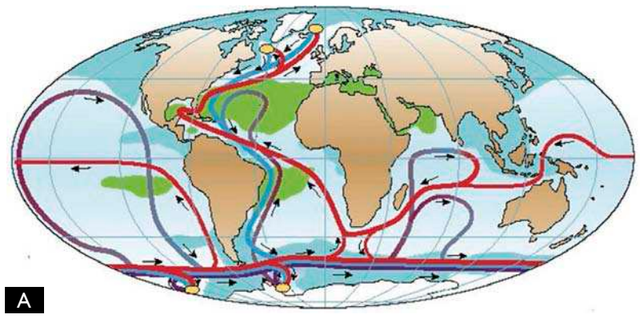


Fig 1

- A-Modern ocean circulation (Red: surface currents; Blue : Deep waters 2000-4000m (e.g. North Atlantic Deep Waters NADW and BC); Purple: Deepest waters >4000m (e.g. Antartic Bottom Waters: AABW) (Rahmstorf, 2002).
- B- Sea Surface Temperature with North and South Subtropical Gyres.
- C- (above) available Marion-Dufresne deep cores with sedimentation rates > 5cm/ka.

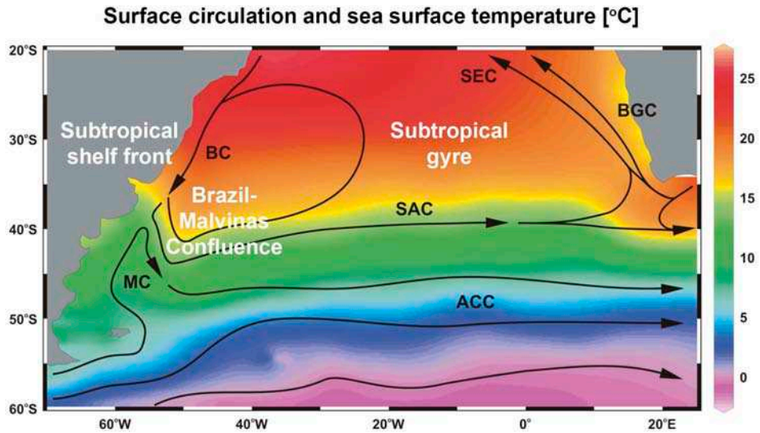


Fig. 2: Properties of water masses in SW Atlantic Stramma and England (1999), Locarnini *et al.* (2010)

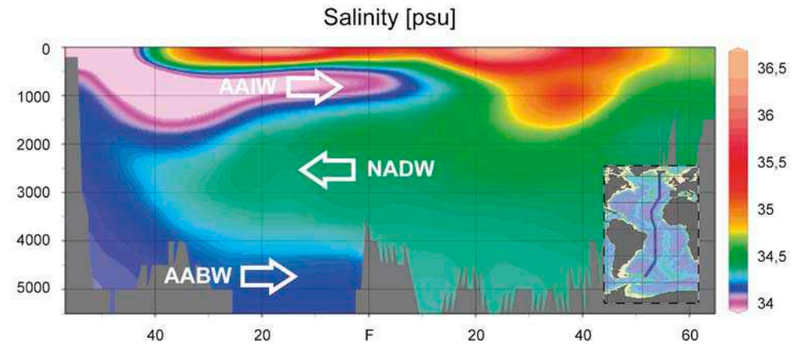


Fig. 3: Atlantic meridional overturning circulation (AMOC) (Antonov *et al.* (2010): a northward heat transport integrated over longitude and depth

Climate models clearly show that sea surface temperature (SST) changes (or variability) on the equatorial and south Atlantic ocean modulate the positions and intensity of the South Atlantic Monsoon System (SAMS), which finally controls the precipitation patterns over northeast and southeastern Brazil. How the South and Equatorial Atlantic SST changed during the past (at centennial and millennial time-scales) and how it affected the continental climate are key questions that remain largely open.

The Equatorial and South Atlantic Brazilian marginal basins are, therefore, unique locations that preserve the record of palaeoceanographic and palaeoclimatic changes, which might be investigated through the analysis of long sediment cores, helping to unveil past environmental conditions, that had a global significance, and to model future climatic behaviour.

Large climatic changes are frequently associated with ecosystems modifications and biotic alterations. Long term analysis of different sedimentary and geochemical proxies on the Brazilian Equatorial marginal basins can also contribute to understand the history of modifications of large South American biomes, such as the Amazon Forest, the Brazilian Cerrado, and the Brazilian Caatinga, whose drainage basins are completely or largely, directed to the Equatorial Atlantic (see connexions with Amazon Blue-Green and Mountain-to-Deep Sea themes).

Paleoceanographic data have also demonstrated that the ocean's current mode of circulation is not unique but can, and has, switched rapidly between dramatically different states, in conjunction with major climate changes. Rapid changes in ocean circulation and climate have been observed in different archives (e.g., marine sediments, ice cores, stalagmites), notably over the last

60 thousand years. Ocean circulation model experiments and reconstructions from proxy data indicate that changes in the Atlantic Meridional Overturning Circulation (AMOC) are associated with ocean-wide reorganizations in heat transport and temperature distribution. Yet, the various processes hypothesized to drive ocean and climate reorganizations are still poorly constrained. Studies based on instrumental data are faced with the difficulty of (i) distinguishing natural variability from anthropogenic change, and (ii) detecting processes operating in time-scales longer than the instrumental record. Therefore, long-term data extracted from natural climate archives (e.g., marine sediments; ice cores, stalagmites) are required to understand the complex dynamics of the climate system.

The Atlantic meridional overturning circulation (AMOC) plays a fundamental role in the oceanography and climate of the Atlantic realm. Atmosphere-ocean general circulation models have predicted a weakening in AMOC strength for the coming decades. Thus, a comprehensive understanding of the response of the western South Atlantic to changes in AMOC on different time scales is a key issue. Both the continental shelf and slope of the tropical and subtropical western South Atlantic have been the focus of recent paleoceanographic studies. However, it is noteworthy that almost no studies addressed the stratification of the upper water column, or evaluated the link between changes in AMOC and the western South Atlantic circulation during the Holocene with appropriate temporal resolution to assess millennial- to centennial-scale variability. In addition, the behavior of the interface between northern- and southern-sourced water masses remains poorly constrained in this portion of the Atlantic.

Global, large scale climate (past and future) and ocean-atmosphere regional processes (e.g. South American Monsoon variability, wind-forced ocean circulation, interaction between the western boundary currents and eastern boundary up-welling systems, modulation of internal deep ocean processes by external natural and anthropogenic forcings ...) occurring during selected time slots of a few decades in the past millennium can be addressed using global general circulation models combined with proxy reconstructions from marine and continental climate archives. In-situ instrumental observations and regional monitoring is also crucial, first for validation of climate model in hindcast mode as well validation of proxies, and above all because the efficiency of present global ocean observing system rely on a sufficient number of observations in the most energetic regions such as the western boundary currents.

The increase in atmospheric carbon dioxide concentrations caused mainly by fossil fuel combustion is changing ocean carbonate chemistry equilibrium and decreasing seawater pH. On continental margins these changes are less clear, mainly due to i) the extreme heterogeneity among coastal ecosystems, ii) the fact that carbonate chemistry is strongly regulated by riverine and open ocean delivery of nutrients and biological processes in these areas, iii) natural variation of pH in these areas at daily and/or seasonal time scales, and iv) lack of observations and the inadequacy of global biogeochemistry models in resolving these areas, especially in tropical and subtropical regions.

Brazil has a vast coastline facing the south-western Atlantic Ocean, with a large diversity of coastal, continental margin and open ocean ecosystems. Among these are included mangroves, coastal lagoons, coral reefs (including deep water corals), rhodolith beds, sea mounts and oceanic atolls and islands. Unfortunately, the state-of-the-art of scientific knowledge for both marine biogeochemistry (e.g. pH, total alkalinity, pCO2, DIC, nutrients) and biodiversity is still has large gaps (spatially and long-term observations) that impede the correct understanding of biogeochemical processes and ocean acidification impacts.

Summary

Paleoceanography and operational oceanography focused on proxies calibration are still extremely scarce and poorly developed in Brazil. The small number of researchers dedicated to palaeoceanography, the lack of analytical infrastructure and the absence of national programs of coring are probably among the main factors that prevent a more effective paleoceanography research in Brazil, especially focused on the southwest Atlantic.

However a large number of current or under construction national and international projects demonstrate the dynamic of the community (e.g. among many: RETRO, iPON, PRIMO, RESSURGENCIA, CLIMACT, PALEOTRACES, SAMOC, LMI, BROA…). We seek to further participate in the development of these projects with some specific orientations as detailed below.

Projects

Understanding the limitations in Paleoceanography research in Brazil, a group of researchers from Rio de Janeiro (Universidade Federal Fluminense) and São Paulo (Universidade de São Paulo) has created the first initiative for a research consortium focusing on palaeoceanography, which was called iPON (Interinstitutional Paleoceanography and Oceanography Network). The main focus is iPON optimize access to analytical infrastructure, as well as converging ideas and collaborative efforts for the development of this science in Brazil.

Monitoring and deciphering the changes in atlantic meridional overturing across rapid climate changes

We propose to retrieve marine sediment cores distributed along depth transects in the tropical and south Atlantic Ocean characterized by high sedimentation rates in order to reconstruct changes in the vertical structure of water masses over the last 30 to 40 thousand years, that is the period covered by ^{14}C dating. One potential area for collecting long cores over this period of time would be the Rio Grande Cone (i.e. off southern Brazil, 32-35 °S). By applying a suite of isotopic, geochemical, micropaleontological and sedimentological proxies, we will assess abrupt changes in AMOC and their impacts surface hydrographic conditions.

Holocene millennial- to centennial-scale variability of the western south atlantic: a review and future research directions

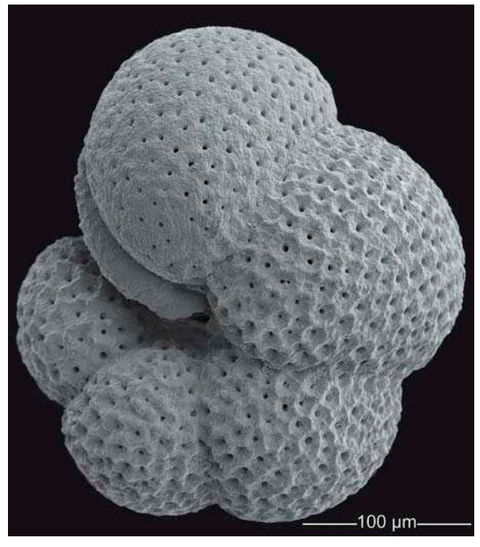
We propose to reconstruct changes in stratification of the upper water column and deep- water geometry in the western South Atlantic during the Holocene in order to explore the response of the western South Atlantic to changes in AMOC on millennial to centennial timescales. Therefore, we suggest analyzing stable oxygen and carbon isotopes as well as Mg/Ca ratios in selected species of planktonic and benthic foraminifera from carefully selected sediment cores from the tropical and subtropical western South Atlantic. The sediment cores will have age models determined based on AMS ^{14}C dating on monospecific foraminifera. Additionally, other proxies as well as numerical model experiments may be used in order to refine/verify the reconstructed conditions. Through this project we expect to:

- (i) improve our understanding about past millennial-scale changes in the western South Atlantic;
- (ii) reconstruct changes in freshwater transport by the AMOC in the western South Atlantic;
- (iii) contribute to the debate of possible impacts that future changes in AMOC may have over the western South Atlantic; and
- (iv) strengthen and/or establish a French-Brazilian cooperation on paleoceanography.

We are aware that only through a strong international collaboration we will be able to tackle these issues satisfactorily in a reasonable amount of time.

Foraminifera as tracers of paleo-bottom currents, ocean fronts and global climatic variations

We are aiming to conduct a thorough study on the equatorial margin of Barreirinhas-Maranhão located off North Brazil. The margin gives the opportunity to reconstruct the surface and deep hydrography and heat transfer within this oceanic setting including currents from the southern hemisphere moving northward and their contribution to northern hemisphere currents. Six gravity cores have been sampled along the Brazilian continental margin during the mission MAGIC. Rich in microfossils, the sediment will help uncover the palaeoclimatic and palaeoceanic histories that may support a global understanding of surface current movements within the west equatorial region as well as in the North Atlantic Ocean. These samples should be completed by the study of other existing corings (e.g. RETRO project cores) but also with new corings on strategic location.



Foraminifera © Zohra Mokeddem

Pacific and Atlantic Tropical ocean inter-annual to decadal variability over the last millennium: a data-model approach

Our project focuses on the last millennia (especially the last 1000 years), and confronts proxy reconstructions from climate archives with climate model results using the IPSL models/CMIP5 database.

We aim at reconstructing using molecular and isotopic proxies (a) the tropical Atlantic and Pacific SST and SSS variability at inter annual to (multi)decadal timescales from marine archives (sediment cores, corals, shells); (b) the hydrological changes over South America from continental archives (lacustrine sediment cores, speleothems, guano deposits); c) the response of ecosystems (terrestrial vegetation, marine productivity) to climate-driven hydrological changes.

Reliable reconstructions based on calibrated proxies and global coupled ocean-atmosphere climate models, both confronted to instrumental time-series, will improve our understanding of the mecanisms responsible for changes in ocean variability over those time-scale and the impact on the past, present and future South American climate.

The project would address the following questions:

- What are the underlying processes within the coupled ocean-atmosphere system responsible for the SST/SSS variability as reconstructed over the last centuries? How are they influenced by the variations of known natural forcings such as variation of total solar irradiance and volcanic eruptions (e.g. using detection-attributions methods)?
- How do the tropical Atlantic and Pacific variabilities respond to global and regional forcings?
- What is the relationship between ocean variability and extremes/trends in the South American Hydrological cycle (e.g. mega-drought, mega-floods)?
- Which S. American regions (especially in Brazil) are mostly affected by the climatic teleconnections with Atlantic and Pacific SST variability over the last millennium and are those teleconnections stationary at decadal timescales?

Integrated studies of physical and biogeochemical regional processes in tropical upwelling current systems

Coastal upwelling current systems are regions of intense productivity and sustain important natural resources. Modifications of ocean properties driven by global climate change are thought to exert important, yet not well- constrained, impacts on marine ecosystems and thus on fisheries, goods and services.

Our objective is to understand the variability of these systems at different spatial and temporal scales, spanning from the (sub)mesoscale to the regional scale and from the intra-seasonal to the long term trends related to climate change. Our interest lies in multidisciplinary approach for process studies, combining modelling and observational data, and particularly (i) regional integrated modelling studies (atmospheric forcing, ocean circulation, biogeochemical processes, larval transport), with a focus on the eastern Pacific (Peru, Chile) and the eastern Atlantic (Senegal, Canary); (ii) ocean time series at key sites in order to evaluate the temporal variability and fate of exported organic carbon in relation with the structure of the surface biological activity and the ocean dynamics. On going time-series (moorings) are currently developed in the SE Pacific (Peru) and SO Atlantic (Cabo Frio-Brazil).

Brazilian Ocean Acidification Research (BROA)

After a successful international Workshop in December 2012 ("Studying Ocean Acidification and its Effects on Marine Ecosystems"), organised by the IGBP-Brazilian Regional Office and the São Paulo University, a group of circa 20 Brazilian researchers have decided to create the research network "Brazilian Ocean Acidification Research" (BROA, www.broa.furg.br), now enlarged and registered at the Brazilian Scientific Research Council (CNPq). After the creation of the group there have been already established several scientific cooperation among national research teams. On medium term, BROA aims at implementing the necessary scientific equipment and analyses certification for ocean acidification research. This goal includes the participation of Brazilian laboratories to international intercalibration exercises, and the cooperation with experimented international groups. On a longer term, BROA envisages the creation of a critical mass of trained researchers, able to deal with the different scientific and societal aspects included in the ocean acidification problem (e.g. identifying vulnerable areas, proposing adaptation and/or mitigation strategies to impacted areas and communities).

Late quaternary changes in the hydrological cycle in south america: circumventing isotopic biases unsing multiple proxies

We aim to obtain new records for past changes in the hydrological cycle using both isotopic and non-isotopic proxies for rainfall and/or riverine runoff in a series of marine and continental archives. We propose to jointly use hydrogen isotopes (measured on biomarkers) and oxygen isotopes (estimated from the planktonic organisms geochemistry) to reconstruct in a quantitative

way past changes in salinity. These results, combined with oxygen isotopes measurements performed on speleothems and non-isotopic proxies such as XRF measurements performed on marine sedimentary sequences will help identify atmospheric pathways of moisture, and by inference biases impacting the estimation of rainfall amount above the continents from which the isotopic composition of the surface ocean is derived. More generally, we aim to identify biases embedded in the isotopic methods routinely used to study the sensitivity of the low latitudes hydrological cycle to different climate forcings. This project will help to provide a diagnostic on how precipitation rates above South America are likely to respond to the anthropogenic climate forcing.

Lithogenic grain-size marker of Aeolian and Fluvial Sedimentary process

The particles are a useful proxy for the reconstruction of deposition processes in the past from aeolian or fluvial origin. Changes in continental aridity and the atmospheric condition determine the composition, amount and patterns of particles transported from the continent.

The approach on the role of aerosols as indicators of climate change and for understanding changes in frequency and intensity of winds through the late Holocene can be used in order to find possible relationship and teleconnections with the Atlantic Ocean on South America and with greater relevance in the more arid zones of the Brazil.

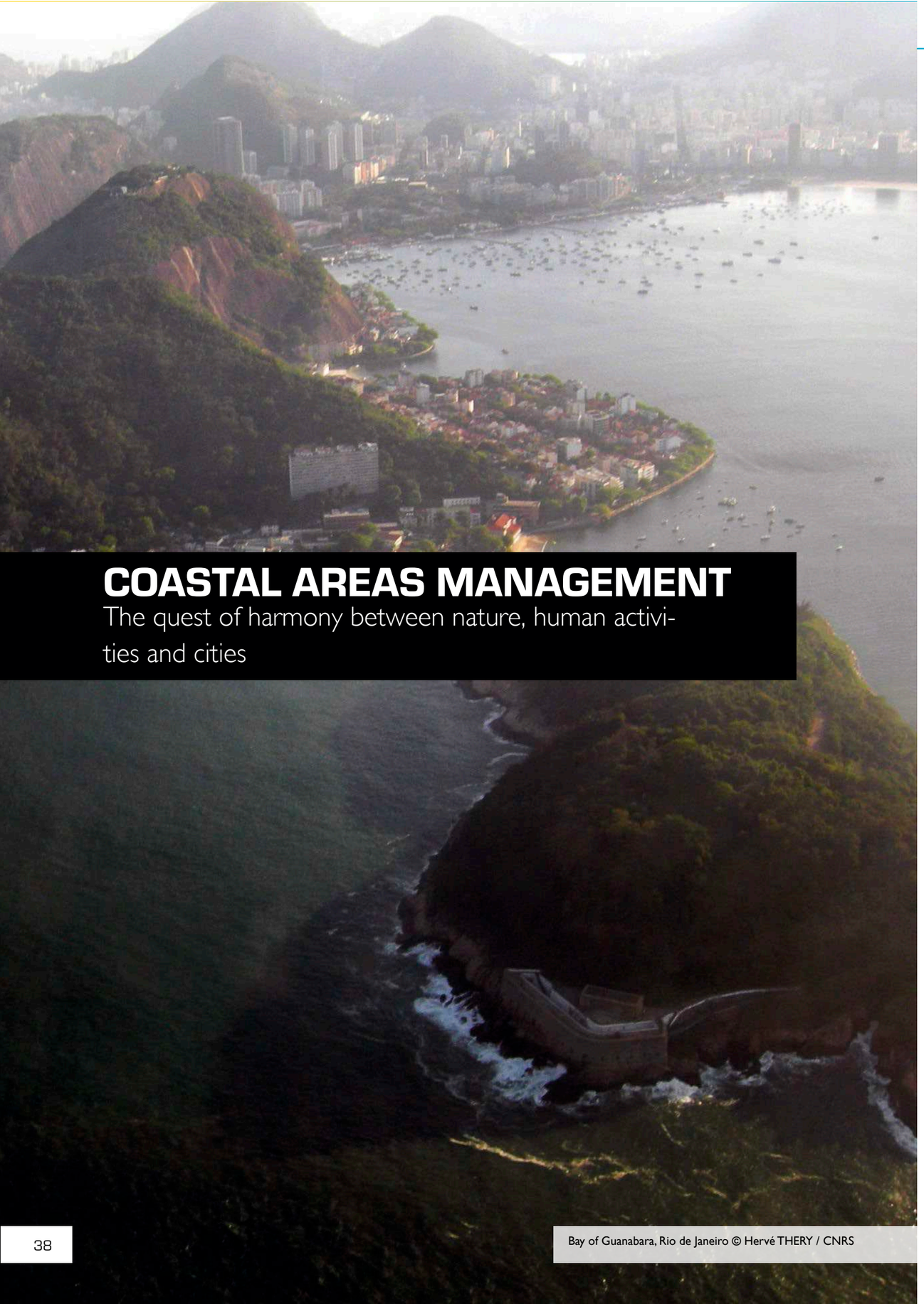
Links with trans-disciplinary projects

The projects mentioned here also have strong connexions with *Coastal Management, Amazone Blue and Green* and *Mountain to DeepSea* Themes.

In particular, the task 5 of *Mountain2DeepSea* proposes to deploy 30 MultiMermaids in the Western part of the South Atlantic, as a part of MariScope, a new, international program for monitoring the ocean environment currently subject of a FET-Open proposal to the EU. These multidisciplinary floats provide high-frequency acoustic signals that allow biologists to monitor cetaceans and noise, meteorologists to estimate rainfall, and that adds temperature and ocean current information to the oceanographic Argo project.

The setting-up of international "Floating Universities" on large coring vessels (such as the Marion-Dufresne) will be crucial for data acquisition and coring campaigns. But, also buoying launch for mapping sea conditions in a long term.

In August 2012, Brazil joined the Integrated Ocean Drilling Program (IODP) and became the newest of the twenty-six member countries in the IODP. These research expeditions engender exchange of scientific ideas and expertise, while fostering long term multilateral collaborative links. Brazil being a new partner within IODP will bring considerable opportunities to prepare new international drilling projects in the Equatorial and South Atlantic margins.



COASTAL AREAS MANAGEMENT

The quest of harmony between nature, human activities and cities

Bay of Guanabara, Rio de Janeiro © Hervé THERY / CNRS

The concentration of population in coastal regions is a world-wide process that is generating an unprecedented confrontation between man and nature. It is also raising multiple scientific issues across all disciplines. Risks and vulnerability are two crucial topics for Europe and Brazil, and they challenge multiple areas, from natural and engineering sciences to economics, planning, law and sociology. The present document constitutes an initial framework towards a multifaceted program that is still widely open for further development.

La concentration des populations humaines le long du linéaire côtier est un processus planétaire, engendrant une confrontation d'une intensité jamais égalée entre l'homme et la nature et soulevant des problématiques scientifiques multiples pour l'ensemble des disciplines. Les questions de risques et de vulnérabilités résonnent avec la même acuité en Europe et au Brésil, interpellant autant les sciences de la nature, les sciences de l'ingénieur que l'économie, l'urbanisme et le paysage que le droit et la sociologie. Le document présenté ici est un premier cadre pour un programme aux multiples facettes, programme encore largement ouvert.

A concentração das populações humanas ao longo da costa é um processo global, resultando num confronto com uma intensidade inigualável entre o homem e a natureza e levantando vários problemas científicos em todas as disciplinas. As questões ligas aos riscos e às vulnerabilidades têm a mesma acuidade na Europa e no Brasil, desafiando tanto as ciências naturais, as ciências da engenharia tão como a economia, o urbanismo e a paisagem, a lei, e a sociologia. O documento apresentado aqui é um quadro inicial para um programa multifacetado, ainda em aberto.

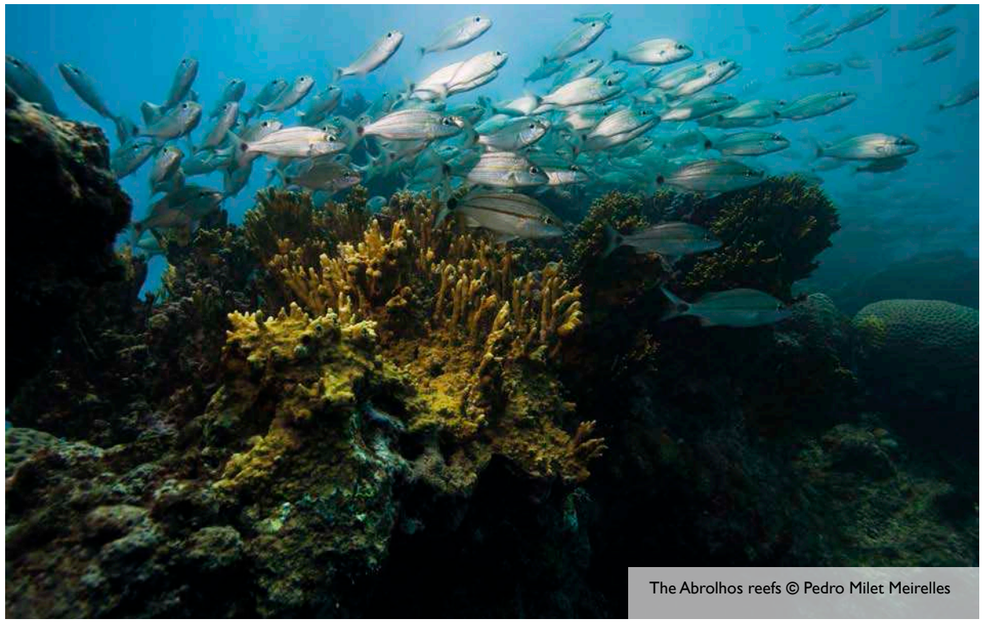
Introduction

Coastal zones constitute a natural interface between earth/water/atmosphere that are subjected to an increasing concentration and diversification of human activities. This global phenomenon, where most of the humanity moves progressively towards a narrow coastal strip, induces consequent impairment of natural resources and ecosystems, which will reach a considerable extent by mid-twenty-first century. Such areas are increasingly affected by natural disasters of all sorts, a growing number of environmental risks and vulnerabilities, such as pollutions, epizooties, harmful algal blooms, flooding, storms, as population and occupation increase. From a biological, ecological and socio-economic standpoint, it appears very important to identify the different threats present into the different environments, such as pollutants (persistent organic pollutants, heavy metals, pesticides, but also emerging pollutants, such as nanoparticles, microplastics etc.), external effects from new activities (windfarms, mining), extreme climatic events, harmful algal blooms, pathogens and diseases, which are an increasing concern in coastal areas. These perturbations can profoundly modify equilibrium of ecosystems, thus modifying key species and communities and having major impacts on living resources and livelihood. They can therefore have profound social, economic and sanitary consequences. How can Cities develop in harmony with the Nature and the Article 25 of the Universal Declaration of Human Rights? Coastal areas management is essential to face rapid environmental changes. The development of new studies, methodologies and models could well be used for mitigation measures, to increase the adaptive capacity of communities and are needed to specify the legal limits and terms of law and to assess policies. Also the international commitments (Rio 1992 conference and subsequent) for a worldwide development of Marine Protected Areas need a well-founded and accurate knowledge of the coastal ecosystem functioning, of the pressures it suffers and of its evolutionary trajectories.

Specific locations and topics need to be targeted as pilot studies along the Brazilian Coast, using French, European and Brazilian experiences, as it has been started in Recife and is narrow, highly embanked and urbanized Rio Capibaribe estuary.



Figure 1: Main estuaries situation along the eastern shelf of the Brazil



The Abrolhos reefs © Pedro Milet Meirelles

The focus of the studies will be the following:

- Morphodynamic and sedimentation rates - anthropic and climatic impacts;
- Changes in physical forcing and sediment dynamics in urbanized estuaries, residual circulation and dynamics of the turbidity maximum zone;
- Biological and ecological pollution, impact on ecosystems, biodiversity and living resources (including aquaculture) — Study of the new threats linked to ecological disorders induced by increased anthropogenic activities, nutrient fluxes, non-native species introduction and pollutant increase
- Coastal observatories development;
- Algae and micro-algae culture and valorisation(Bioprocess, Food, Bioenergy)
- City development and slump risks;
- Study of sea water intrusion in coastal aquifers from high frequency and autonomous downhole hydrogeophysical observatories;
- Urbanisation and landscape architecture
- Short time variations of the climate and fisheries reports.
- Law and jurisdiction
- Cost-benefit analysis
- Information, education, involvement of Brazilian citizens in this overall observatory and invitation to participate on that environmental laboratory.

The Brazil coast is one of the most inhabited coasts of the world, with numerous dense coastal cities (Figure 1). The geomorphology of the eastern Brazilian coast induces a specific situation for these cities: they are caught between beaches in front and lagoonal estuaries behind, situation which triggers different problems such as the erosion of beaches, pollution in the internal estuaries and the salinization of drinkable waters used in the cities (example of Recife).

Face to such risks, the first objective is to obtain a deeply improved understanding of erosion processes under physical, chemical, climatic and anthropogenic effects. The second objective is to study the mechanical consequences of erosion on the soil behaviour and the biological consequences on environment. The third objective is to develop and to evaluate the efficiency of various protection systems. The fourth objective is to question the way to design new urban developments.

These objectives need an inter-disciplinarity, holistic approach in order to investigate all the aspects of the problems, and especially the human en nature interactions, and the mutual impacts they have, in this context of climatic global change.

Annual studies must be scheduled, including cruise on river and oceanic vessels, where young researchers, students and local population must be deeply involved. In this project, experimental characterizations, numerical modelling, holistic studies will be combined and compared to field measurements and monitoring experiences. A program of information and education (see below the education program) will be conducted at the same time. The idea is to involve the Brazilian citizens in this Observatory and invite them to participate on the environmental laboratory.

Natural setting

Monitoring the geomorphological evolution of the coast - Measurement of bathymetry and sea level to evaluate the erosion - Integrated spatial and temporal scales

On these sandy coasts, the coastal erosion, a worldwide phenomenon, affects both front coasts and estuaries environments. Moreover, climatic changes may induce the sea level rise and the increase of danger and severity of meteorological events. In consequence, the hydraulic loading on coast will grow all along the seaboard and also along river coasts. By waves action, tidal currents and internal seepage, soil particles or aggregates from coastline can be detached and then transported. Erosional processes will result in landforms such as pipes, columns, sinkholes, settlements and thus the coastal retreat. And the feedback results may be the intensification of the risk of flooding of downstream areas because of the erosional processes.

The first step to approach such problems is to establish an actual "reference map" to be able to follow (to see) the geomorphologic evolutions of the coastal and estuarine system. The measurement of bathymetry, with a very high resolution, is necessary to quantify the eroded volumes from a year to another one, which implies a repetitive acquisition of bathymetry data along a definite period. These bathymetric maps (Fig. 2) may be acquired by an interferometric sonar similar to the one which equips the Haliotis ship from Ifremer. Sonar images will give simultaneously an idea of the seafloor nature with the backscatter amplitude and the chirp or sediment echo-sounder will allow us to evaluate the vertical distribution of the different sedimentary bodies, if they do exist.

The second step would be to evaluate the hydrodynamical forces of such a system and to try to take into account the sea level. The use of hydrodynamic models (ALDO) and the deployment of monitoring tools would be necessary to access to and to determine the volume and the paths of the water fluxes. At least, it should allow us to access to amplitude and variability of the hydraulic loading applied to the coastline, as this last parameter appear to be very important in the erosional processes.

The geological fabric of considered soils

The magnitude of coast lengths induces large heterogeneity in soils whose geological facbric can significantly vary according to the considered site. The water seepage within soils can generate a detachment and a transport of particles from these soils and this process of internal erosion can modify the hydraulic properties such as "permeability" (Bendamane *et al.*, 2008); Marot *et al.*, 2009; Marot *et al.*, 2011). But recent numerical simulations (Scholtès *et al.*, 2010) and experimental tests (Chang and Zhang, 2011) showed that soil shear strength and stiffness can also be strongly reduced by erosion processes. These results obtained with gap graded soils have to be completed in order to verify their generalisation for a large range of soils. The influence of erosion on mechanical properties of soils remains an open question, and may strongly depends on the initial soil grading and may be influenced by scale effects.

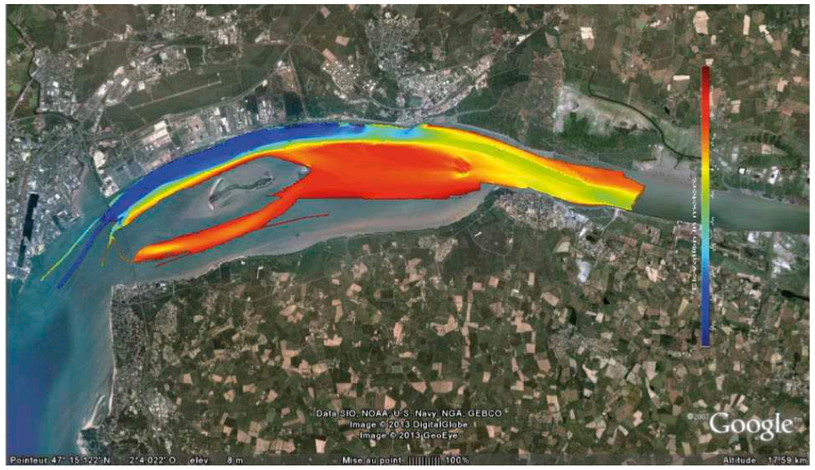


Figure 2: Bathymetric map of the Loire Estuary (Haliotis map from Clouet, 2012)

The erodibility of coastal soils, which are submitted to multi frequential hydraulic loading, has to be evaluated thanks to dedicated devices. Several experimental field campaigns on soil erodibility characterization (under monotone hydraulic loading) show the influence of the history of the hydraulic loading (Nguyen *et al.*, 2012), the mineralogy of the soils and the water saturation ratio (Regazzoni and Marot, 2011). These results suggest that the erodibility characterization of the coastal soils absolutely needs to take into account these key parameters with a geotechnical approach, combining the geological fabric of the site and the interstitial water measurement is necessary.

Moreover, it will be very important to study and quantify the impacts of the chemical properties of soil and interstitial water, and to evaluate the impact of human activities and practises on the water fluxes and the water quality.

Chemical characterization of considered soils and also interstitial water

Sandy beaches act as biogeochemical reactors with a complex circulation inside the permeable sediment, where freshwater from coastal aquifers mixes with seawater (Rocha, 2008; Anschutz, Mouret *et al.*, 2009; Rocha *et al.*, 2009; Loveless *et al.*, 2010; Avery *et al.*, 2012; Charbonnier, Mouret *et al.*, 2013).

The works of the laboratory BIAF (University of Angers) is involved in **porewater biogeochemistry** focus on the evaluation of impacts of salt water intrusion **in permeable sandy beaches** on the biogeochemistry of coastal aquifers. Effects of sea-water circulation in coastal sands on organic matter mineralization processes and nutrient recycling are particularly studied. This laboratory has experience into the study of the spatial and temporal variability of porewater biogeochemistry and the monitoring of such measurement (example of the island of Yeu). The main results of their research is that oxygen and nutrient concentrations of porewaters suggest that mineralization of organic matter occurs in the beach sediments. During flood tide, oxic and nutrient depleted seawater penetrates the upper beach coarse sediments, which are water-unsaturated down to 80 cm at low tide. In the lower beach, the sediment remained always water-saturated and the sand is finer, reducing the permeability. The renewal and the flow of porewaters depend on beach topography and sand permeability, which are not homogeneous along a beach. These results highlight that porewater composition is progressively modified along the tidal cross-shore transect because of the production and consumption of chemical components due to organic matter mineralization. There is also the occurrence of a seasonal evolution of the porewater chemistry. At the end of summer, the presence of dissolved iron and sulphide in the lower part of the beach indicates that iron and sulphate reductions occurred in the anoxic sands. The depletion of dissolved iron deeper in the sediment suggests the precipitation of an iron sulphide phase below 40 cm. At the end of winter, the production of dissolved iron was lower with no accumulation of sulphide. The seasonal temperature difference in the sediment (15°C in summer; 10°C in winter) may explain the enhanced mineralization during summer. Would it be the same within a tropical climate environment?

Preservation of the sand on beaches and the protection of banks or cliffs need to develop and to test different methodologies. This project should be performed at the laboratory scale but also in-situ, in order to avoid any scale effects and to verify the efficiency according to the type of considered soil. The characterisation of water fluxes "across" a sandy beach (which could be assimilated to a sand spit) may help to understand the biogeochemical processes and the geochemical characterization of water fluxes from land (the estuary or lagoon) to the sea (quantification of geochemical fluxes to the coastal ocean) and from sea to land (sea water intrusion, salinization) .

A potential experimentation may be the Eco-Plage system which would offer at the same time a possibility to avoid erosion of the beach.

The Eco-plage project : a possible experimentation

The ECO-PLAGE system, developed by Audrain, is a process to reduce or even potentially stop the beach erosion and facilitates a natural accretion, depending on geomorphology and the environment of this beach. It consists of placing a drainage system beneath the beach, parallel to the coastline. The filtered water is transported by gravity to a pumping station and then evacuated to be re-used (thalassotherapy, desalinisation..) or back to the sea.



An interesting point is that this system lowers the level of the water table under the beach. It creates by this action a dry area which facilitates the infiltration of water carried by waves and thus limits the amount of sand carried back to the sea. In the same time, the system absorbs a part of the waves energy and will reduce the erosive effet of the backswash. As this system will interact with water fluxes, it should be possible to study and characterize these fluxes.

Ecoplage system is considered to have no negative impact on the environment, such erosion on adjacent beaches or on flora and fauna.

Human setting

Identification of social and economic impacts of the erosional process

The impact of natural events on the social and economic activities may be evaluated to decide if it is worth protecting or not such coastal area or not. The ONECAD software has been developed in the Laboratory Géolittomer by P. Pottier, at the University of Nantes. The aim of this software is to evaluate the economic potential of a coastal area (beach) with the objective to contribute to the coastal management. The social and economic impacts of erosion have to be studied for an evaluation of a preserved coast. Another methodology could lie in the implementation at a fine-scale grid of a vulnerability index along the coast taking jointly into consideration the sea rise level in case of flooding, the distance to shelters and the architectural type of buildings (Creac'h 2014).

Anthropogenic impacts on Biology, Ecosystem and Health

The impact of pollution and human activities is tremendous and needs to be analysed in details and mitigated or controlled as much as possible. From a biological and ecological standpoint, it appears very important to identify the different threats present into the different environments, as they represent an increasing concern in coastal areas. Indeed anthropogenic perturbations can profoundly modify equilibrium of ecosystems, thus modifying key species and communities and having major impacts on living resources.

In marine organisms, exposure to pollutants, infections caused by parasites or pathogens and harmful algal blooms are after the physical and chemical perturbations (temperature, salinity, dissolved oxygen, etc.), the stress most affecting physiological responses. Pathogenic bacteria and protozoa parasites are often cited as factors limiting aquaculture production of bivalves (Lauckner, 1983; Lees, 2000, OIE, 2006). Similarly, toxic and harmful microalgae are increasingly recognized as the cause of many physiological disturbances in populations of marine organisms (Landsberg, 2002). In addition, an alarming increase in the frequency of harmful algal blooms and diseases due to pathogens has been described worldwide in recent decades (Harvell *et al.*, 1999). This increase in biotic stress contributes to disrupt the physiological balance of the populations of many marine species and could lead to disruptions in the entire coastal ecosystem. It is therefore essential to observe, analyze and understand the effect of these microorganisms on the physiology of marine organisms.

Harmful Algal blooms for example are increasing in frequency, intensity and geographical distribution worldwide (Hallegraeff, 2003). Recently, blooms of toxic benthic microalgae of the genus *Ostreopsis* appeared, both on the Brazilian, but also on the French coast. In addition, blooms of dinoflagellates of the genus *Dynophysis*, *Gymnodinium* or *Alexandrium*, and more recently the toxic diatom *Pseudo-nitzschia* have been observed in Brazil. These different algal genus are also present and recurrently responsible for harmful algal bloom events on the French coast. Indeed, these microalgae produce different types of toxins responsible for diarrheic, paralytic or amnesic shellfish poisoning respectively. Filter feeders, such as bivalves are the first organisms in contact with these toxins, which further accumulate within the trophic food web towards high levels. The algae and toxins can have deleterious effects on marine organisms themselves, but can also be responsible for human poisoning. It therefore appears important to evaluate and monitor the presence and toxicity of these harmful microalgae, the effect of these harmful microalgae on marine populations, especially filter feeders themselves, but also their impact in terms of human health.

Similarly, recent investigation in Brazil has demonstrated the presence of several parasites, such as *Perkinsus* sp., or viruses, such as Herpes virus, in marine organisms such as oysters, which could be used as aquaculture species. Pathogenic agents of the same genus are present in France as well, and responsible for disease or death of some bivalve species. There again, it thus appears very important to monitor the presence of these parasites on marine organisms and investigate the impacts they can have on coastal and potentially commercially exploited species. Similar issues associated with pollutants, occurring both in France and Brazil, whether they are metals, plastics, PCBs or PAHs can also be raised and should also be taken into account, as far as their impacts on marine organisms and thus on the ecosystem they sustain.

Amongst the four main topics developed in the "From Ocean to Human" approach (Cf. Biology, Ecosystem, Fisheries and Health Document), three are deeply connected with the *Coastal Management project* and need to be developed:

- Better understanding of the ecosystem functioning, including biodiversity, biogeography, biogeochemistry, monitoring, population, community & landscape ecology, through past and present approaches.
- A better knowledge and understanding of living resources, including biodiversity, conservation, fisheries, aquaculture, microorganisms, threats (bio-invasions, harmful algal blooms, pollutants, pathogens, acidification, impact on human health…), with three particular topics which should be focused on:
- Harmful Algal Blooms and their toxins: impacts on marine organisms, accumulation within the trophic food web and human health issues;
- Impacts of diseases on marine organisms and human health issues;
- Impacts and accumulation of pollutants on marine organisms and human health issues
- The development of biotechnology, including bioprocessing and bio-refinery, antifouling etc., also associated with a better knowledge of bio- and chemical-diversity etc.

Coastal observatories development

In Brazil and in Europe as everywhere in the world, the development of coastal observatory networks is a priority. In the short and mean terms, it is the only way to improve security, monitor the fate of human discharges and survey the variability of biological production and associated processes. In the long term, observation is the most important way to contribute to a deeper knowledge of coastal zone, ecological and biogeochemical functioning, particularly by allowing the necessary numerical modeling environmental prediction. Finally, a network of coastal ocean observatories in a prerequisite condition for the development and validation of all coastal management ambitions.

Coastal waters are heterogeneous and complex and don't present the relative contextual constancy of the open ocean, the faced challenge is so particularly complex. The tools, as buoys and associated sensors should be specifically thought in each specific case, and the deployment array adjusted to the topographical characteristics of the site and of its presupposed main physical and chemical patterns.

In this thematic, Brazilian and French researchers which were gathered in Buzios, have put forward the subject of phytoplankton observation, either toxic or not. The occurrence of phyto and cyanotoxins appears in fact as a major threats not only for human health but also for the ecosystemic processes themselves. In France, specific observatory networks are in progress, some involving participatory science (http://www.phenomer.org/). In the same time national scientific networks are in progress (http://www.phycotox.fr/).

Some new type of observations, corresponding to new problematics and/or new tools have also been considered. Among them the microplastics, presently very poorly monitored, have been cited as a priority for the future, both in Brazil and Europe.

In the same way, some discussions on metagenomic observations of the microbiome in coastal waters have been launched. The microbionts (eucarya and procarya) constitute the basis of the marine foodwebs and are, to date, the biodiversity part less studied and known on the earth. Inversely, it concerns the forms of life the most récative to local anthropogenic change as well as to global climate changes. To be relevant, the barcoding methods must be associated to oceanographic approach and modeling. Such a thematic is now in progress in France and could be a future theme of bilateral collaboration.

Changing cities

> *"Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care and necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond his control."*

Article 25 of the Universal Declaration of Human Rights.

Following the work done in Ireland or in France by S. Dunne and her co-authors, Changing cities is interdisciplinary (Architects/urbanists, Landscape designers, sociologists, geographers, historians) program that aims to look at the complex multi layered socio-economic and geographic parameters and conditions that participate in shaping urban environments.

A Changing City means changing way of living, but also changing citizen's representation of their common territory, changing relation to environment and landscape. With this in mind, the challenge is to imagine propositions that suit to global and local strategies, to current and future situation and development, engaging people in democratic processes.

The urban project means firstly to understand a situation, its origin, the evolution and the reasons of the way of its development, then to construct a strategy that in-

tegrates the existing context but also generates changes into social and urban environment. One has to consider common issues at large scale and local problems that implies everyday's life of inhabitants.

The proposition is to create several workshops and studies with interdisciplinary team of European and Brazilian students, architects landscape designers, sociologists, historian, sedimentologists, ecologists, local politicians, associations and inhabitants…, giving to the students the opportunity to cross experiences and points of view and to draw on each discipline to build up a comprehensive understanding of the territory.

The different project sites and programs will be chosen by students in consultation with the interdisciplinary team, focusing on social and physical fabric of the area with a large number of themes (housing, education, transport, pollution, industry, urban agriculture, social service, nature trails, waste and recycling, tourism and commerce, sport, etc.).

Law – Integrated management of the coastal area.

During the first Building Marine Science workshop at Buzios (Brazil), the need of crossed viewpoints between the E.U. and Brazil for an integrated management of the coastal zone was pointed out. The proposition takes the form of a book mainly concentrated on sustainable development. Crossing European and Brazilian views, the difficulties and the tools will be analysed in both Brazil and European Union and proposals to overcome these difficulties will be discussed through diferent topics and local or general examples, for instance:

- The framework for the exploitation of non-living resources in the Brazilian continental shelf
- Management of coastal areas and environmental protection in France
- The ICZM Protocol in the Mediterranean
- The legal status of genetic resources of the deep seabed
- The French legal system for the exploitation of marine renewable energy
- The European process for of the maritime space and integrated coastal zone management.

EDUCATION

Education program

Education and training are crucial, especially for a sustainable development of the cities and for the quest of Harmony between Nature, Human Activities. A program of information and education will be conducted in each part of the program, when it is possible. The idea is to involve note only scientists and students but the Brazilian citizens in this Observatory and invite them to participate on the environmental laboratory. Some of the actions are already intrinsically connected with that strong commitment (as Changing Cities for instance), the rest will be built depending of the schedule and the opportunities, but there are already programs in discussion:

- Following the work done by José Camapum Carvalho and co-authors (Univ do Brasilia, the first goal is to invite the youth to follow and comment, through French and Brazilian publication for children, the entire project, from the beginning of the building (How a research project starts?, What are the difficulties? How important in a multidisciplinary approach and how to deal with?), to the fieldworks and operations (for each part or in a more holistic point of view) and the impact on the future politic management and development.
- Developing an online course on "Harmful Algal Blooms"
- The idea on the long run is also to build a virtual platform for the study of phytoplankton and phytoplankton taxonomy by developing specific tools : « the Plankton Station – PS4 »
- Developing a summer course involving Brazil, France, U.E. and African margin on fisheries

ACTION

Identification of "TEST Areas"

Several works have already been achieved, and the project can start on the basis of previously established networks. A potential area, to test all these experiments, can be the town of RECIFE as it is a narrow, highly embanked and urbanised area, which has been already studied by Aldo Sottolichio (University of Bordeaux) and Carlos Schettini (University of Pernambuco). Another interesting point is the salt intrusion in Boa Viagem, which has been studied by Suzanna Montenegro (UFPE) and P. Pezard (Univ of Montpellier). The Guanabara bay, in Rio de Janeiro, must be also considered as a potential test area for collaborations. Indeed, it's the site of numerous scientific studies mainly by the UFRJ, but not still the subject of a real integrated scientific program of monitoring and study. One of the ideas could be to match similar approaches on the both sides of the atlantic ocean, involving for example the bay of Brest, one of the most studied embayments in France, now a CNRS reference site for a coupled approach Natural sciences / Humanities.



Aereal view of Recife © Guilherme Jofili

Bibliography:

Bendahmane F., Marot D., Alexis A. (2008). Experimental parametric study of suffusion and backward erosion. Journal of Geotechnical and Geoenvironmental Engineering (ASCE), 134(1), pp. 57-67.

Chang, D.S., Zhang, L.M. (2011). A stress-controlled erosion apparatus for studying internal erosion in soils. Geotechnical Testing Journal, 34(6), pp. 1-11.

Hallegraeff, G.M. 2003. Harmful algal blooms: a global overview. In Hallegraeff, G.M., Anderson, D.M., Cembella, A.D. (eds): Manual on harmful marine microalgae UNESCO publishing, pp 25-49

Harvell, C.D., Kim, K., Burkholder, J.M., Colwell, R.R., Epstein, P.R., Grimes, D.J., Hofmann, E.E., Lipp, E.K., Osterhaus, A.D.M.E., Overstreet, R.M., Porter, J.W., Smith, G.W., and Vasta, G.R., 1999. Review: Marine ecology - Emerging marine diseases - Climate links and anthropogenic factors. Science 285(5433), 1505-1510.

Landsberg, J. H., 2002. The effects of harmful algal blooms on aquatic organisms. Review in Fisheries Science 10(2), 113-390.

Lauckner, G., 1983. Diseases of Mollusca: Bivalvia. In: O, K. (Ed.), Diseases of Marine Animals, Introduction Bivalvia to Scaphopoda. Biologische Anstalt Helgoland, Hamburg, pp. 477-961.

Lees, D., 2000. Viruses and bivalve shellfish. Int. J. Food Microbiol. 59, 81-116.

OIE (World Organization for Animal Health), 2006. Manual of Diagnostic Tests for Aquatic Animals. Fifth Edition, Paris, France.

Marot D., Bendahmane F., Rosquoët F., Alexis A. (2009). Internal flow effects on isotropic confined sand-clay mixtures. Soil & Sediment Contamination, an International Journal, 18(3), pp. 294-306.

Marot D., Bendahmane F., Konrad J.M. (2011). Multichannel optical sensor to quantify particle stability under seepage flow. Canadian Geotechnical Journal, 48, pp. 1772-1787.

Nguyen H.H., Marot D., Bendahmane F. (2012). Erodibility characterisation for suffusion process in cohesive soil by two types of hydraulic loading. La Houille Blanche, International Water Journal, 6, pp. 54-60.

Regazzoni P-L, Marot D. (2011). Investigation of interface erosion rate by Jet Erosion Test and statistical analysis. European Journal of Environmental and Civil Engineering, 15(8), pp. 1167-1185.

Scholtès, L., Hicher, P.Y., Sibille, L. (2010). Multiscale approaches to describe mechanical responses induced by particle removal in granular materials, Comptes Rendus Mécanique (CRAS), 338(10-11), pp. 627-638.

AN INTERNATIONAL "UNIVERSITY ON BOARD"

WHY A "UNIVERSITY ON BOARD"?

The Marion Dufresne oceanographic vessel © Gildas Roudaut / Pôle Image IUEM / IRD

The experiment at sea during a scientific cruise or land operations is the best way to acquire a complete experience; French, European and Brazilian students, living together in a close area, with the best scientists of our countries, during scientific operation connected with the four main projects and involving technology, engineering and science, for a duration that can vary from one week to two months, will never forget this outstanding scientific and human experience. Hopefuly, they will learn, following Diderot and its *Encyclopedia*, « the taste of being carried by an issue that transcends ».

Recherche et formation sont intimement liées et dépendantes. L'expérimentation, le travail sur le terrain, en équipe multidisciplinaire et avec des chercheurs expérimentés, est l'assurance d'un complet transfert des connaissances et d'une pérennité des valeurs épistémologiques. Impliquer des étudiants français, Européens ou Brésiliens lors d'opérations scientifiques liées aux quatre projets principaux, dans un travail en équipe liant technologie, ingénierie et science, est la garantie d'une collaboration soutenue pour l'avenir. Gageons que ces expériences de partage multiculturel et multidisciplinaire lors des campagnes en mer ou à terre sauront enseigner à ces étudiants, a l'instar de D. Diderot et de son *Encyclopédie*, « le goût d'être porté par un enjeu qui les dépasse ».

A experiência adquirida no mar durante um cruzeiro científico ou durante operações terrestres é a melhor maneira de adquirir uma experiência completa. O estudantes brasileiros, franceses e de outros países europeus, vivendo juntos numa área próxima, juntos também com os melhores cientistas dos nossos países, durante uma operação científica ligada com quatro projetos principais que envolvem tecnologia, engenharia e ciência, por um período que pode variar de uma semana a dois meses, nunca irão esquecer esta experiência científica e humana excepcional. Esperamos que eles venham a aprender, na tal como dizia Diderot e sua *Enciclopédia*, «o gosto de ser transportado por uma questão que nos transcende».

The link between higher education and research is obvious. Nevertheless, high level research programs are usually disconnected with the formation of the new generation of young researchers.. We propose to give a systematic educational approach for each project or pieces of the jigsaws presented here.

Floating Universities are proposed as laboratory at sea, surveying and investigating scientific targets. The experiment at sea during a scientific cruise is the best way to acquire a complete experience: the French, European and Brazilian students, living together in a close area, with the best scientists of our countries for a duration that can vary from one week to two months will never forget this outstanding scientific and human experience. Involving together students for France, Europa and Brazil, mixing classic learning and practical high up-to-date research experiment, in a multidisciplinary team, is definitively the best way to build a constructive future and perennial partnership.

Floating Universities will be on small ships for coastal and fluvial researches, or larger French or Brazilian Research vessels for deep sea. Topics of research will involve technology, engineering or science, depending on the project and the needs of both countries.

Previous experiences

A dozen "Universities on board" have been organized with French and European Universities in the recent past using the unique facilities offered by the Marion Dufresne Vessel, IPEV. They all were a real success both for Science and for Educational purposes. Indeed, the "University on board" is a unique opportunity for students to get high-level training in marine geology, oceanography, biology and geophysics in the framework of an actual research cruise. Students were integrated in the scientific teams and were on duty during two 4-hour shifts per day. During their shifts ("watches"), they participated in the exploitation of the cores or of the water samples, from their recovery, cutting, opening, archiving, all the way to their physical parameter measurements and description. Additionally, classes took place between the watches and in transit times, taught by the scientists on board. Students were also in charge of writing the contents of this web site.

In several cases the Education Programme on board was also effective through the Operation called "Teachers at Sea": School teachers from different european countries were also invited on board in order to participate to the scientific cruise, to learn from coring at sea, and to enjoy the exciting life of scientists at sea.

These previous experiences, using exclusively the Marion Dufresne, are really fruitful steps toward an international extension.

Our idea is to create a "Brazilian-European University on board", possibly using the Marion-Dufresne vessel but also other oceanic or coastal research vessels, and even during on-land experimentations, to train both Brasilian and European Students on the huge variety of margins around brazil on a variety of scientific thematic including in particular Sedimentology and Paleoclimate studies that intensively use giant corings, but also biological, oceanographical and geological sampling and analysis.

Clues for high-level education improvement

Today, scientific education, at least during the first four years of University, primarily consists of conventional classes and conferences, leading to limit the efficiency of the scientific knowledge transmitted and the interests that students may find in Science. Additionally, students often fail to acquire enough confidence in their own ability to decipher the scientific reasoning and to practically apply their skills in the frame of their future professional life. Especially in Earth Sciences and Ecology, in which answers to theoretical and practical problems have to be found by collecting and analyzing data sets, a key factor to fill this gap is to make students directly involved in the research process. Indeed:

- students learn how to behave in a group of scientists ;
- they become actors of the process of data acquisition and processing ;
- they feel responsible themselves of the quality of the work done ;
- they have the opportunity to make the link between a conceptual knowledge and the ability of data to constrain it.

A scientific cruise at sea provides all these opportunities in a relatively short time span.

It is also worth to underline that this activity at sea is fully complementary of a personal research study generally offered during Masters, since they have to practice this activity collectively, within a group of students, scientists, sailors, etc..., which makes a big difference.

Finally, the English language is often not fluently understood and spoken by students: the involvement during several weeks in international teams with foreign students and scientists, for which English is the communication language, strongly helps to enhance and improve their ability to communicate (listen, write and speak) in English, which is obviously a great benefit for their professional life to come.



KEOPS II oceanographic campaign on board the Marion Dufresne © Frédéric planchon / UBO

Previous «Universities on board» successfully organized with French & European Universities

The important training allowed by a marine cruise is often proposed in Educational programmes in Europe for instance. However, very few vessels can provide the conditions offered by the R/V Marion Dufresne of IPEV (Institut Polaire Paul-Emile Victor):

- unique coring system (world-record of the deepest piston core),
- room on board (hosting of up to 30 students and a scientific team of ~40 people jointly),
- exceptional facilities for a direct and continuous participation of students to the scientific tasks on board (deck, Conference room).

Since the end of the 90's, IPEV has opened the access of the R/V Marion Dufresne to this kind of Educational programmes, either by favouring student embarkment coming from Universities of the scientific teams in France and abroad, or by providing this possibility to Universities in France for which marine research studies are key parts of their teaching programmes in Master studies. This was the case for Brest (Université de Bretagne Occidentale, Institut Universitaire Européen de la Mer) and Bordeaux I (UFR des Sciences de la Terre et de la Mer) Universities but also for European Universities.

This experience presents probably one of the best we can do, but many other R/V vessels would be well designed for such scientific cruises.

A practical and integrative way to approach high-level marine research

The main objective of this educational and scientific program is to reveal the potential interest to Master students of scientific fields dealing with oceanography s.l. and to enlarge exchanges with other Universities, strengthening a pool of excellence at a high international scientific level. It is a unique opportunity for the students to discover and be involved in the work process of collecting scientific data on board of a ship, to understand how to get the proxies used in climate modelling, and to attend international research courses given by the scientists involved in the program.

One of the key aspects is that students realize on board that all the professional activities are dependent each other: navigation, vessel propulsion, meteorological observations and analysis, fitting of tools, repairing and maintenance tasks, kitchen, logistics, all these works must operate together and are absolutely necessary in order to make the cruise a success. Beyond the scientific activity itself, the lesson from this for the students is the sense of responsibility: they are consequently aware as individuals of the quality of the work they have to carry on board and are much more sensitive after the cruise to the importance and invaluable price of the data collection, and they do behave accordingly.

Ideally, Universities on board should last around 30 days, to let students have time to accommodate with condition at sea, learn technical aspects and be efficient for data collection.

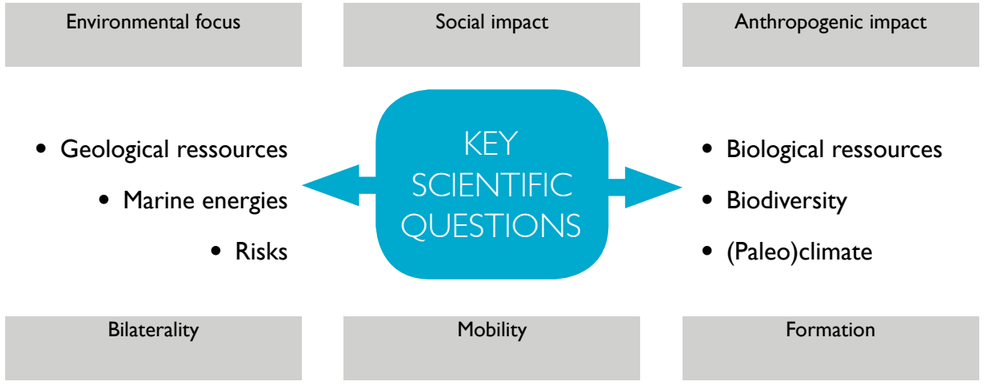


LETTER FROM BÚZIOS

The French-Brazilian Meeting: **Building Marine Sciences**, held in Búzios, 3-8 November 2013, is the continuity of several workshops, which were initiated since 2010 between France and Brazil. The will of the Brazilian and French scientists to strongly collaborate in a true bilateral manner is illustrated by their participation (more than 200) and their enthusiasm during these five intense days. Many Brazilian and French Universities as well as scientific organizations and institutions were also participating and supporting in the event.

Beautiful works from both countries, strong collaborations, great projects already exist. But, as Carlos Nobre said: "*This huge area requires an integrated approach for investigating the South and Tropical Atlantic*". The main focus of the Búzios Meeting was to propose a complete **Holistic approach**, including different disciplines and connexions between geographic and thematic areas, and a new openlarge French-Brazilian network, which include Science, Technology and Formation, in 10 years strategic projects in tight consociation. This long-term approach intrinsically includes human exchanges and formation of the future generation of scientists, engineers and technologists who will build the next French-Brazilian partnership and the future of Marine Sciences.

During these five days, discussions were conducted with a tough philosophical strategy, which can be illustrated by the following scheme:



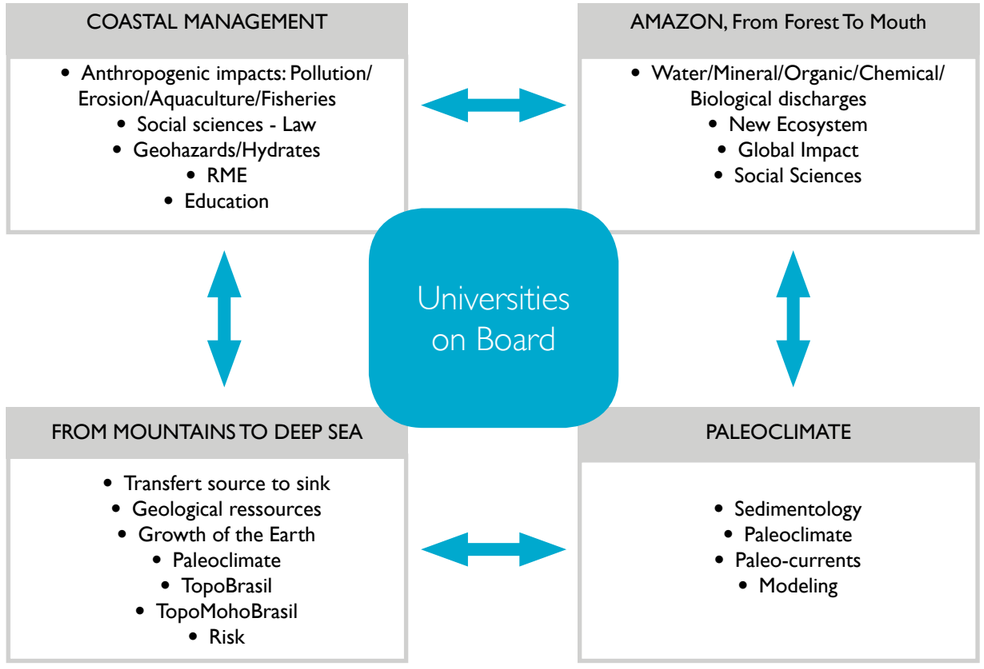
Each block of this diagram was taken into consideration in each discussion, when it was possible. Transversal issues, such as Human Sciences, Law of the Sea and Technology, not shown on this diagram, participated as much as possible in building the different approaches.

The first level of outcome from Búzios is, in fact, proportional to the connexions that were favoured by the meeting: exchanges of students, mobility, seek for post-doctorates, participation of researchers into existing projects. Indeed, the meeting was a great opportunity for a long list of French and Brazilian scientists get together to discuss on the future of marine sciences and further collaboration between labs.

The second level of outcome implies strongly on multi-disciplinary and multi-layers projects, including pre-existing and new programs, which perhaps will be also conducted at a high political level by INPOH, INCTs and other Brazilian Institutions. Projects that were defined from thematic sessions, then in plenary assemblies in order to connect pieces like some huge jigsaws.

Búzios meeting has highlighted the South Atlantic Ocean as a common scientific interest for setting a major effort in Marine Sciences within a French and Brazilian network. Firstly, it is virtually unknown compared to the world oceans and, secondly, it is a key to understand global processes such as climate changes, continental margin break up and sedimentation, oceanic crust processes, biodiversity and life on deep sea.

Four main scientific targets have arisen looking at to the past and future of the ocean: (1) Amazon from land into sea; (2) Climate/paleoclimate and circulation/paleoceanography; (3) Transfer budget of continent-ocean sediments and nutrients and (4) Coastal management. Each target shall be addressed here as Observatories for the Future, with tight connexion between technology and science.



Universities On Board

Universities On Board is proposed as laboratory at sea, surveying and investigating scientific targets. The experiment at sea during a scientific cruise is the best way to acquire a complete experience: the French and Brazilian students, living together in a close area, with the best scientist of both countries (or world), for a duration that can vary from one week to two months will never forget this outstanding and human experience in science.

Universities On Board will be small ships for coastal and fluvial researches, or larger French or Brazilian Research vessels for deep sea. Topics of research will involve technology, engineering or science, depending on the project and the needs of both countries.

A day on the Universities On Board will be divided into on-board courses given by the French-Brazilian scientists and sea scientific operations.

Coastal Areas Management

Coastal zones constitute a natural interface between earth/water/atmosphere that are subjected to an increasing concentration and diversification of human activities, demonstrating a consequent impairment of natural resources and ecosystems, with emphasis of trends for mid-twenty-first century. Such areas are increasingly affected by natural disasters of all sorts, a growing number of environmental risks and vulnerabilities, as population and occupation increase. Coastal areas management is essential to face rapid environmental changes and helps local government policies. The development of new studies, methodologies and models could well be used for mitigations measurements, and are needed to specify the juridic limits and terms of law and policies to apply. Specific locations and topics need to be targeted as pilot studies along the Brazilian Coast, using French and Brazilian experiences, as it has been started in Recife and is narrow, highly embanked and urbanized Rio Capibaribe estuary.

The focus of the studies will be the following: morphodynamic and sedimentation rates - anthropic and climatic impacts; changes in physical forcing and sediment dynamics in urbanized estuaries, residual circulation and dynamics of the turbidity maximum zone; pollution, city development and slump risks; study of sea water intrusion in coastal aquifers from high frequency and autonomous downhole hydrogeophysical observatories, and short time variations of the climate and fisheries reports.

Annual studies must be scheduled, including cruise on river and oceanic vessels, where students must be deeply involved. A program of information and education (see below the education program) will be conducted at the same time. The idea is to involve the Brazilian citizens in this Observatory and invite them to participate on the environmental laboratory. Fisheries, aquaculture will be an important part of this project.

Amazon from Forest into Mouth

The Amazon River represents the second water and sediment supply in the world, and the first for the entire Atlantic Ocean. Any study on the Amazon water, sediment, chemical and organic discharges, helps the knowledge and the modelling of processes at global scale. The Amazon submarine delta and the Amazon Deep-Sea Fan hold continuous records of terrestrial material accumulated by the river over time. These records provide a unique insight into the historic climate and geography of the land.

We propose an integrated network from the mouth of the Amazon River to the deep-sea fan, which will connect: Geophysics- Sedimentology (morphology, sedimentary facies distributions, facies variations in time, hard substrate for settlement), physics of sediment transport (suspended matters, bed-load transport), Biology - Biogeochemistry (biodiversity: micro, meso & macro fauna, health status. Environmental conditions: T, salinity, nutrients, pH, turbidity), Environmental Studies (fishery, pollution), Human Sciences (for instance, tuna fishery reports and short paleoclimate variations).

In particular, the unknown reef systems in the outer shelf of the French Guiana and the Amazonas need an integrated holistic approach. Reef systems, widespread trough different environments and trough geological times, are formed by calcified organisms, such as corals, rhodoliths, sponges, and molluscs and are highly sensitive to ocean warming, acidification, overfishing and pollution. Our aim is to characterize this new reefs systems with geophysical, remote sensing, biological (gene to whole holobionts) and biogeochemical (e.g. isotopes, organic and inorganic nutrients) methods.

Annual studies must be scheduled for studying the evolution of the system and the anthropogenic impacts, but also specific one-shot cruises on the French or Brazilian fleets (geophysical, geo-biological, paleoceanography and so on), with both students of the North Brazilian Universities and French students, with researchers of both countries.

Paleoclimate: Climate variability and Paleoceanography

The oceanic heat transport from the Southern to the Northern hemisphere is highly influenced by the North Brazil Current (NBC), which is a fast western boundary current formed by the South Equatorial Surface ocean circulation when it meets the Brazilian north-eastern coastline. This oceanic circulation has a strong effect on climate variability, as the NBC transport is correlated with north-south migration of the Intertropical Convergence Zone (ITCZ), resulting in associated changes in precipitation on land, especially in the north-eastern and northern Brazilian territory. It has also been displayed that these precipitation changes can generate wet to dry anomalous conditions registered on a variety of time scales (intra-annual, decadal, centennial/millennial).

Climate models clearly show that sea surface temperature (SST) changes (or variability) on the equatorial and south Atlantic ocean modulate the positions and intensity of the South Atlantic Monsoon System (SAMS), which finally controls the precipitation patterns over northeast and southeastern Brazil. How the South and Equatorial Atlantic SST changed during the past (centennial and millennial time-scales) and how it affected the continental climate are key questions.

The Equatorial and South Atlantic Brazilian marginal basins are, therefore, unique locations that preserve the record of palaeoceanographic and palaeoclimatic changes, which might be investigated through the analysis of long sediment cores, helping to unveil past environmental conditions, that had a global significance, and to model future climatic behaviour. Large climatic changes are frequently associated with ecosystems modifications and biotic alterations. Long term analysis of different sedimentary and geochemical proxies on the Brazilian Equatorial marginal basins can also contribute to understand the history of modifications of large South American biomes, such as the Amazon Forest, the Brazilian Cerrado, and the Brazilian Caatinga, whose drainage basins are completely or largely, directed to the Equatorial Atlantic.

Universities On Board will be crucial for data acquisition and coring campaigns. But, also buoying launch for mapping sea conditions in a long term.

From Mountains to Deep Sea

The cycle of growth of the continents on Earth implies mountains building, erosion and peneplenation, sediment and nutriment transfers trough river into continental plate-form and deep ocean through canyons and turbidite currents. Integrated analysis of deep structure, tectonic movements, sedimentary transport and recording in the deep basin, at different time-scales, applying direct and indirect methods (geophysic, chemistry…) in different disciplines (Oceanography, biology, geology) allow to restore the overall evolution of the margin, the continental geomorphology and tectonic history, the birth and evolution of the Atlantic Ocean.



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